The 13 th International Conference on
Engineering and Computer Graphic

BALTGRAF-13

June 25-26, 2015, Vilnius

Scientific Proceedings of the 13th International Conference on Engineering Graphics

BALTGRAF-13

Vilnius Gediminas Technical University (VGTU)
2015

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

RTU

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Scientific papers were peer reviewed. English (U.K.) was used for the spellchecking of all submissions

eISBN 978-609-457-835-9

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CHRONOLOGY OF BALTGRAF CONFERENCES

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BALTGRAF-3	Tallinn	Estonia	1996
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BALTGRAF-11	Tallinn	Estonia	2011
BALTGRAF-12	Riga	Latvia	2013
BALTGRAF-13	Vilnius	Lithuania	2015

HISTORY

It was back in 1991 on November 5th at the Vilnius Technical University when following the initiative of the professor Petras Audzijonis the representatives of seven Departments of Engineering Graphics from six universities of the Baltic States came together. Assuming the lately changed political situation in Eastern Europe in general and in the Baltic region in particular at this meeting an International Baltic Association BALTGRAF was founded. The Declaration of the Association was accepted and Council elected, the main goal determined and the tasks set. The principal purpose of the BALTGRAF was to establish a new scientific journal for publications, organize the scientific conferences, coordinate the efforts and exchange the ideas in the field of engineering background education dealing with wide range of Engineering Graphics matters. Special attention was paid to the emerging computer graphics technologies, how to integrate them both into syllabus in particular and into engineering curricula in general.

The conference is occurring every two years at the technical universities of three Baltic countries according the rotating schedule. The conference language is English.

Find out more about BALTGRAF on website www.baltgraf.org

a) b)

Fig. 1. The logo of BALTGRAF a) before conference BALTGRAF-13, b) after conference BALTGRAF-13

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AUTHOR LISTING

BIM EDUCATION IN RIGA TECHNICAL UNIVERSITY

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Abstract. Building Information Modelling (BIM) is a complex process of managing not only design documentation in 3D form but it also includes all the consecutive stages of the design analysis, followed by construction management, and including facility management after the site completion. The success in the collaboration to unite common efforts of architects, constructors and HVAC engineers would make the work of all involved stakeholders more productive because the existing information technologies provide this option already for a long time. The training for effective use of this relatively new and very complex approach from the very beginning of the building lifecycle in the construction industry is even a more complex task. Universities have to join the promotion of BIM ideas not only to the designers and engineers, but to a much wider public than at present. The history of BIM teaching and the approaches used at Riga Technical University (RTU) are outlined in this paper. RTU along with several other universities from Lithuania have joined the EU sponsored Leonardo da Vinci project BIMTRAIN initiated by regional software distributer and developer AGA-CAD which facilitates the BIM implementation through the training.

Keywords: BIM, BIM Teaching, BIM Curriculum, CAD, Engineering Graphics, Engineering Education

Introduction

Over the past decade the emerging benefits of BIM application have been recognized by many governments worldwide. The UK Government has mandated that all public building projects will have to be using BIM design processes at ‘level 2’, fully collaborative 3D BIM, or higher by 2016 (McGough, D.; Ahmed, A. *et al.* 2013). The ‘level 2’ is defined as file-based collaboration and library management. However in majority of countries the BIM implementation in practice has caused considerable resistance from many stakeholders, involved because of its complexity. There are several reasons for this, but the most important one is the misunderstanding about what the BIM process is in general. Some will compare the BIM with just the 3D modeling and visualization tools, followed by structural analysis at best. The first two options nowadays are integrated into numerous CAD software packages. The teaching of the use of different CAD software in the university courses over the past three decades has gone through the everchanging issues due to enourmous increase in both the PC hardware performance and the software potentials. It all started with computer aided drafting software like AutoCAD when the former classic manual engineering graphics drafting skills had to be reoriented towards PC usage, which was problematic issue especially for elderly specialists. In some cases the CAD software teaching turned into specific keystroke training. As a result the instruction was mainly focused on training the particular special courses with the support of computer aided solutions if at all, but in many cases these courses remained isolated on their own, rather than coordinated between each other. The BIM involves much greater challenges than the pure computer aided drafting and therefore the main concept of BIM is the whole building information coordination and sharing. Without these aspects there will hardly be any effect in the use of the most powerful hardware and the most expensive software. The problem of cooperation between parties involved exists almost at the same scale both in industry while implemementing this concept and in education while training effectively and preparing the future users of this technology.

1. BIM development

It is assumed that the first trace of BIM concept originates from the projects of Professor Charles Eastman at the Georgia Tech School of Architecture. Abbreviation BIM stands for Building Information Modelling (or Model) in early 1970s. The developed Building Description System (BDS) was the first software which manipulated with individual library elements from the database in the model on PDP computers. This idea was developed a long time before the victorious march of personal computers and therefore could not get a wide popularity because not many architects had a chance to get grips on it. Later several similar systems (GDS, EdCAAD, Cedar, RUCAPS, Sonata and Reflex) were developed and tested on practical projects in United Kingdom in 1980s (Bergin, M. 2012). A wider application of this concept into practice became possible only with the development of personal computers, when the ArchiCAD software from Graphisoft Company appeared on the scene, which incorporated the idea of Virtual Building rather than drawing from the very first of its versions - Radar CH (ArchiCAD 1.0) in 1984. The power of software was amplified by flexible built-in programming environment for its parametric library components using GDL (Geometric Description Language).

The Virtual Building concept, realized by Graphisoft in its software ArchiCAD v. 2.0, which debuted in 1982, could be considered as the first broader application of BIM in practice. The representation tool BIM starts as a three-dimensional model

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.001

tied to a database of project information, with this current support tool being the most powerful for Integrated Project Delivery (IPD) projects (Becerik-Gerber, B. 2010, Wright, J. A. 2012). This is because BIM integrates the design, fabrication, assembly instructions, logistics and project management into a database, also providing a platform for collaboration for all the IPD members. This is a tool, not a method; a tool that still is not frequently used in the sector; but it may end up enabling the efficient development in very complicated projects, or projects that are easily understood by all the agents. The project team reaches an understanding regarding how the model will be developed, introduced and used. In order to carry out the introduction of this information modelling, a series of usage protocols must be established in the conceptualization phase within the IPD model by the different agents.

The next step was when Irwin Jungreis and Leonid Raiz split from Parametric Technology Corporation (PTC) and started their own software company called Charles River Software in Cambridge, MA. They were equipped with the knowledge of working on Pro/ENGINEER software (released 1988) development for mechanical CAD that utilizes a constraint based parametric modelling engine (Bergin, M. 2012). The two wanted to create an architectural version of the software that could handle more complex projects than ArchiCAD. A trained architect David Conan joined the project and designed the initial user interface which lasted for nine releases. By 2000 the company had developed software called Revit, which was written in C++ and utilized a parametric change engine, made possible through object oriented programming.

In 2002 the power and promising future of Revit was noticed by Autodesk which purchased the company and began to heavily promote the software in competition with its own object-based software Architectural Desktop (ADT). This provided a transitional approach to BIM, as an intermediate step from CAD (Howell I.; Batcheler B. 2005). At that time ADT created its building model as a loosely coupled collection of drawings, each representing a portion of the complete BIM.

Approximately at the same time period the concept of BIM was adopted by another two software developers Bentley and Nemetschek in their further products. Bentley Systems interpreted BIM differently as an integrated project model which comprises a family of application modules that include Bentley Architecture (internationally known under Microstation Triforma name), Bentley Structures, Bentley HVAC, etc. Nemetschek provided a fourth alternative with its BIM platform approach. The AllPlan database was “wrapped” by the Nemetschek Object Interface (NOI) layer to allow third-party design and analysis applications to interface with the building objects in the model (Howell I.; Batcheler B. 2005).

2. Most important dimensions of BIM

BIM concept uses parametric object-oriented three dimensional or 3D data in virtual models in contrary to the conventional 2D drawings, a long time used so far by engineers and designers. Instead of drawing just a filled rectangular in plan view which represents a wall of a building in section, in BIM concept supporting software the model is built virtually in 3D space. The relative location of all neighbouring elements is precisely determined and easily observable from arbitrary viewpoint for visualization purposes. The model includes not only the geometric relationships between all building elements, but these elements carry information on many real attributes associated with them, like material, paint, class of fire safety, cost, etc. The drawings – plans, elevations, and sections – are obtained automatically from the unique virtual building model, along with the bills of materials and are updated immediately after any changes are performed in the original building model. Amount of wall material in specifications (schedules) is updated as soon as real virtual building elements like windows and doors are placed in the model. This method highly eliminates the human errors while producing drawing documents, which cannot be avoided using the conventional 2D drafting technique. The synchronization between views, elevations and sections in the manually produced drawing documents is the responsibility of all parties involved, which in the case of large projects and many stakeholders involved could be a serious problem.

The concept of BIM besides the conventional three dimensions of the model and real attributes attached to these elements includes the fourth dimension – time. The so called 4D design approach allows the coordination between parties involved not only during the building construction phase but also during exploitation, reconstruction and finally even utilization. The information is maintained and updated in the common database from the initial stage of the design through the whole lifecycle of the building.

The fifth dimension incorporated in the BIM concept is “money”. One of the most important attributes for elements and processes of the real building included in the virtual model is a cost. In this case the process is described as 5D design approach. The databases may include building elements with their attributes from many vendors and the designers could easily simulate several variants of the design. Numerous design scenarios “what if” could be played to find out the most effective solution.

Besides the five more or less known dimensions the current BIM concept supports also the sixth dimension which are facility management applications like CAFM (Computer-Aided Facility Management) and the seventh dimension with procurement solutions e. g. contracts, purchasing, suppliers, and environmental standards.

In order to support all these dimensions of the BIM concept in the numerous software and applications, it is evident that a common standard has to be used to share the information between so many different “players on the field”. There are many problems which have to be solved before this undoubtedly effective BIM process can be widely used in practice (Eastman C.; Teicholz P. *et al.* 2008). Therefore the core technological and modelling principles of BIM were defined and the IFC (Industry Foundation Classes) and aecXML standards are used. These standards define the data structures for representing the information which is used in BIM. There are a few other data structures developed by commercial vendors in the BIM domain besides the two mentioned.

Wikipedia describes the technology adoption lifecycle model as the adoption or acceptance of a new product or innovation, according to the demographic and psychological characteristics of defined adopter groups. The process of adoption over time is typically illustrated as a classical normal distribution or “bell curve”. The model indicates that the first group of people to use a new product is called “innovators”, “followed by early adopters”. Next come the early and late majority, and the last group to eventually adopt a product are called “laggards”.

Since these BIM tools and techniques have become increasingly complex, architectural and civil engineering schools have been faced with a great challenge not to lie behind and not to become laggards. To train specific software requires first of all mastering itself provided there is a financing for it. In general, industry lies behind and picks up the innovations slowly. A student with knowledge of only one type of software may well be trained to design according to the biases of the programs that they are using to represent their ideas (Bergin, M. 2012). In the case of BIM tools, the building is represented as parametric components including walls, roofs, floors, windows, columns, etc. These components have pre-defined properties, rules or constraints which help them perform collaborative tasks thanks to shared project model data.

In a blog by Shilovitsky, O. 2008, the BIM is characterized as the process of generation and management of the “building data” during its lifecycle. BIM is accepted by major vendors in architecture, engineering and construction industry and is widely used in all building types – from simple warehouses to many of most complex new buildings. BIM covers multiple domains – geometry, spatial relationships, geographical information, quantities and properties of building components. It helps manage a wide scope of works, system assemblies and other related processes. BIM provides potential future as a virtual information model to be handled from design teams to contractors and subcontractors, and then to owners, each adding their own additional discipline-specific knowledge and tracking of changes to the single model.

BIM uses 3D, real-time, dynamic building modelling software to increase productivity both in design and construction. This process successfully coordinates products, project and process information throughout new product introduction, production, service and retirement among the various players, internal and external, who must collaborate to bring the concept to life. OpenBIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows and it is an initiative of buildingSMART and several leading software vendors using the open buildingSMART data model. Educators have to seek contacts/relationships with a view of developing joint actions with industry and enterprises. Particular attention should be paid to small and medium sized enterprises as they account for an enormous part of economic growth and could be the places where the innovations could be introduced much easier. There is an evident role for universities to play in lifelong learning and continuing education thought them to offer possibilities of companies to increase competitiveness, productivity and efficiency, total costs estimation, and to become concurrent also on the global rather than the local market.

3. Problems in industry

Contemporary hardware and software provides enormous potentials for the nowadays designers. How come that these potentials are not introduced in everyday practice and are not used in full scale? The two main factors that affect this are the expenses and training. The BIM’s learning curve could be one of the top barriers of implementation in construction. There is an opinion that wide use of BIM concept mainly fails because of another two much more important factors – people factor and change factor (Shilovitsky, O. 2012). BIM implementation is not really about the software, but it is about organizational change. The experiences of clients have demonstrated that people and processes are far more important than technology.

BIM is an absolutely wonderful tool, and it has great potential to streamline costs and processes, to help different disciplines communicate effectively and to ensure little confusion on a job site. But to get to that promised land of benefits, you have to pass through the wilderness of adoption, which always seems to hinge on organizational change, not technology. This is the inconvenient truth.

People’s factor has been acknowledged by many AEC/CAD/CAM analysts (Barison, M. B.; Santos, E. T. 2011, Shilovitsky, O. 2012). The influence of people is significant factor in software product implementation that requires from people to re-think the way they are doing their business. BIM software can eliminate some roles in organizations and change business processes between organizations. It makes the process of software adoption long and complicated. This is a place where failure comes very often.

Changes are another aspect, which very often comes together with data and object and/or process oriented software like BIM and PLM (Product Lifecycle Management). The specific character of almost every enterprise-level data and process management software is to focus on how to change the organization – improve processes, re-organize business relationships, change tools, etc. It is extremely hard to people, since the change is hard, it consequently leads to failures (Shilovitsky, O. 2012).

During all phases of a construction project, the involved parties have an increasing need to define more precisely what is being modelled and how the modelling is done. In Finland as a response to the rapidly growing use of BIM in the construction industry the set of documents “Common BIM Requirements 2012” or COBIM were published in 14 Series (BIM Guide, 2012). COBIM is based on the previous instructions of the owner organizations and the user experiences derived from them, along with the thorough experience the writers of the instructions possess with model-based operations. The project was properly funded by Senate Properties in addition to several other real estate owners and developers, construction companies and software vendors. BuildingSMART Finland also participated in the financing of several projects.

A vague attempt has been initiated by a group of enthusiasts from private companies to embrace similar documents in Latvia. No support or any funding has been provided from the governmental agencies side. This initiative has resulted in some documents translated in Latvian – BIM Handbook (BIM Rokasgrāmata, 2013) and first two COBIM series (COBIM v. 1.0a 2013; COBIM v. 1.0b 2013) with adjustments for the peculiarities of local industry. Local BIM compatible software distributors are active promoters of this initiative as well. They actively organize information seminars on BIM issues.

4. Problems in education

Innovative companies nowadays require professional employees who are able to work effectively on projects undertaken with BIM. Several universities throughout the world have been running a wide range of courses to meet this demand and provide students with experience on this new paradigm. However, this learning experience is relatively new and based on a pedagogical system that has not yet been consolidated. In a recent analysis (Barison, M. B.; Santos, E. T. 2011) an attempt was made to address the main obstacles encountered with BIM teaching, as well as to give examples of how to overcome them and introduce new strategies at introductory, intermediary and advanced levels.

The programs that are planning to introduce BIM into the curriculum face a number of obstacles that can be grouped into three types: academic circumstances, misunderstanding of the BIM concepts and difficulties in learning/using the BIM tools (Kymmell, W. 2008). In an academic environment a wide range of problems occur, just to name the topics: time, motivation, resources, accreditation, and curriculum. Misunderstanding of BIM concepts is associated with individualized instruction, traditional teaching, little teamwork and week collaboration or lack of collaboration between courses or curricula at all. The weakness of BIM tools is associated with creativity, learning, teaching, and knowledge aspects.

An extensive survey on 119 building construction schools in the United States found that only 9% of them teach BIM at a degree level (Sabongi, F. J. 2009). The main problems named by the respondents are as follows: lack of time or resources to prepare a new curriculum, lack of space in the curriculum to include new courses and a lack of suitable materials to teach BIM. Another survey (Becerik-Gerber, B.; Gerber D. J. *et al.* 2011) involving 101 Architecture, Civil Engineering and Construction Management programs in the U.S. found that, apart from these obstacles, there is a shortage of trained personnel in BIM, that the curriculum is not focused on BIM, that its implementation takes time and that the accrediting bodies for the construction programs have not drawn up clear guidelines for BIM.

The summary on BIM education analysis (Barison, M. B.; Santos, E. T. 2011) showed that only a few engineering schools have been teaching BIM since 2000, e.g. Georgia Institute of Technology, which has carried out research on BIM since the early 1990s. Several international schools have begun teaching BIM tools around 2003, but the vast majority introduced BIM between 2006 and 2009. In exceptional cases, the architecture programs were those that first showed interest in this area. Rapid advances were made and today there are a large number of BIM courses developed around the world and their number is constantly growing (Barison, M. B.; Santos E. T. 2010, Becerik-Gerber, B.; Gerber D. J. *et al.* 2011, Pavelko, C.; Chasey, A. D. 2010).

5. Teaching approaches

UK is one of the BIM concept support and implementation leaders in Europe and has developed well-structured approach. In late 2011 BIM Academic Forum UK (BAF) was established to respond to the growing needs in education area (Embedding, 2013). The BAF is a group of representatives from a large number of UK universities formed to promote the academic aspects of BIM. In particular, BAF is focused on the development of a 'BIM academic framework', the aim of which is to propose a roadmap towards a longer-term vision of embedding BIM learning at the appropriate levels within 'discipline-specific' undergraduate and postgraduate education. This would facilitate the development of professionals with the relevant BIM knowledge considered necessary. Professor David Philp, Head of BIM at consultancy firm Mace and head of BIM implementation at the UK Government's Cabinet Office has pointed out: "At this point in the evolution of the UK BIM strategy it is of increasing importance that our teaching institutions are equally well informed of the progress that is being made across those Government departments which are spearheading implementation on projects and across its asset base. The BAF has taken great steps by bringing together and providing a focus for UK academia. The agenda supports that of the BIM task group in promoting UK BIM adoption and leadership both home and abroad to ensure that the UK is at the vanguard on new, more efficient ways of working".

Using the surveys the current educational programs throughout the world were reviewed and recommendations developed to assist universities with curriculum development. Based on an extensive research on BIM teaching experience (Barison, M. B.; Santos E. T. 2010) three skill levels are given which define the BIM learning and teaching strategies. These skill levels include: introductory, intermediary and advanced. At introductory level BIM usually is taught in typical engineering design graphics courses including courses like Computer Aided Design.

The main purpose in an introductory level of curricula courses is to develop the skills of geometric modelling using BIM supporting software. These courses do not require the essentials of classic 2D CAD skills like AutoCAD, which are still considered as a compulsory knowledge for architectural and civil engineering graduates. The objective is to preferably learn those BIM tools that are most commonly used in the field in order to obtain a good background of BIM concepts. The BIM tools can be taught through lectures, workshops and labs. The students do problem-solving exercises and carry out small individual tasks to practice the BIM tool. Some university researchers found that it is recommended that before the students start the modelling they make modifications to an existing model (Barison, M. B.; Santos E. T. 2010, Brown, N. C.; Peña, R. B et al. 2009, Taiebat, M.; Ku K. et al. 2010). This allows an exploration of the basic concepts of geometric modelling and provides understanding how to communicate different type of information.

BIM software could be successfully used also in numerous other applications. One of the most interesting seems to be in the area of digital heritage, for example, a digital preservation of historical architectural sites (Boeykens, S. 2011). Another promising area is game industry, especially the aspects which concern the use of games in contemporary engineering education (Jurāne, I. 2013).

The students create their own model of a small building (or parts of it), usually with an area of or less than 600 square meters to extract quantities from it, and learn how to manipulate the model, types of basic components and their behaviour. It is recommended that a modern single family residence is used as a project. The modelling can be accompanied by analogue methods, sketches and axonometric views, which allow the students to perform suitable adjustments to the physical proportions (Barison, M. B.; Santos E. T. 2010, Brown, N. C.; Peña, R. B *et al*. 2009, McGough, D.; Ahmed, A. *et al.* 2013).

The architecture student can make a volume/mass representation of the house, carry out an investigation of primary components (doors, windows, panels and furniture) and, based on his/her research, develop and refine a new component. The engineering student can do the following: identify a construction component of his/her choice in the structural and/or mechanical, electrical and plumbing (MEP) areas, make a list of the necessary information required for the construction of that component, categorize this information throughout the life cycle to show how it can be linked and managed from a life cycle perspective and decide how they should be shared with the other subject-areas (Brown, N. C.; Peña, R. B et al. 2009, Koch, D.; Hazar D. 2010). Barison, M. B.; Santos E. T. 2010 suggested that the assessment of the students' performance can be conducted through individual exercises (components or simple models), written exams about BIM concepts and their presentation of models.

BIM could be introduced in different courses of the curriculum and the study (Barison, M. B.; Santos E. T. 2010) grouped them into eight categories: Digital Graphic Representation (DGR); Workshop; Design Studio; BIM Course; Building Technology; Construction Management; Thesis Project and Internship.

This approach is used at RTU in programs Architecture and Civil Engineering. ArchiCAD software at first was introduced in RTU Architectural programs back in 1997, when Graphisoft Company granted free licences for university. In 2002 the elements of 3D modelling using ArchiCAD were introduced also in Civil Engineering program. Extensive support materials both theoretical and practical tutorials are available for both the educators and the students (Learning, 2015). Further practical training with an alternative BIM concept supporting Revit Architecture software was possible only in 2006 after acquiring a new lab with powerful CAD workstations. Permanently growing requirement for hardware performance from the software developers' side has always been and still is one of the main drawbacks of much wider application of new technologies in engineering education not only in our region but many other countries worldwide.

Introductory information about BIM at Riga Technical University is delivered to the students of Architecture program in a separate compulsory course in the fall semester in the third year. The program administrators have an opinion that it is crucially important to train to the students the skills of manual drafting and sketching the concept ideas. Just a few years ago it was even restricted the submission of computer generated and printed projects. Lately this restriction has become moderate. The students of Civil Engineering program get introduced to BIM in the compulsory course which is designed as a course combining the classical manual engineering drafting practices with computer aided applications. The students have to apply the knowledge about the basics of architectural design practices both ways – manually and by use of PC. Four formal lectures are accompanied with the training exercises on 3D modelling using ArchiCAD software. Advanced skills may be later trained in a free choice subject Computer Aided Design where the students have to virtually build their own „dream residential house" which was analysed and designed before in a separate compulsory course Architectural Design using the classical manual drafting technique. In this course even AutoCAD drafting technique was not allowed to prevent the submission of Copy&Paste home assignments.

In the free choice subject Computer Aided Design the students can choose between ArchiCAD or Revit software. In the final project the students have to provide all the required basic supporting architectural documentation – plans, elevations, sections, detail drawings, room inventory, exterior and interior renderings both in structured manner in computer and on a single sheet of A1 or A0 format paper for presentation. A standard or self-created zone lists for room inventory have to be used. Standard or modified door and window schedules have to be used to see the power of built-in features in the BIM supporting software. Figures 1-2 demonstrate the complexity of individual projects used in the introductory level of BIM concept study.

At the end of the course only one informative lecture is provided on the possibility to streamline the prepared IFC compliant project for further energy analysis or structural analysis on compatible software like Axis VM, Tekla Structures, and Revit Structure which are typically used by local companies. Educators can receive well prepared presentation materials and support from some BIM software developers (Learning, 2015). Unfortunately, the practice in the classroom reveals that our students are quite reserved when they are offered just the theoretical lectures about global issues. Practical training exercises during the class hours are more appreciated, but the contact hours for the last two decades for classical engineering design graphics subjects have decreased more than twice (Dobelis, M. 2007). Further development of civil engineering curricula is possible through the interaction between different courses based on BIM collaboration. This would highly benefit the preparation of graduates for the next BIM challenges.

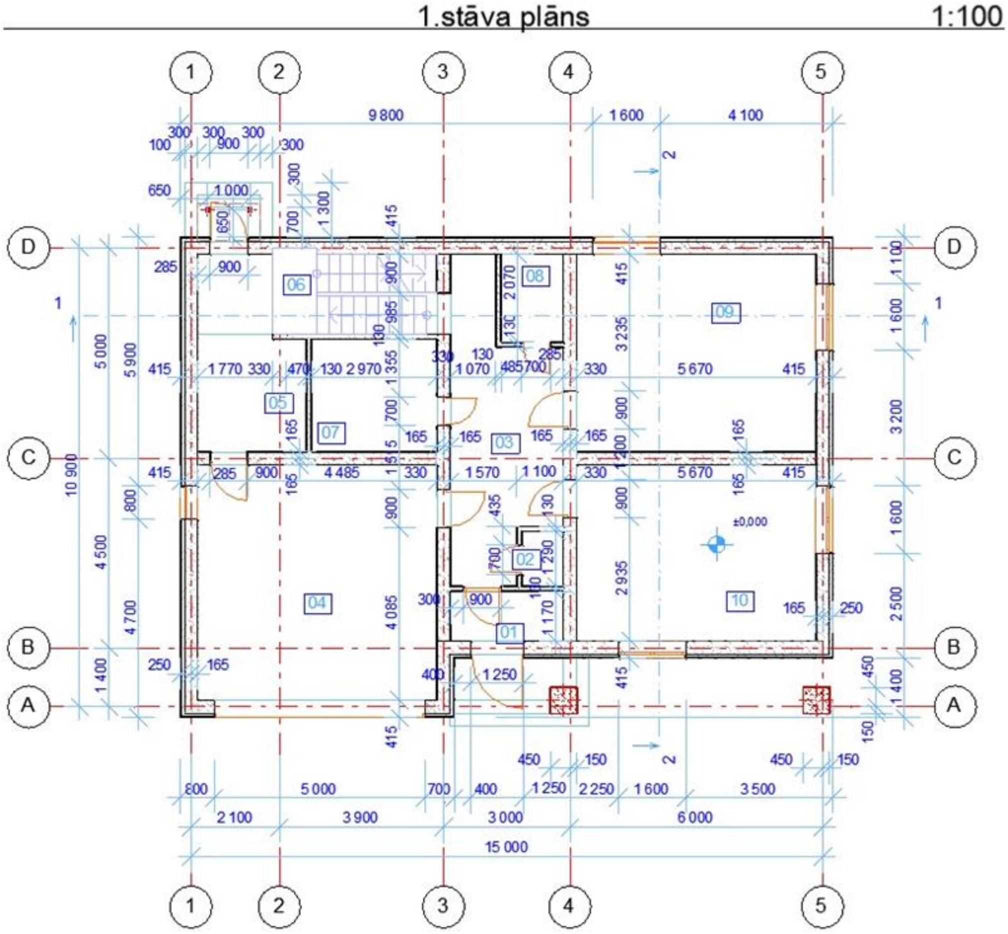

Fig. 1. A plan view of a two story building: An example showing the complexity of project in the course „Computer Aided Design" for undergraduate students in civil engineering program.

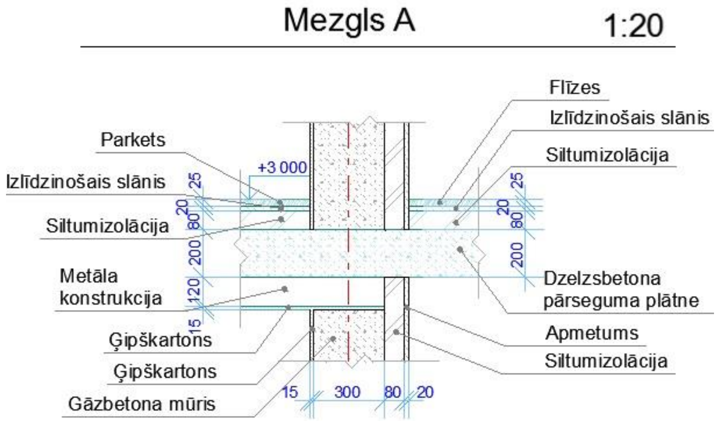

Fig. 2. A detail view of a two story building: An example showing the complexity of project in the course "Computer Aided Design" for undergraduate students in civil engineering program.

The coordination of mechanical, electrical, and plumbing (MEP) systems has become a major challenge for project delivery teams especially when the project size exceeds the size of individual residential buildings. The MEP coordination process involves locating equipment and routing heating, ventilating, and air-conditioning (HVAC) duct, pipe, electrical raceway, and fire protection systems in a manner that satisfies many different types of constraints (Korman, T. M.; Simonian, L. et al. 2008). For the past several years MEP coordination has involved sequentially comparing and overlaying drawings from multiple trades, in which representatives from each MEP trade work together to detect, and eliminate spatial and functional interferences between MEP systems. This multi-discipline effort is time-consuming and expensive. With the recent development of BIM this process has been able to evolve with the software technology thus enabling new teaching methods. The first attempt to teach the students how to perform the MEP coordination with BIM technology utilizing MagiCAD on AutoCAD and Revit platforms was performed in Fall semester 2014 for Heat, Gas and Water Technology program at RTU. The absence of individual student licenses for MagiCAD restricts more advanced training outside the CAD lab.

Further boost in BIM concept study at RTU was possible thanks to the initiative of AGA-CAD Company from Lithuania. Three higher educational institutions from Lithuania and Latvia joined EU sponsored project "Transfer of Building Information Modelling Training Tool for the Increasing Competencies of Building Sector Specialist". Web-based video instruction materials about BIM concept itself and the practical training with Revit software will be available for the students and industry representatives in the Fall semester in 2015.

Conclusions

The development of a well structured and properly balanced BIM course content is critical in sucsessful preparation of future specialists for the new contemporary engineering environment. The ideal course content should sattisfy both the general understanding about the fundamentals of BIM content and the skills of practical mastering CAD applications. Most of the courses struggle with the time deficit for in depth coverage of both focus areas. Implemention of continuos sessions in CAD lab at RTU have proved the effectiveness of blended study of theory and practical training in the same class. A split sessions between lecture, demonstration and lab-tutorial has been found to be less effective and requiring a slowerlearning curve has been found by some other researchers. The nature of engineering graphics course objectives with CAD as a tool calls for a different method of assessment. Instead of the exam in the subject it was found that a project based BIM software training approach is more interesting and entertaning to the students and facilitates more in depth individual studies. Instead of trying to force through changes in the curriculum, the academic world could join together with industry to promote BIM or collaborative thinking and setting up a research, teaching and consultancy projects. A closer partnership is expected between universities and industry. Unfortunately the local building industry has faced well-known global issues and seems that the current period is not yet the right time for changes. In fact, industry must be willing to provide funding for the academic world. Besides this the government should realize the acute need of funding for engineering education in practice not only in their slogans before regular elections over decades. The advanced IT technologies used in contemporary engineering are not cheap and require regular investments. The industry representatives must spend their time to visit universities and be prepared to discuss the current trends and scenarios with educators and students, share generic models from the local industry and provide current materials for students to enable them to practice the knowledge they have learned theoretically. However, the biggest obstacle to the progressive changes will be a human factor.

Funding

This work was supported by the European Union Leonardo da Vinci Project "*Transfer of Building Information Modelling Training Tool for the Increasing Competencies of Building Sector Specialist"* [grant number LLP-LDV-TOI-2013-LT-0133].

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eISBN 978-609-457-835-9

3D MODELING OPTIONS ANALYSIS IN AUTOCAD2015 VERSION

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Abstract. 3D design technology is the basis for the modern computer graphics. AutoCAD 2015 is a powerful version of computer-aided design system. We can solve complex tasks, without which this instrument can't be solved in general. Using 3D design technology we not only save time working with a drawing. The geometric models are the foundation of the design basics, for working with drawing we can create projections, footnotes, sections and other modern graphics elements. AutoCAD can use and process the data from the model. This progressive design technology includes all parts of the design, starting from machine details, furniture and finishing with architectural forms of complex object models.

Keywords: 3D graphics, modelling technology, AutoCAD, Layout space, projection, footnotes, section

Introduction

Modern computer graphics is oriented to 3D design technology. The design basis is the formation of a geometric model followed by the model drawing with the help of AutoCAD program in the automatic mode. Based on the data of the model AutoCAD itself creates its projections, footnotes sections, and etc. It follows that the computer created virtual model is a computer "raw material" used for making its drawings. This progressive design technology includes all parts of the design, starting from machine details, furniture and finishing with architectural forms of complex model objects.

1. AutoCAD opportunity

It is very important that 2D design method is a process object created and analyzed by 2D images - projections. Undoubtedly 2D computer graphics uses skills needed to work in creating 3D models. 3D geometric modelling technology is carried out mainly in surgery of spatial objects, but not their projections. Using the existing standard AutoCAD 3D geometric shapes, logic operations, and other technologies, like in the Logogame, we can create any complexity form of a spatial body.

Further we will focus not on the creation of a three-dimensional model, but on its use as a "raw" material for creating automatic projections, images, sections, footnotes and so on inAutoCAD2015 version (Nenorta, Pilkaitė, Kupčinas 2006, Danaitis, Usovaitė 2010).

After the creation of a three-dimensional model of the body, further operations are to be carried out in paper space (**Layout**). After the shift to paper space **Layout,** 

a new group – **Layout** appears among the falling command group names, which, when activated, shows the **Layout** interface instead of AutoCAD interface (Fig. 1).

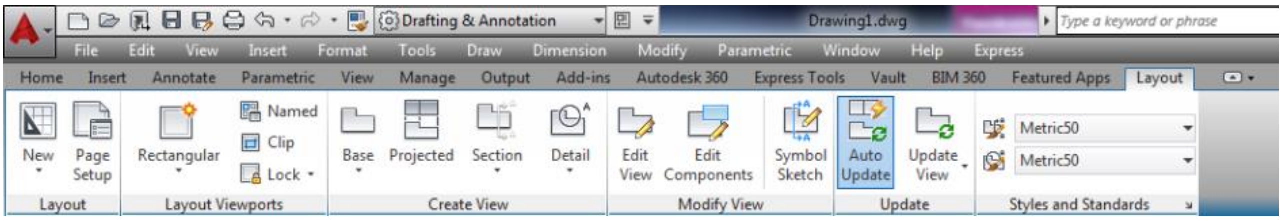

Fig. 1. AutoCAD 2015 interface

Further examples will show some of the possibilities of the 3D technology. For this purpose a three-dimensional model of a clutch will be made, (Fig. 2) which consists of the base, damper, springs, washers and lock, pads, pads linings.

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.002

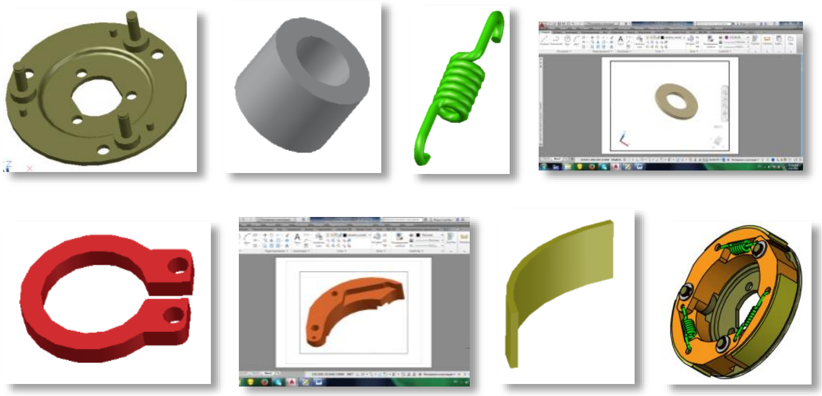
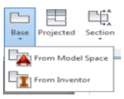
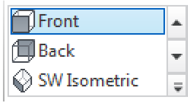
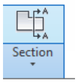


Fig. 2. Model of a clutch, which consists of the base, damper, springs, washers and a lock, pads, pads linings.

2. Projection formation

From the clutch model in the Model space we will shape its horizontal projection in the paper Layout space.  By using the icon **Base From Model Space** we will generate the desired projection selected from the window. 

In this way we will get the horizontal projection of the clutch. Further, by using the icon 

SessionFull we mark a horizontal section A-A and with the help of the mouse we indicate its location. The program automatically generates a horizontal sectional projection with a hatching. When necessary, the projection can be edited using the **Edit View** or **Edit Components** icon. In this way, we are doing the horizontal projection of the vertical section B-B. Activation of the mouse opens the editing interface (Fig. 3), that allows editing of the hatching. (Čiupaila, Vinogradova, Zemkauskas 2008).

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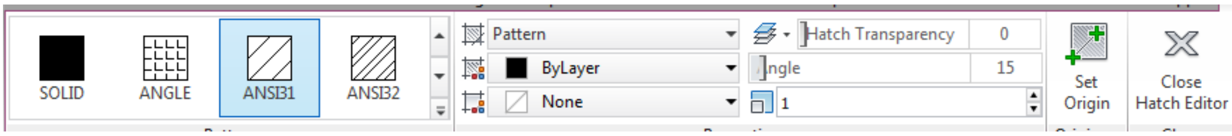


Fig. 3. Dashed editing interface

To move the vertical section to the profile section place we have to terminate the connection between the horizontal projection and rotate it at 90° angle. To this end we activate the projection by clicking on the cursor in the projection frame (Fig. 4) and with the right mouse button we open **Properties** context menu where we cancel the projection connection by the command **Broken** and by the command **Rotation we** rotate it at 90°angle.

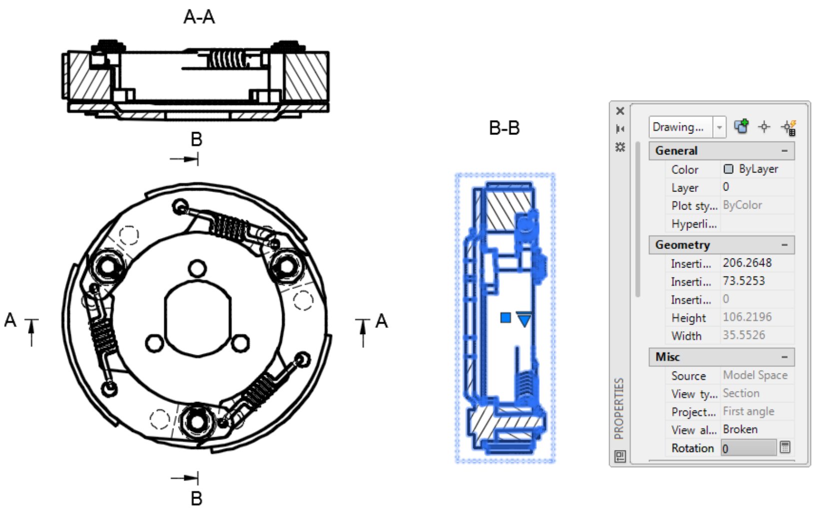


Fig. 4. Model projection

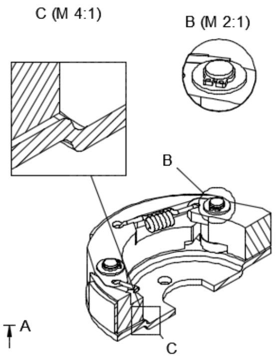
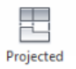
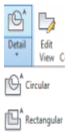
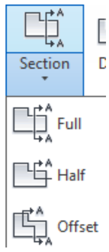


Fig.5.The projection elements and footnotes

There is a possibility to make an isometric projection from any projection by  using the **Projected** icon . We can provide any  projection elements footnotes (Fig. 5). This requires to use icon **Detail CircularRectangular** with a Ring B or a square C form. There is a possibility to change the scale of the footnotes.



To demonstrate a complex section let's choose a different model (Fig. 6).Parallel to the clutch model let's make the horizontal projection of the model. Complex section is made with the help of the icon **Section Offset** and in horizontal projection the location of the section is marked. After the program generates the sectional projection its location has to be indicated. By using the icon **Projected**  **we** produce a complex isometric section. The desirable drawing elements can be edited and additional axis with marked dimensions can be created.

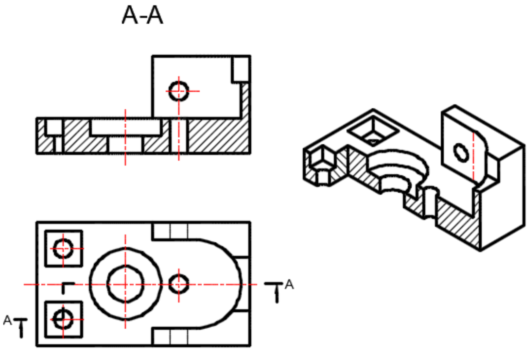
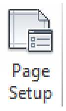
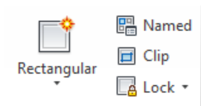


Fig. 6. The projection elements and sections

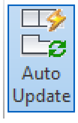
The remaining unused **Layout** interface icons, can be used for  the following operations:

- The creation of a new, or a template-based Layout; 

1.
2.
3. - **Layout** space parameters dispatcher management, format settings, etc.;

- Creation and management of different forms of windows; 

eISBN 978-609-457-835-9

- Image automatic update / not update by changing the original model; 

4.
5. - Update of the selected image by changing the original 

model.

This way we have made sure that geometric modelling in the 3D design technology is performed by operating on the basis of spatial objects, but not their projections. With three-dimensional objects a computer may carry out many geometric modeling operations programmatically by itself, in an automatic mode: sections, footnotes, and other various projections. This way, part of the intellectual exertion moves from the designer to the computer. This is the main motivation to master the AutoCAD 3D design technologies, because here everything is together - complex and simple.

Conclusions

The AutoCAD 2015 program is the 29th version of Autodesk company product. During the long years of development, this product has transformed from a simple instrument, which managed to change the drawing board into a powerful computer-aided design system. Using 3D design technology we not only save time working with a drawing, but we can solve such complex tasks, without which this instrument can’t be solved in general. And to do this you need to learn AutoCAD program operation. It is an investment in a product that is very cost effective.

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USING LAYERS

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Abstract. Computer Aided Design (CAD) has some specific features compared with hand-drawing. Quite beneficial opportunities arise using Layers. Object's properties (color, linetype, lineweight) may be assigned individually to each object or grouped by belonging to a particular Layer (ByLayer). Layers are like transparent overlays on which we organize and group objects in a drawing. We can use Layers to control the visibility of objects and to assign properties to objects. Layers can be locked to prevent objects from being modified. Layer Properties Manager informs us about layers' parameters and allows to change these values. We can change the name of a layer and any of its properties, including color and linetype and you can reassign objects from one layer to another. We can control which layer names are listed in the Layer Properties Manager and sort them by name or by property, such as color or visibility. We can save Layer settings as named layer states. We can then restore, edit, import them from other drawings and files, and export them for use in other drawings. Which number of Layers is optimal? The answer depends on several considerations – using every Layer should be adequately argumented. The skilled use of Layers can turn the construction process into a more flexible and rational one. But adding any new Layer must be justified. Otherwise, some uncomfortable problems could arise.

Keywords: CAD, AutoCAD, Layers, Properties, Rationality, Dangers, Safety

Introduction

One specific feature of CAD is using Layers. Layers are like transparent overlays on which we organize and group objects in a drawing. We can use Layers to control the visibility of objects and to assign properties to objects. Layers can be locked to prevent objects from being modified. As our prior analysis (Mägi et al 2009) showed some problems appear from time to time.But in the work of the designer there should not be unsolvable problems. Otherwise, it would be impossible to complete this work. Quite important is to use comfortable settings not contrariwise, uncomfortable settings.

1. Examples of use of layers

Every graphical object is characterised by many properties – color, linetype, lineweight etc. These properties may be attached to the object individually or completely – by Layer. Each object can belong only to one Layer. Switching On/Off the suitable Layers allows to show the solution process step by step (Fig.1).

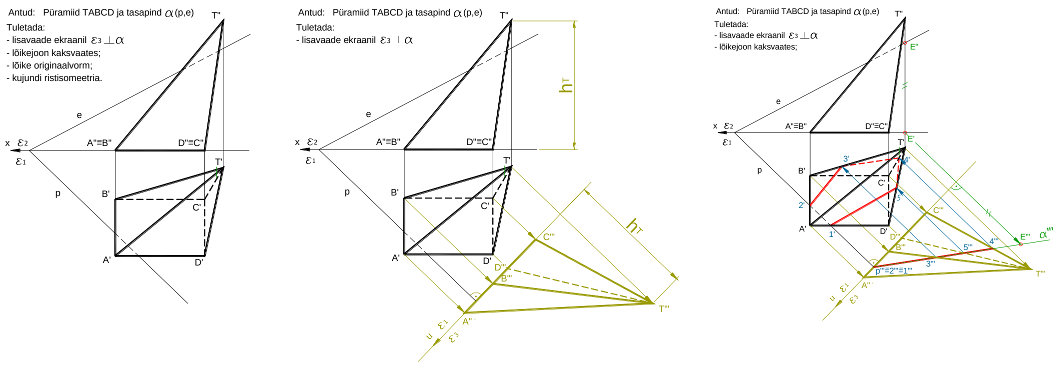

Fig. 1. Solving order demonstrated by switching On new Layers.

Using Layers is quite effective in construction drawings. Although standards ISO 13567 give recommendations for organization and naming of Layers for CAD, in practice it is often chaotic.

Sometimes auxiliary lines can help the construction process. For example connection lines between different views (Fig. 2). After completion of drawing we do not erase these help-lines, but only switch off the layer of auxiliary lines (Fig. 3).

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.003

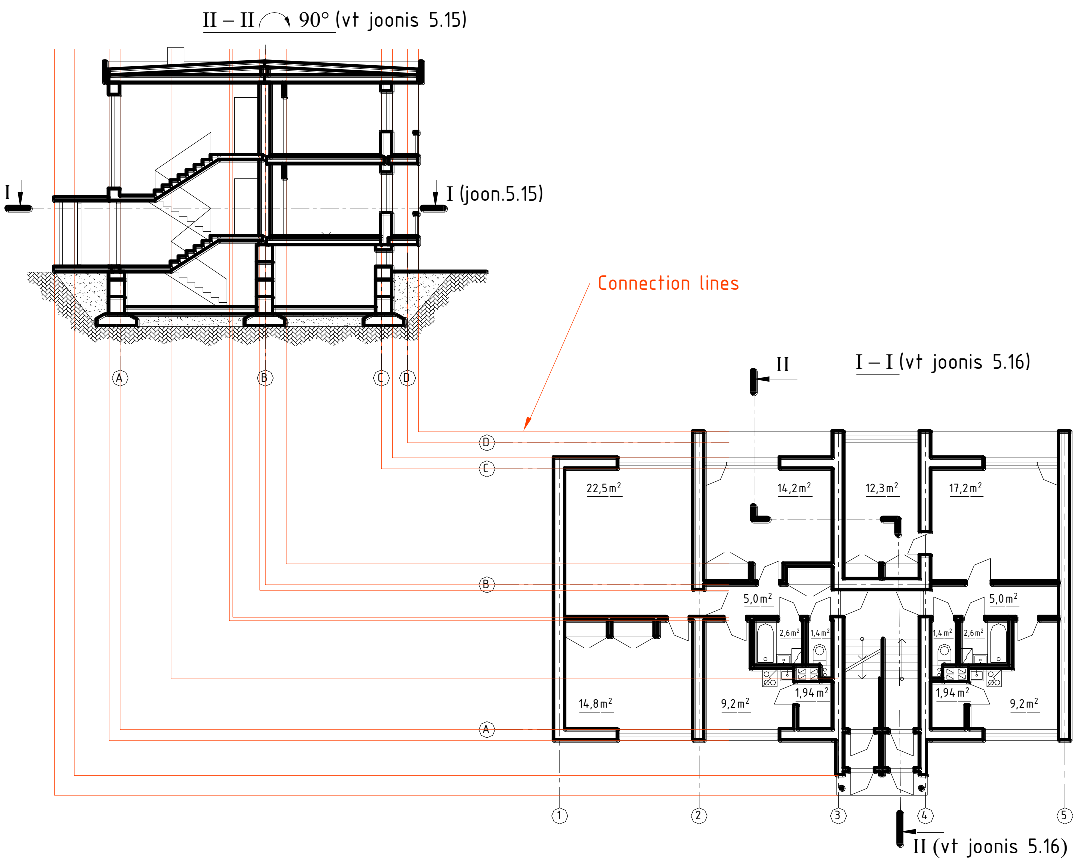

Fig. 2. Connection lines (equidistant polylines in separate Layer) between horizontal and vertical section of house.

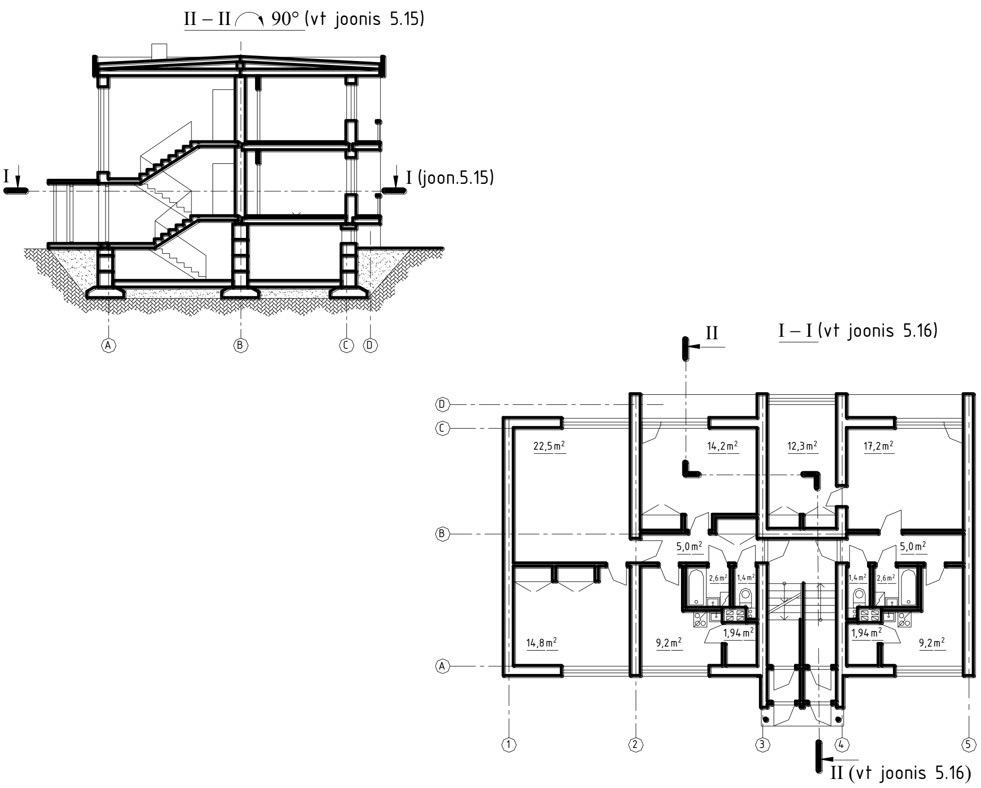

Fig. 3. The same drawing after switching OFF the Layer of connection lines.

Quite effective is to determine plot area switching OFF printability of the layer with auxiliary lines (Fig. 4).

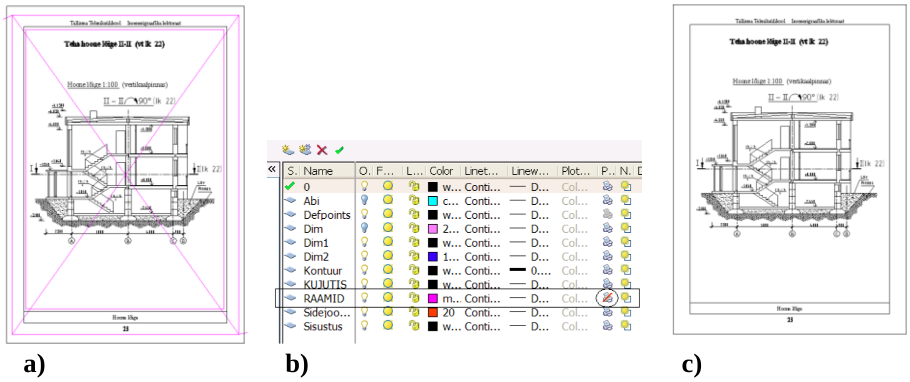

Fig. 4. a - Auxiliary lines for defining plot area, b - Switching OFF printability of layer with auxiliary lines, c - The printed page without auxiliary lines.

Quite an attractive and effective presentation will be using Layers to illustrate the assembling process of the clamp (Fig. 5).We can switch ON layers according to the order of different parts. But how to remember the right order of switching layers? We can fix the sequence list. But the other opportunity is to use Layer States Manager (Fig. 6).

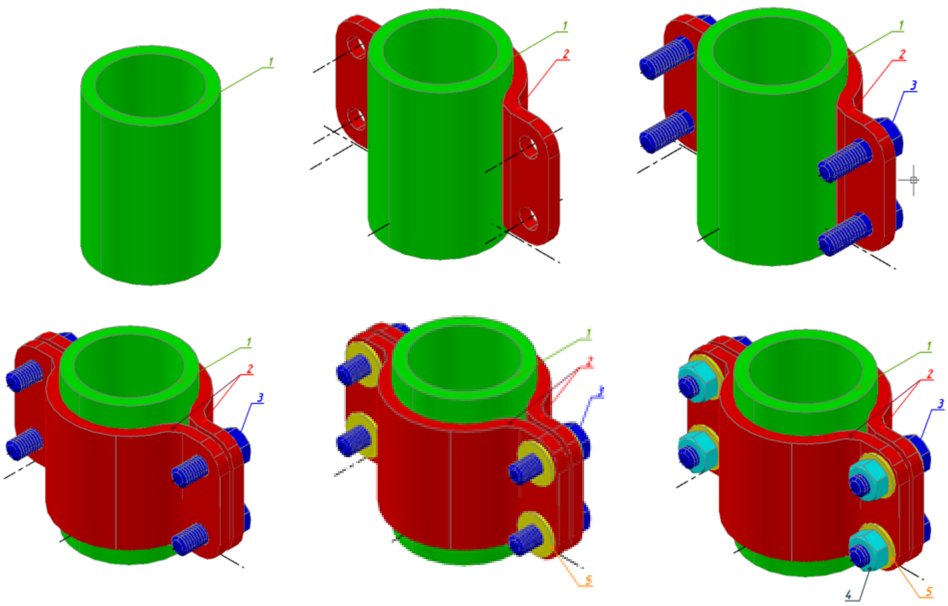

Fig. 5. Assembling process illustrated by using Layers for different parts.

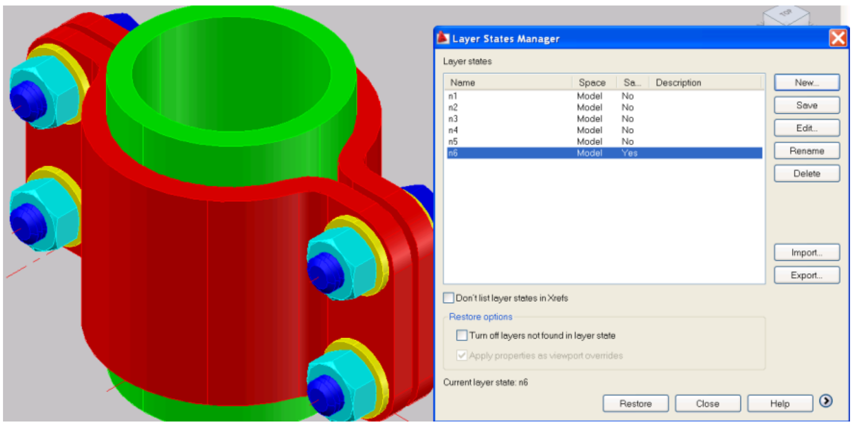

Fig. 6. Using Layer States Manager

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Interesting opportunities to artistic design is to override layers' colors in different viewports (Fig.7).

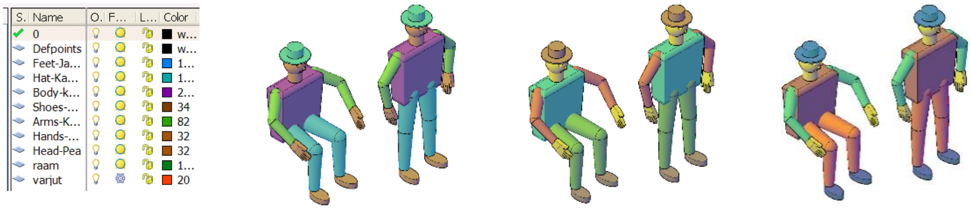


Fig. 7. Results of overriding layers' colors

2. Problems and solutions

Despite interesting possibilities of using layers, occasionally some problems may appear. Fortunately, the program warns us about it (Fig.8). For example, it is not recommended to switch off the current Layer – in this case we cannot see our operations on display.

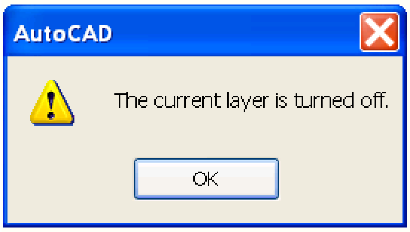


Fig. 8. Warning message on screen

If we do not want to operate with some objects, we can place them into the Locked Layer. AutoCAD informs us about it (Fig.9).

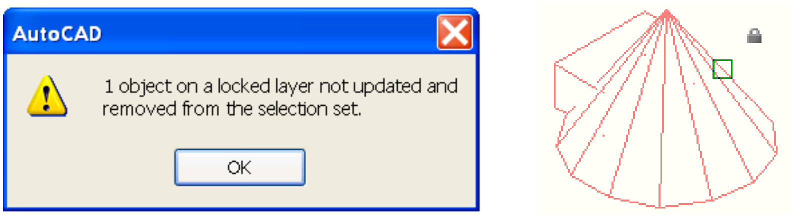
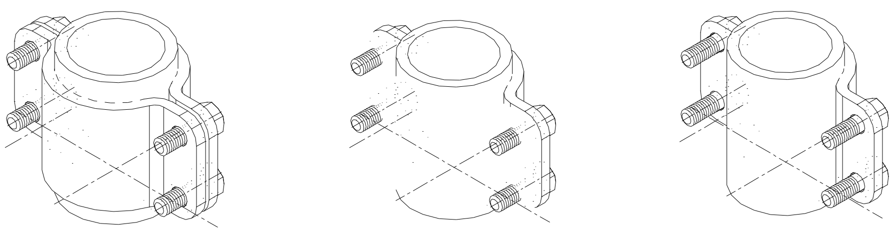


Fig. 9. Warning info about Locked Layer

Quite surprising visibility may occur after turning OFF the desirable Layer and command Hide (Fig. 10 b) - the front clamp is not visible, but its "shadow" covers the rear parts. After Freeze this Layer the mystical "shadow" is removed (Fig. 10 c).



a) b) c)

Fig. 10. a - source assemble placement, b - situation after turned OFF Layer with front clamp and command Hide, c – normalized situation after Freeze this Layer and command Hide.

How about copying objects from one file to another file with the same Layer-name [6]? Surprises (without any warnings) would appear when we transfer (by Copy&Paste) objects from file A to file B using the same names of Layers (Fig. 11). If to call file A as “guest-file” and B – “host-file”, then the rule is “host is always right!”

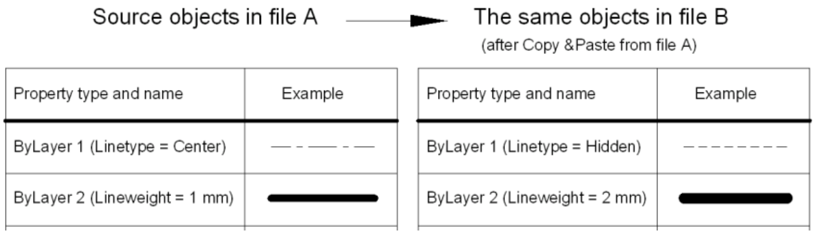


Fig. 11. Results of transferring objects from file A to file B using the same names of Layers

How to solve this problem? The recommended solution is to rename the Layer before transferring.

Which number of Layers is optimal? The more the better, or the less the better? The answer depends on several considerations – using every Layer should be adequately argumented. Quite often we can deal with only one layer (Layer 0). But benefical using of many layers requires more skilful approach.

Layers are lined up in alphabetical order in the Layers’ list. Using numerical names of Layers this order is a little complicated – not: 1,2,3,4,5,6,7,8,9,10,11; but: 1,10,11,2,3,4,5,6,7,8,9.

More comfortable way for presentation is to transfer pictures (by Copy&Paste) from AutoCAD to PowerPoint.

How to understand the layers’ system of the file? Which objects belong to one or another layer? An experimental analysis (turning OFF all other layers) can give the answer. But more comfortable and visually observed opportunity is to use different colours of layers. Quite a recommended variant is to formulate rules for use of Layers in this file.

Conclusion

Compared with hand-drawing quite beneficial opportunities arise using Layers. We can use Layers to control the visibility of objects and to assign properties to objects. The skilled use of Layers can turn the construction process more flexible and rational.

But adding any new Layer must be justified. Otherwise, some uncomfortable problems could arise. The system of Layers should be user-friendly both for the creator and the reader of the drawing file.

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Example task 1: http://www.hot.ee/r/rmagi/Exi1.pps

ISO 13567-1:1998 Technical product documentation. Organization and naming of layers for CAD. Part 1: Overview and principles

ISO 13567-2:1998 Technical product documentation. Organization and naming of layers for CAD. Part 2: Concepts, format and codes used in construction documentation

ISO 13567-3:1999 Technical product documentation. Organization and naming of layers for CAD. Part 3: Application of ISO 13567-1 and ISO 13567-2

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eISBN 978-609-457-835-9

ENGINEERING GRAPHICS' KNOWLEDGE: ITS PERSISTENCE AND APPLICATION EVALUATION

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Abstract. The article deals with the knowledge of engineering graphics, obtained during studies and its application in architectural and constructional design. Data analysis was carried out and the relationship between the exams' grades in lower and upper semesters was determined. The evaluations of the following subjects have been examined: General Engineering Graphics, Applied Engineering Graphics, Building Architecture and Structures 1, Building Architecture and Structures 2. The present paper describes the development of an approach that uses a real data set. The investigated data illustrates relevant concepts and methods in the application of introductory civil engineering. The creative use of students' scores evaluation data is recommended to facilitate the learning of civil engineering. The course has enrolments of approximately 250 students.

Keywords: Engineering Graphics, Building Architecture and Structures, knowledge, motivation

Introduction

Development and dynamics of new information technologies and technical sciences greatly influences engineers' educational process. These processes are continuous. Learning information could be presented as a textual, numerical, or graphical data. Therefore there's a need for a comprehensive understanding of literacy. General learning objects (content objects, **educational objects**, information objects, knowledge objects, learning components,), subjects (physics, chemistry or mathematics) in a certain level influence further successful studies in civil engineering and are background of a comprehensive literacy developing (Holzinger 1997, Dutson et.al. 1997).

The last 30 years have brought a relatively high development of computer tools supporting engineers in their design activities. For studying graphics at VGTU there were used different versions of AutoCAD, 3D Max, Revit Architecture, Solid Works and CAE systems have become industrial standards. Many other engineering problems like simulation, analysis and decision making have been supported by both commercial and non-commercial software. There is a wide variety of computer tools, from which every designer selects a group and uses it in his individual and subjective way.

A significant part of Civil Engineering faculty graduates are pointing that the learning modules, which deal with mathematics modules, are too redundant compared to other fundamental subjects of study. . "Engineering Graphics" learning processes can be classified as routine, innovative or creative.

However, effective practical engineer's work is impossible without mathematics (Kukreti et al. 2014). There were made several researches on transfer of real world applications to educational class (Ahern 2007).

Recent researches have indicated that the traditional learning method based on "reading", "listening" and "observing" are ineffective (Chua et al. 2014). Nowadays, increasing competition in construction requires multi skilled engineers and technicians who have enough knowledge and expertise. Design is an activity where designers create new solutions of a vision of a product concept, that is then evaluated and subsequently the designers generate a project in detail.

Civil engineering is significantly different from many other areas of human's activities. The engagement of civil engineering students with their university is an important factor in the quality of their learning experience. The objectives of educational system for studying graphics can be classified into three groups: foundational knowledge in civil engineering, training in the use of graphing and application of graphing systems of concepts (designs) to modern engineering (Bather 2013). Designer, based on analysis of different aspects, evaluations and synthesis, decides what is modeled and how. The design procedure is carried out by designers working individually or in design teams. The detailed documentation is nowadays mostly done by computer (Pourabdollahian et al. 2012).

The common practice of relying on average scores of students' performance evaluation, ,as the primary measure of learning effectiveness for promotion and tenure decisions should be abandoned for substantive and statistical reasons: there is strong evidence that students' performance does not measure teaching effectiveness. Students' performance ratings are valuable when they ask the right questions, report response rates and score distributions, as well as are balanced by a variety of other sources

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.004

and methods to evaluate teaching. The use of a real data set has the potential to increase engagement and learning in students who enrol in a civil engineering course at university.

A student's knowledge is dynamic, personal and consequently very subjective. From the entire designer's knowledge we only get to know what is explicitly expressed by him. However, the overall process of expressing knowledge requires effort as well as training time. It is also influenced by exterior factors such as personal relationships with other students (Santora et.al. 2013, Nesbit et.al. 2012).

"Engineering Graphics", although attributed to the general studying objects, is practically only studied by students of technological sciences, including engineers. Their future activities are inconceivable without graphic works. The research analyses on how knowledge, obtained in the learning process of t "Engineering Graphics" subject, is adaptable in the studying process of the design object's subject "Building architecture and structures" and in coursework projects.

1. Modules and the main objectives of the study subjects

The paper investigates the interdependence between two study subjects: graphics ("General Engineering Graphics" (1 sem.), "Applied Engineering Graphics" (2 sem.)) and design ("Building Architecture and Structures 1" (3 sem.), "Building Architecture and Structures 2" (4 sem.)) in the study process of Civil Engineering faculty.

Engineering Graphics (IG) and Applied graphics (AG) subjects introduce with the general engineering graphics' bases, standards, design principles, modern computerized design systems. During two semesters of engineering graphics courses students get theoretical and practical basis for not only general an engineering sophistication but also the necessary knowledge in the design of building structures: the ability to apply computer-aided design (AutoCAD) to constructional drawing and elsewhere.

During "Building Architecture and Structures" studies students are introduced with the architectural and functional structures, building design standards, and course projects of the different buildings are developed.

According to the opinions of teachers and students, the greatest impact on the studies' quality for "Building Architecture and Structures" is made by the previously studied two subjects in engineering graphics (IG and AG). The most important knowledge was identified as follows (Fig. 1, 2):

- Ability to understand and be able to form graphical information,
- Knowledge of construction drawing standards,
- Ability to work in computer-aided design (*AutoCAD*).

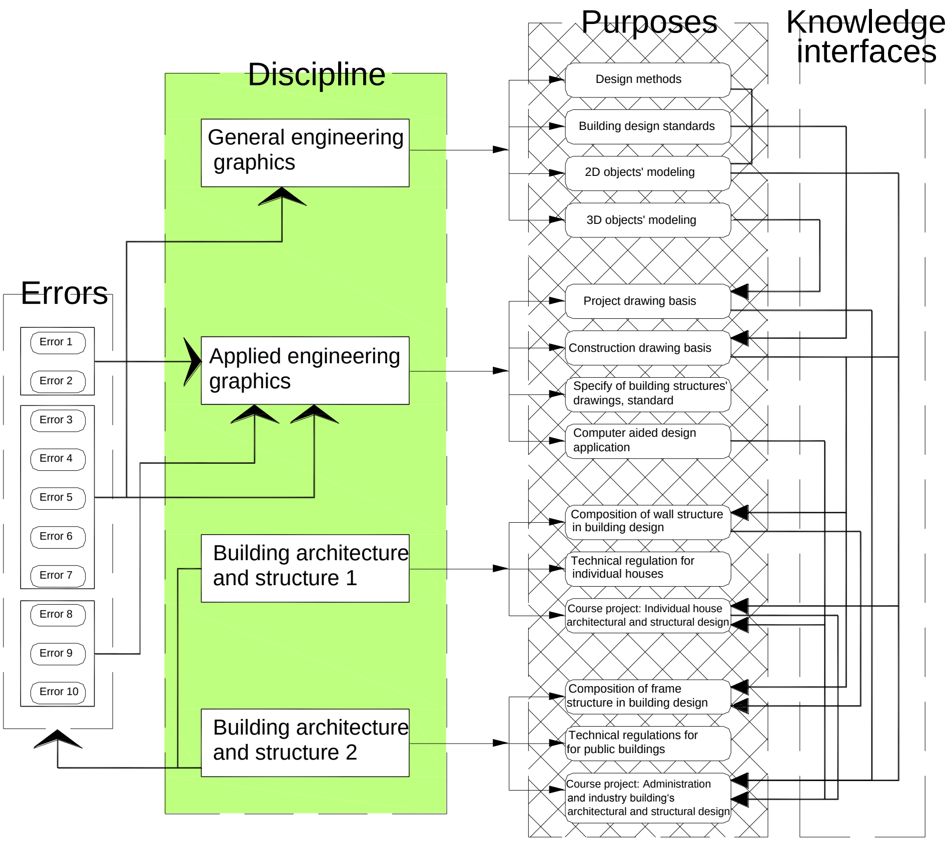

Fig. 1. Interdependence of design and graphics learning objects in civil engineering studies

2. Knowledge interface

The knowledge acquired in the "General Engineering Graphics" studies is applied in "Applied Engineering Graphics" studies, such as:

- studying the basics of projection drawing it's necessary to know not only what the design methods are, but also the application cases of them,
- drawings standards and application of their features are reflected in the machinery and construction drawings,
- having learned to draw by program AutoCAD (2D drawings), a very wide range of applications appears: from charts and tables to construction drawings,
- The learned 3D modelling with computer graphics' program is applied in preparing the projections of automated components.

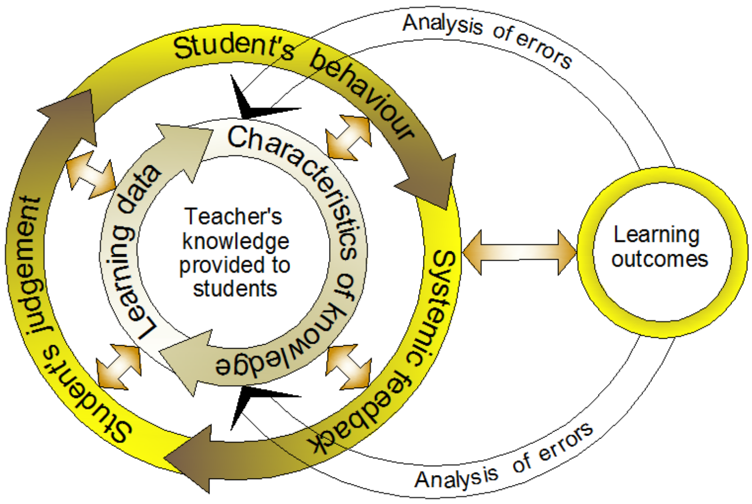

Fig. 2 Summary of the provided knowledge and observations about the most often made errors

With the knowledge of these two subjects, students prepare two "Buildings architecture and structures" course projects. Practically all knowledge obtained during the training of graphics subject is needed for performing of the design projects and preparing for the exam on this subject. However, the authors of this article have noticed that these studies reveal different errors in relation to the lack of knowledge of engineering graphics (Fig.1):

- projection relationship between the images (Error 1),
- representation of objects in images and sections (Error 2),
- position of building's axes and their marking (Error 3),
- Walls' „tethering" to axes (Error 4),
- portrayal of walls, doors, windows in plans and sections (Error 5),
- line widths in different images (Error 6),
- dimensional (linear and elevation) marking (Error 7),
- displaying horizontal and vertical projections of stairs according to the standard (Error 8),
- Adjustment of dimension elements' scale to the drawing elements and overall scale (Error 9),
- Others (mistake 10).

In fact, errors are one of the most powerful learning tools at our disposal for graphics studies (improvement of learning based on investigation of mistakes). The mistakes indicate failure only if we fail to learn from them. The development learning is a wonderful resource in this respect.

3. Comparison of students' scores

Student's performance ratings have been used, studied, and debated almost through the centuries. This article examines ratings of students' performance from a statistical perspective. Evaluation of students' scores is one of the most popular methods to evaluate students' learning. Students' average scores mean, that the difference of performance level between 9 and 10 means the same thing as the difference between 5 and 6.

The following calculations of the basic statistics of students' scores were made: average, standard deviation, coefficient of variation, coefficient of determination (Table 1).

Table 1 Statistics' of students learning evaluation

No.	General Engineering Graphics	Applied Engineering Graphics	Building Architecture and Structures 1. Exam	Building Architecture and Structures 1. Course work	Building Architecture and Structures 2. Exam	Building Architecture and Structures 2. Course work
	B	C	D	E	F	G
A_1	10	10	10	10	10	10
A_2	10	10	10	10	10	10
A_3	10	10	10	10	10	10
A_4	10	10	10	10	10	10
A_5	10	10	10	10	9	10
A_{137}	9	7	5	6	5	5
A_{138}	9	7	5	5	5	5
A_{139}	9	6	7	6	8	5
A_{140}	9	6	5	8	6	8
A_{238}	5	8	7	5	7	5
A_{239}	5	8	6	5	5	5
A_{240}	5	8	5	5	7	5
A_{241}	5	7	5	5	5	5
Correlation coefficient B/x		0.241	0.212	0.421	0.277	0.307
Correlation coefficient C/x			0.293	0.308	0.209	0.413
Correlation coefficient D/x				0.331	0.358	0.365
Correlation coefficient E/x					0.402	0.469
Correlation coefficient F/x						0.444
Average deviation	1.15	1.30	1.27	1.42	1.31	1.79
Mean of the observed data	8.63	8.29	6.80	6.98	6.46	6.89
Median	9	9	7	7	6	6
Standard deviation	1.38	1.55	1.49	1.69	1.57	1.99
The total sum of squares	18425	17123	11677	12413	10662	12386

According to the graph, presented in Fig. 3, it is obvious that lack of knowledge and skills at the beginning of the learning process impacts a number of errors and knowledge performance of civil engineering students.

Correlation analysis is one of the most widely used and reported statistical methods in summarizing scientific research data. It is often useful to determine if a relationship exists between two different variables. The correlation coefficient is a statistic used to measure the degree or strength of this type of relationship.

Correlation coefficients whose magnitude is between 0.9 and 1.0 indicate variables which can be considered *very highly correlated*. Correlation coefficients whose magnitude is between 0.7 and 0.9 indicate variables which can be considered *highly correlated*. Correlation coefficients whose magnitude is between 0.5 and 0.7 indicate variables which can be considered *moderately correlated*. Correlation coefficients whose magnitude is between 0.3 and 0.5 indicate variables which have a *low correlation*. Correlation coefficients whose magnitude is less than 0.3 have little if any (linear) correlation.

The three most statistically significant (biggest) correlation coefficients are determined as follows:

- A correlation coefficient of 0.469 (statistically significant) was noted between the "Building Architecture and Structures 1. Course work" and the "Building Architecture and Structures 2. Course work" in the evaluation of 241 students.
- The reported correlation 0.444 between the "Building Architecture and Structures 2. Exam" and "Building Architecture and Structures 2. Course work" was statistically significant.
- "General Engineering Graphics" and "Building Architecture and Structures 1. Course work" 0.421.
- The three least statistically significant correlation coefficients are as follows:
- "Applied Engineering Graphics" and "Building Architecture and Structures 2. Exam" 0.209;

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– “General Engineering Graphics” and “Building Architecture and Structures 1. Exam” 0.212;
– “General Engineering Graphics” and “Applied Engineering Graphics” 0.241.

The fact that 0.209 < (correlation coefficient) < 0.469 indicates variables which can be considered *low correlated.*

A low value for *correlation* does not mean that there is no correlation; there could be a nonlinear correlation.

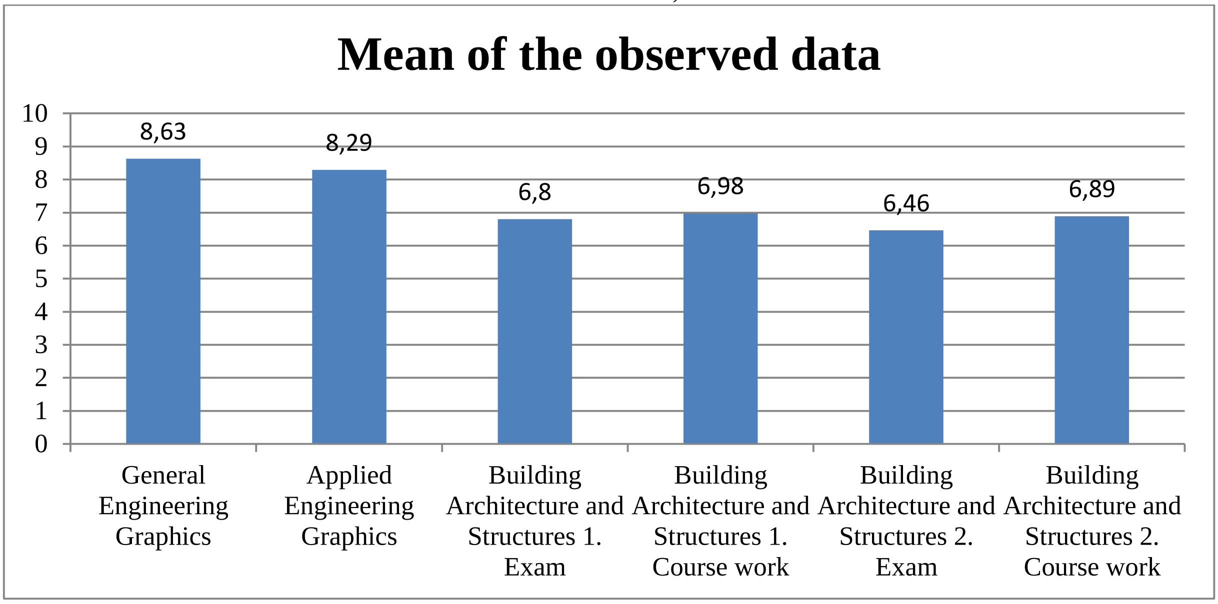

Fig. 3 Mean of observed data.

Conclusions

– Engineering Graphics’ knowledge acquired during the study allows understanding the imaging (portrayal, representation) of the buildings’ elements in different projections.
– Mastering the basics of 2D computer simulation helps students perform the necessary construction drawings quicker, more accurately and more efficiently.
– Learning the 3D modelling fundamentals allows to better visualize the spatial structure of the building and to understand its elements’ imaging in projections.
– The interdependence between the subjects referred in the article is much closer than just the ability to use tools for building graphics display elements, therefore the teachers of engineering graphics subjects should pay attention to the above errors and highlight links to future courses.

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VIDEOGRAMMETRY AND ONE OF ITS APPLICATIONS

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Abstract. Videogrammetry is presented in the paper as a new branch of photogrammetry that offers some effective algorithms for direct reconstruction of moving objects from video records. Videogrammetry can solve two major problems: reconstruction of surfaces (body, face, etc.) and determination of trajectories of moving targets. Videogrammetry can inspect permanently provided and stored records taken by video cameras, so it can be used for additional measurements and re-measurements, and verification at any time. Basic concepts and algorithms for reconstruction of real dimensions of a 3 dimensional moving object from its video records are introduced. Basic formulas for algorithms of point positioning and calibration calculation are explained.

Keywords: videogrammetry, photogrammetry, 3D data reconstruction, video records, calibration

Introduction

Videogrammetry is a new branch of photogrammetry that offers some effective algorithms for direct reconstruction of moving objects from video records. It works in a non-contact mode, can determine and track even very complex point clouds, delivers very precise and reliable results, and can be fully automated. After a decade of intense research and development this technique can be used in very diverse applications, such as surface reconstruction of human faces (in medicine, doll manufacturing), tooth measurement, human movement studies (biomechanics), determination of insect trajectories (biology, pharmacy), architectural structures (archaeology, monument preservation), measurement of car (industrial design, quality control and crash testing), measurement of airplane surface patches and jet engine parts (material testing and industrial inspection), high-resolution 3D particle tracking in turbulent flows (hydromechanics, space science), chemical reactions in turbulent flows (chemistry, hydromechanics), monitoring of crystal growth (material science), self-orientation and egomotion determination of a vision-based robot (robotics). Videogrammetry can solve two major problems: reconstruction of surfaces (body, face, etc.) and determination of trajectories of moving targets. Videogrammetry can inspect permanently provided and stored records, so it can be used for additional measurements and re-measurements, and verification at any time.

The aim of this paper is to present basic principles and algorithms of the fundamentals of videogrammetry, as presented e.g. in (Gruen, A.1997), in comparison to classical photogrammetric methods used in 3D reconstruction from two digital camera images on the principles of epipolar geometry, as given e.g., in (Gruen, A.1985). Example of the practical application of presented algorithms is provided, where reconstruction of 3D data has been processed from the video recordings.

1. Basic concepts

Usually, the measured object is recorded (imaged) by a certain number of frames taken by video cameras from different locations. Two frames (stereo model) provide mathematically sufficient information; anyhow, such representations feature several serious drawbacks:

1. it does not provide sufficient redundancy in observations for detection and location of important points of the measurements,
2. there remain object parts that are completely invisible for the two cameras,
3. not suitable geometric configurations of visible object parts may appear leading to inaccuracy of measurements,
4. very large objects cannot be covered with only two images at a given accuracy level.

Due to these reasons, in case of a static point cloud, two cameras in different position are sufficient, but for a moving object, up to 4 cameras should be used for simultaneous imaging. Fig. 1., source (Gruen, A.1997), shows a photogammetric (or videogrammetric) network arrangement also called a block. Object points P_i (i = 1, 2, ..., n) are imaged onto the video camera frames F_j (j = 1, 2, ..., m) according to the laws of perspective projection. Any one frame may include a large number of points, up to a few thousands, depending on the type of the camera sensor used. Any one object point may be imaged onto an arbitrary number of video camera frames, while usually a maximum of about nine is used. It is recommended to use more than two frames, thus generating a geometrically strong and statistically reliable network. Typical measurement configuration is presented in Fig. 2, source (Gruen, A.1997), where the object, a 3D the point cloud, is imaged onto four frames. Such point cloud could represent a targeted object (e.g. a human marked with retro-reflective targets) or a surface marked with a projected dot pattern, while targeting is not mandatory for a videogrammetric solution. If the image of the object contains a sufficient amount of texture, natural object features can also be measured and tracked. For a static point cloud it is sufficient to use just

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.005

one camera, and to move it from one position to the other. In case of a moving point cloud four cameras should be used for simultaneous imaging.

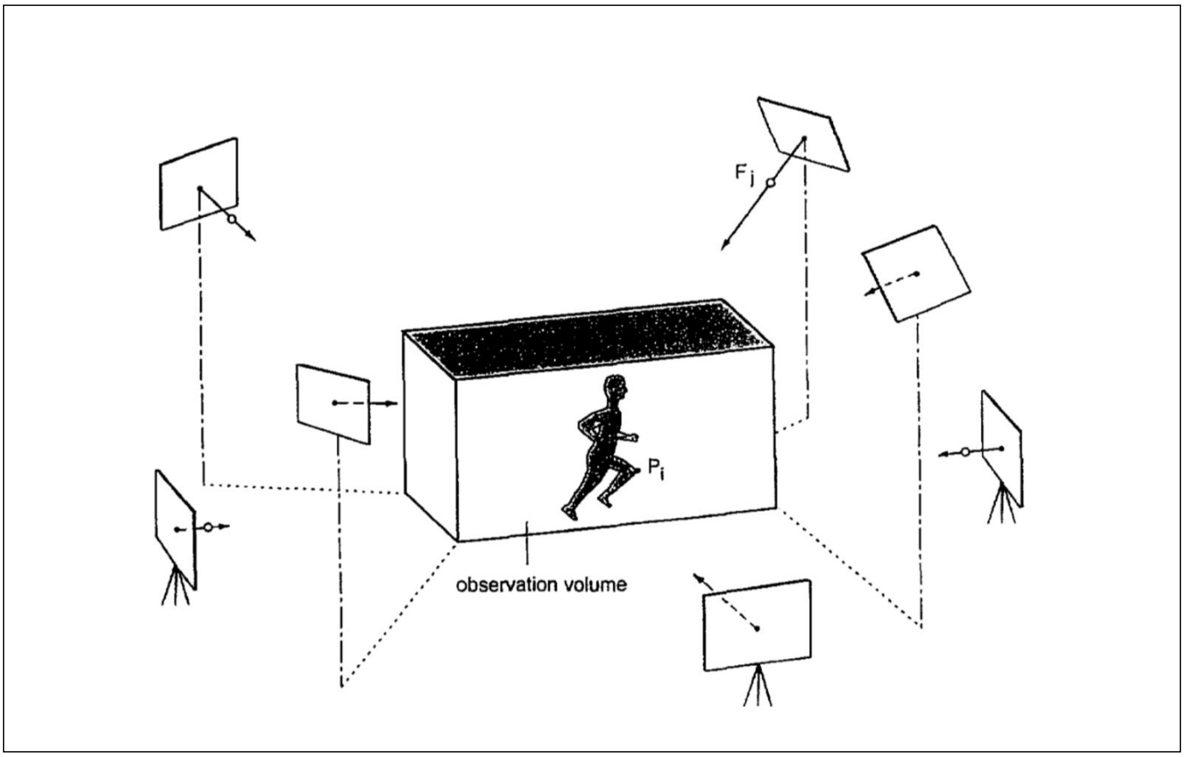

Fig. 1. Videogrammetric block.

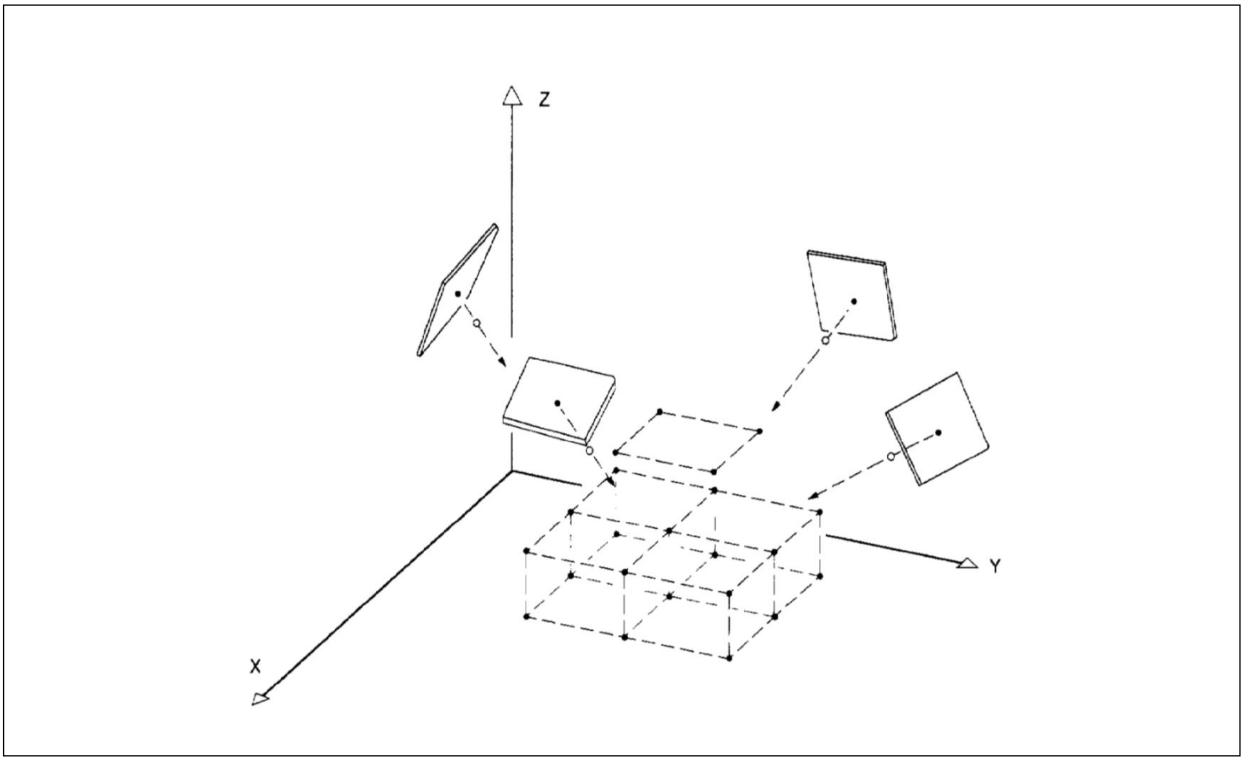

Fig. 2. Recording of 3D point cloud with multi-station configuration of 4 cameras.

The underlying mathematical model is the so called bundle method based on principles of perspective projection. The object points $P_i = (X_i, Y_i, Z_i)$, $i = 1, 2, ..., n$, $n \in N$ in the space are projected by a straight line through several centres of projection O_j =

(X_{0j}, Y_{0j}, Z_{0j}) onto the points with coordinates $P'_{ij} = (x_{ij}, y_{ij}, 0)$ in the image planes. This collinearity condition can be formulated by equations

$$(X_i, Y_i, Z_i)^T = \lambda_{ij} \mathbf{R}_j (x_{ij}-x_{0j}, y_{ij}-y_{0j}, 0 - c_j)^T + (X_{0j}, Y_{0j}, Z_{0j})^T, \tag{1}$$

where the orthographic images of projection centres O_j into the image planes are the principal points $H_j = (x_{0j}, y_{0j}, 0)$ and c_j are the camera related constants, i is the number of projected points, λ_{ij} is the scale factor for image rays ij and $\mathbf{R}_j$ is the rotation matrix between image and object space coordinate systems.

In any frame the interior orientation is given by parameters x_{0j}, y_{0j}, c_j and parameters X_{0j}, Y_{0j}, Z_{0j}, and angles of rotations φ_j, ω_j, κ_j from the matrix $\mathbf{R}_j$ represent the exterior orientation. By canceling the scaling factor λ_{ij} and re-arranging the 3-component equation (1) we will receive equations

$$\begin{aligned} x_{ij} &= -c_j f_{ij}^x + x_{oj} = \\ &= -c_j \frac{r_{11j}(X_i - X_{0j}) + r_{21j}(Y_i - Y_{0j}) + r_{31j}Z_i - Z_{0j})}{r_{13j}(X_i - X_{0j}) + r_{23j}(Y_i - Y_{0j}) + r_{33j}(Z_i - Z_{0j})} + x_{0j} \end{aligned}$$

$$\tag{2}$$

$$\begin{aligned} y_{ij} &= -c_j f_{ij}^y + y_{oj} = \\ &= -c_j \frac{r_{12j}(X_i - X_{0j}) + r_{22j}(Y_i - Y_{0j}) + r_{32j}Z_i - Z_{0j})}{r_{13j}(X_i - X_{0j}) + r_{23j}(Y_i - Y_{0j}) + r_{33j}(Z_i - Z_{0j})} + y_{0j} \end{aligned}$$

where r_{11j}, …, r_{33j} are the elements of the matrix $\mathbf{R}_j$.

Depending on the parameters of the equations (2), which may be considered as known or these may be a-priori treated as unknown, while coordinates of the point images x_{ij}, y_{ij} are always regarded as known observed entities, the following problems can be solved:

1. general bundle method - all parameters on the right hand side of (2) are unknown,
2. bundle method for metric camera system – interior orientation (x_{0j}, y_{0j}, c_j) is given,
3. spatial resection:
    a) interior orientation and object point coordinates (X_i, Y_i, Z_i) are given, while the exterior orientation has to be determined,
    b) only object point coordinates are given, the interior and the exterior orientation has to be determined,
4. spatial intersection: Both the interior and the exterior orientation are given, and the object point coordinates have to be determined.

In videogrammetry, the following terms are distinguished:

- Point positioning – The aim is to determine 3D coordinates of object points within a specified accuracy
- Orientation – The aim is to determine parameters of the exterior orientation
- Calibration – The aim is to determine the parameters of interior orientation plus additional parameters for the systematic image errors
- Simultaneous solution – Integration of all previous tasks.

2. Point positioning

Equations (2) are considered as relating observations x_{ij}, y_{ij} – coordinates of points in the images, to the parameters of the right-hand side as the relation $l = f(x)$. Estimation of x is performed using the Gauss-Markov model of the least square estimation. Linearization and introduction of a true error vector e leads to the form $l - e = \mathbf{A}x$. A is $n \times u$ matrix (n is number of observations, u is number of unknown parameters), while in general $n \geq u$ and rank $(\boldsymbol{A}) = u$. The estimation of x is usually attempted as unbiased, minimum variance estimation, performed by means of least squares, and results in

$$\hat{x} = (\mathbf{A}^T \mathbf{P} \mathbf{A})^{-1} \mathbf{A}^T \mathbf{P} l, \quad \upsilon = \mathbf{A}\hat{x} - l, \quad \sigma_0^2 = \frac{\upsilon^T P \upsilon}{r}, \quad r = n - u \tag{3}$$

where σ_0^2 is the variance factor, $\mathbf{P}$ is the weight coefficient matrix of l, and υ is residuals of the least squares. For $\mathbf{A}^T\mathbf{PA}$ to be uniquely invertible, the seven parameters of the spatial similarity transformation of the network need to be fixed. This can be achieved by introducing control points with at least seven fixed coordinate values, or by fixing seven appropriate elements of the exterior orientations of two frames.

A major problem in bundle adjustment is caused by the fact that the model for the observation equations is non-linear. Linearization using Taylor expansion leads to the necessity to iterate the solution, which requires approximate values for all system unknowns in order to start the first iteration. The automatic and reliable computation of good approximate values is not a trivial problem.

One of the most widely used methods is the representation of the projective transformation between 3D object space and 2D image space in the following form

$$x_{ij} = \frac{L_{11j}X_i + L_{12j}Y_i + L_{13j}Z_i + L_{14j}}{L_{31j}X_i + L_{32j}Y_i + L_{33j}Z_i + 1}$$
$$y_{ij} = \frac{L_{21j}X_i + L_{22j}Y_i + L_{23j}Z_i + L_{24j}}{L_{31j}X_i + L_{32j}Y_i + L_{33j}Z_i + 1}, \qquad (4)$$

which can be reformulated into linear least square observation equations

$$x_{ij} - e_{xij} = X_i L_{11j} + Y_i L_{12j} + Z_i L_{13j} + L_{14j} - x_{ij} X_i L_{31j} - x_{ij} Y_i L_{32j} - x_{ij} Z_i L_{33j}$$
$$y_{ij} - e_{yij} = X_i L_{21j} + Y_i L_{22j} + Z_i L_{23j} + L_{24j} - y_{ij} X_i L_{31j} - y_{ij} Y_i L_{32j} - y_{ij} Z_i L_{33j} \qquad (5)$$

System (5) allows to estimate the coefficients $L_{11}j$, …., L_{33j} of the linear transform of every frame *j*. Advantage of the formulation (5) is that the parameters of the interior and exterior orientations are implicitly included in L_{11}, …., L_{33} and their approximate values need not be determined. On the other hand, it is necessary to have at least 6 control points available in a very good 3D spatial distribution.

3. Calibration

Many various calibration methods have been developed so far and are used in videogrammetry for different purposes, see e.g. in (Ma, Y., Košecká, J., Soatto, S., Sastry, S. 2001), or (Stachel, H. 2006). Laboratory calibration is based on using special equipment (goniometers) and various methods for determination of the interior orientation and systematic errors of the used camera, which is a quite expensive and time-consuming procedure. Reference frame calibration uses a reference object (distance bar, or regular polyhedral model) consisting of certain number of precisely measured points, which is imaged. Mathematical model is used, where the required parameters can be derived from the mathematical relations between the reference frame coordinates *X*, *Y*, *Z* and measured pixel coordinates *x*, *y* of the image. Point cloud calibration works with a 3D cloud of well signalized points, which need not to be measured beforehand, which is fast and cheap, but a disadvantage is, that to determine all the necessary parameters, at least four images from different locations have to be taken. Self-calibration can be considered the most universal and flexible method, based on the expansion of basic equations (2). Introducing corrections Δx_{ij} and Δy_{ij} to image coordinates x_{ij} and y_{ij}, including coordinates x_{0j} and y_{0j} of the principal points and camera constants c_j, new relation system is derived

$$x_{ij} = c_j f_{ij}^{x} + x_{0j} + \Delta x_{ij}$$
$$y_{ij} = c_j f_{ij}^{y} + y_{0j} + \Delta y_{ij} \qquad (6)$$

The formulation of the added parameter functions is crucial, as it can quite unpleasantly influence the physical distortion of the reconstructed 3D objects. The following functions have proved to be effective, according to [1], in various applications:

$$\Delta x = -\Delta x_0 + \frac{\bar{x}}{c}\Delta c + \bar{x}s_x + \bar{y}a + \bar{x}r^2k_1 + \bar{x}r^4k_2 + \bar{x}r^6k_3 + (r^2 + 2\bar{x}^2)p_1 + 2\overline{xy}p_2$$
$$\Delta y = -\Delta y_0 + \frac{\bar{y}}{c}\Delta c + 0 + \bar{x}a + \bar{y}r^2k_1 + \bar{y}r^4k_2 + \bar{y}r^6k_3 + (r^2 + 2\bar{y}^2)p_1 + 2\overline{xy}p_1$$
$$\bar{x} = x - x_0, \bar{y} = y - y_0, r^2 = \bar{x}^2 + \bar{y}^2 \qquad . \qquad (7)$$

The individual parameters represent

- change in interior orientation elements –Δx, Δy, Δc
- scale factor in coordinate axis *x*, affinity – s_x
- shear factor, jointly in *x* and *y* – *a*
- first three parameters of radial symmetric lens distortion – k_1, k_2, k_3 (whereas k_3 is a-priori disregarded if normal and wide-angle lenses are used)
- first two parameters of de-centering distortion – p_1, p_2

The specification of the principal point is not specified for most cameras and it varies from one to another, as it depends on the frame grabber. The scale factor in x is therefore required to model the imprecise specification of the sensor element spacing and additional imprecision introduced with line synchronization. The pixel spacing in x must be computed from the sensor element spacing *ssx*, the sensor clock frequency *fsensor* and the sampling frequency *fsampling*of frame grabber in accordance with the formula $psx = ssx.(fsensor/fsampling)$.

The shear factor must be included for compensation of the geometric deformation which can be induced by line synchronization. The extended bundle model then yields as

$$l - e = \mathbf{A}x + \mathbf{A}_3 z, \tag{8}$$

where $\mathbf{A}_3 z$is vector of additional parameters and associated design matrix.

4. Simultaneous solution

In a general bundle concept all parameters are treated as stochastic variables. This permits to consider a-priori information about these parameters to be included, which covers both situations when parameters are excluded from the considerations or they are treated as free unknowns. The general bundle model may be extended by more equations modeling the observations of geometric constraints in a particular scene, such as parallel straight lines, horizontal and vertical lines, points in specific planes or on quadratic surfaces, see in [3], which stabilize the solution for calibrations and orientation and point tracking.

One of the parameters responsible for the system's overall precision and accuracy is the quality of measurement algorithms for image targets. In applications detecting human movement, the targeting spans from very well defined retrospective targets to the use of natural features. The accuracy of image features measurements varies according to the quality of signal content.

A very simple and computationally fast algorithm for blob measurement is the "centre of gravity" algorithm, where coordinates of the blob centre are calculated as

$$x_c = \frac{\sum g_i x_i}{\sum g_i}, y_c = \frac{\sum g_i y_i}{\sum g_i}, \tag{9}$$

where x_i, y_i are pixel coordinates of the image pixels containing the blob, and $g_i$are the associated grey values.

A concept of multi-image analysis has been designed as a search procedure for image features, which allows establishing almost unambiguous correspondence, which is of a great value especially in those cases, when a large number of targets follow very complex trajectories in 3D space.

5. Application example

Videogrammetric methods can be used e.g. for detection of a human being that is moving in the camera recorded security space. Some of the invader basic body dimensions can be reconstructed using the described measurement methods applied to the received point clouds as recorded by the installed stable cameras. Measurements accuracy depends on the achieved precision in attaching observations x_{ij}, y_{ij} – coordinates of points in the recorded images in the separate frames, called point tracking. These rather sensitive input data strongly influence the reliability of the resulting measurements. Therefore, a quite large point sets had to be detected in order to receive statistically reliable data.

Fig. 3. Security camera pictures of a suspect while entering security recorded space.

Fig. 4. Suspects entering space recorded by security video cameras.

In Fig. 3. and Fig. 4. examples of pictures taken by video cameras are presented, where persons committing a bank robbery had been recorded while entering the recorded security space. Reconstructions based on the described algorithms led to a description of the suspect, where basic body dimensions as height, weight, size and form of head, hair colour and haircut, and specific movement gestures were described in details. This offender description had been used as a proof of evidence when the suspected persons were investigated and convicted from committing the criminal act of bank robbery.

Conclusions

Basic videogrammetric algorithms and methods can be used in a plethora of applications for practical purposes, when reconstructions of objects, stable or moving in the 3-dimensional scenes, are performed for various purposes. Mathematical analytic relations represented in the paper as algorithms for 3D reconstruction solve basic measurements problems and can help in tracking moving bodies in the recorded space, where calibration can be given due to stability of camera positions. Situation for moving cameras and changing scene can be much more difficult to reconstruct, as calibration is computed on the flow, using self calibration methods, and targeted object must be followed while determined by a fuzzy point cloud with changing set of determining points.

Acknowledgements

This paper was supported by the grant APVV-1061-12.

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PECULIARITIES OF STAIRCASE REPRESENTATION IN EDUCATIONAL PROCESS

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Abstract. Every day we climb the stairs. The Lithuanian documents such as construction standards and technical building regulations show the rules of graphical representation of staircase elements. The graphical representation of staircase in the training measures for VGTU students is explained in two ways: old “pencil” methods (such as vertical and horizontal sections of the elements) and the adapted computer program in AutoCAD. Despite the different approaches, it is important to future building engineers to be able to understand and draw relationships between the elements of the stairs in the plan and cut. Students need to draw stairs projections in single family and public building course projects in two semesters. However there is no time to explain the peculiarities of drawing, although it should be done. Therefore, the authors believe that graphical representations .are necessary for additional demos (posters) helping to realize the features of stairs elements.

Keywords: stairs, stairs projections, standards, STR (Technical Construction Regulations), engineering graphics, demos

Introduction

One of the last engineering graphics students’ works at Civil Engineering Faculty of Vilnius Gediminas Technical University is construction drawing. Students have to draw a building plan, façade and staircase cut. It seems, that everyone could easily describe a staircase horizontal projection after finding out the construction drawing standards and teaching material of engineering graphics, because it is a simple example of building horizontal cut according to the technical standards and STR (Technical Construction Regulations). Unfortunately, there are a number of graduates of civil engineering and architectural specialties who do not know how to display stairs in architectural plans. Why architectural? Primarily we must begin to talk about an architectural plan as it should be drawn first. Architects display stairs in the building plan according to internal walls and geometrical sizes. Only then constructors design stairs bearing elements and staircase construction. If a staircase is drawn with mistakes and not according to the requirements, or architectural cut is not made via staircase, constructors may not correctly understand information about the situation of the stairs.

The aim of the work is to explain the peculiarities of staircase representation associated with the legal documents, to discuss the most common mistakes of students’ works and to prepare demos helping students to develop the understanding of stairs images (horizontal and vertical cuts).

1. Staircase representation in the Lithuanian legal documents

The legal documents are intended for certain drawing rules: principles of imaging, graphic conventions and etc. The first standards explaining the general rules of design and drawings, which were eventually used in Lithuania, were approved in 1928. (Vyšnepolskis, 1984). Although the drawings of this period were not carried out strictly according to the rules (that could be seen nowadays), but building elements (windows, doors, columns, stairs, etc.) were represented quite accurately. We can indicate the clear number of the stair steps, cut building elements including stairways which are shown in a different colour and so on (Fig. 1).

Unfortunately, nowadays the Lithuanian legal documents (STR and the standards) give much less attention to construction drawing comparing them with standards for mechanical drawing. The standard “General principles of presentation for general arrangement and assembly drawings” published in 1991 (LST EN ISO 7519:2001) offers only one drawing meant for stair representation (Fig. 2). In the standard published in 1998 “Design of construction works. General requirements“ (LST 1516:1998) we can find the drawing which explains how to mark vertical dimensions in floor plans (Fig. 3). STR published in 2003 (STR 1.05.08:2003) refers to the following standards and presents the same drawing of the stairs plan (Fig. 2). By the way, if we compare the mentioned standards with the standard for drawing lines (LST ISO 128-23:2002) we will notice the differences (Fig. 4). It is also necessary to pay attention to the standard for environment (LST EN ISO 11091:2001) in which vertical dimensions (Fig. 5) are not marked according to the previous standards (LST 1516:1998), although it was published in 1994.

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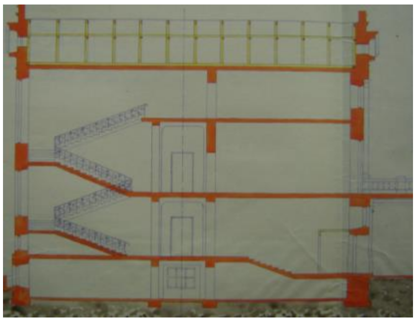
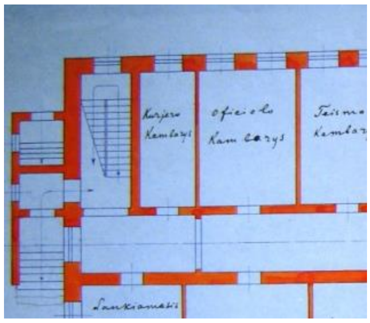
eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.006



a)



b)

Fig. 1. The fragments (a – vertical cut, b – horizontal cut) of the Kaišiadorys diocese project (1931)

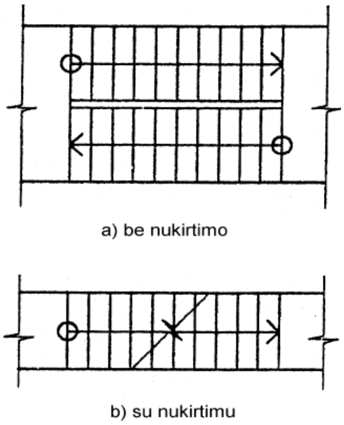


Fig. 2. Stairs in plane

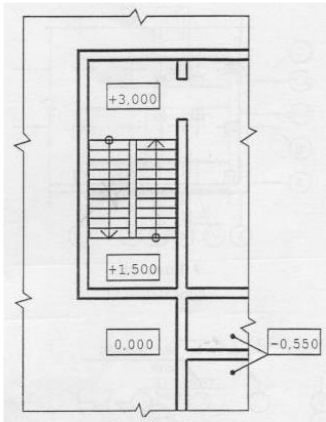


Fig. 3. Vertical dimensions in floors plane

So, according to the differences in the standards, the line width and vertical dimensions may vary in the architectural drawings of stairs, as an architect thinks only about the drawing aesthetics and the mentioned aspects are not important for the real project design. But today the situations when young architects do not know how to draw stair projections correctly, are too often.

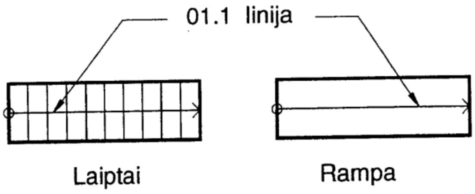


Fig. 4. Arrow lines on the displayed stairs and ramps

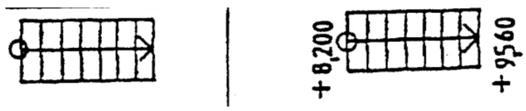


Fig. 5. Steps and stairs plotted in landscaping drawings

2. Graphical representation of staircase in the training measures

It is not enough to know only the drawing rules, which show the final result of the drawing, but do not explain how to reach it. So students at technical colleges and higher educational institutions are taught construction drawing and applied graphics.

Construction drawing course is taught to environmental, civil engineering and architectural professions students. Of course the significant part of the course information is about stair representation.

eISBN 978-609-457-835-9

The colleagues, who teach construction drawing, say: "Informatics, despite the positive aspects, has brought some confusion in engineering graphics education" (Makutėnienė, Čiupaila 2011). However some lecturers do not agree on this matter and always discuss what teaching methods are more effective.

Smart TAIGRA created in the AutoCAD computer system by the colleague (http://www.ikg.projektas.info/) is adapted to solve various aspects of the study process of engineering graphics. The colleagues say that old "pencil" methods are not already proper examples; despite this fact the foreign teachers (Filisiuk, Krasovskaja 2012) explain engineering graphics requirements using the same classical methods (Fig. 6). We would agree with criticism of "pencil" methods, if students using information measurements would be able to develop and understand the links between elements of the plan and cut of the stairs.

Unfortunately, too few students at Civil Engineering Faculty are able to display the contours of the staircase plan and cut preparing the "Building architecture and design" course project. So lecturers need to draw examples on the board explaining how to image staircase in the cellar, on the first or on the second floor, as representations in various floors are different. This is the subject of engineering graphics!

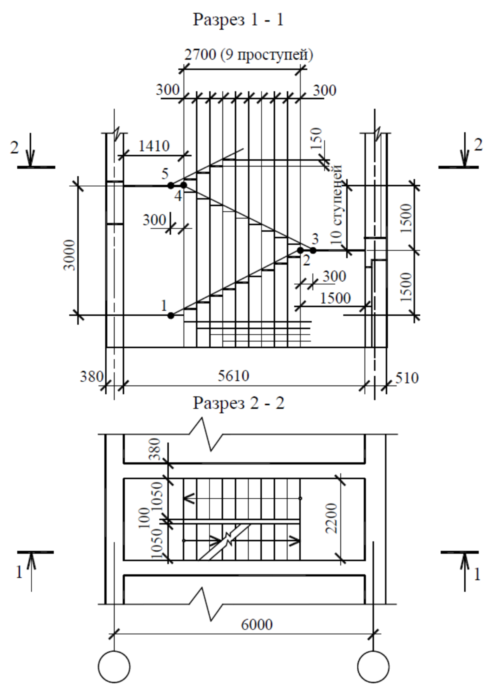
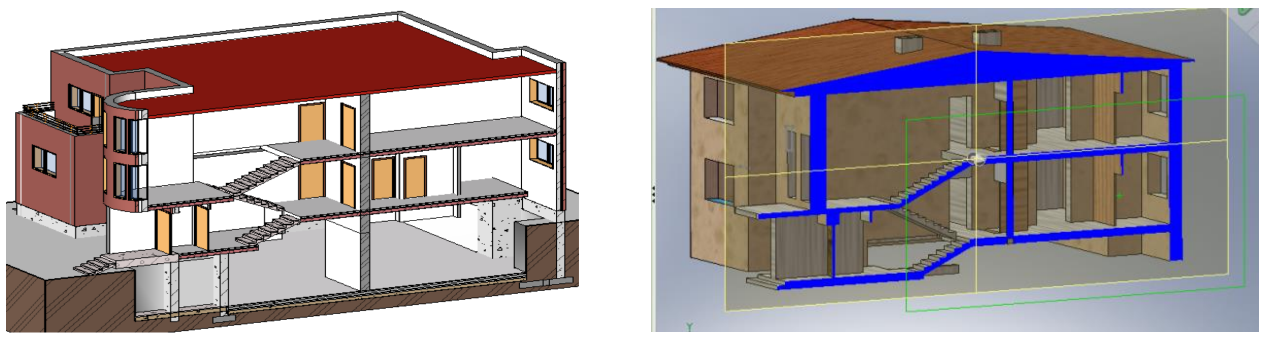


Fig. 6. The image of horizontal and vertical staircase cut in the Russian training book (Filisiuk, Krasovskaja 2012)

3. Demos of staircase representation

Stair forms are innumerable; some of their representations are not clear not only for 4-year students, but also for young architects and construction graduates.

Teachers have to look for ways to provide the necessary information helping students to understand the stairs in space and represent them in the drawing. For that purpose such computer programmes as Revit Architecture (Fig. 7a) are used, which are intended for structure design or SolidWorks (Fig. 7b) which simulate machine details (Vdovinskienė, Vilkevič 2009).



a) b)

Fig. 7. The images of the buildings cuts, performed by Revit Architecture and SolidWorks computer systems

The most frequent mistakes in students' works of staircase projections representation are as follows:

- different number of stair steps in plane and cut,
- line width of the vertical staircase projection is not correct,
- the first step of the staircase is incorrectly presented,
- horizontal projections of stairs on different floors are incorrectly drawn.

Prepared demos require the consistent application of the drawing requirements (it is need to display the stages of the drawing, to show lines connecting staircase projections, to explain representation of the first staircase step, etc.) The last mentioned error mostly influences the further students' works, so we present the sketch explaining only this error.

The first year students start learning about staircase projections from simple forms of stairs. So we recommend using the demonstration poster which shows staircase connecting two floors, and comments (Fig. 8).

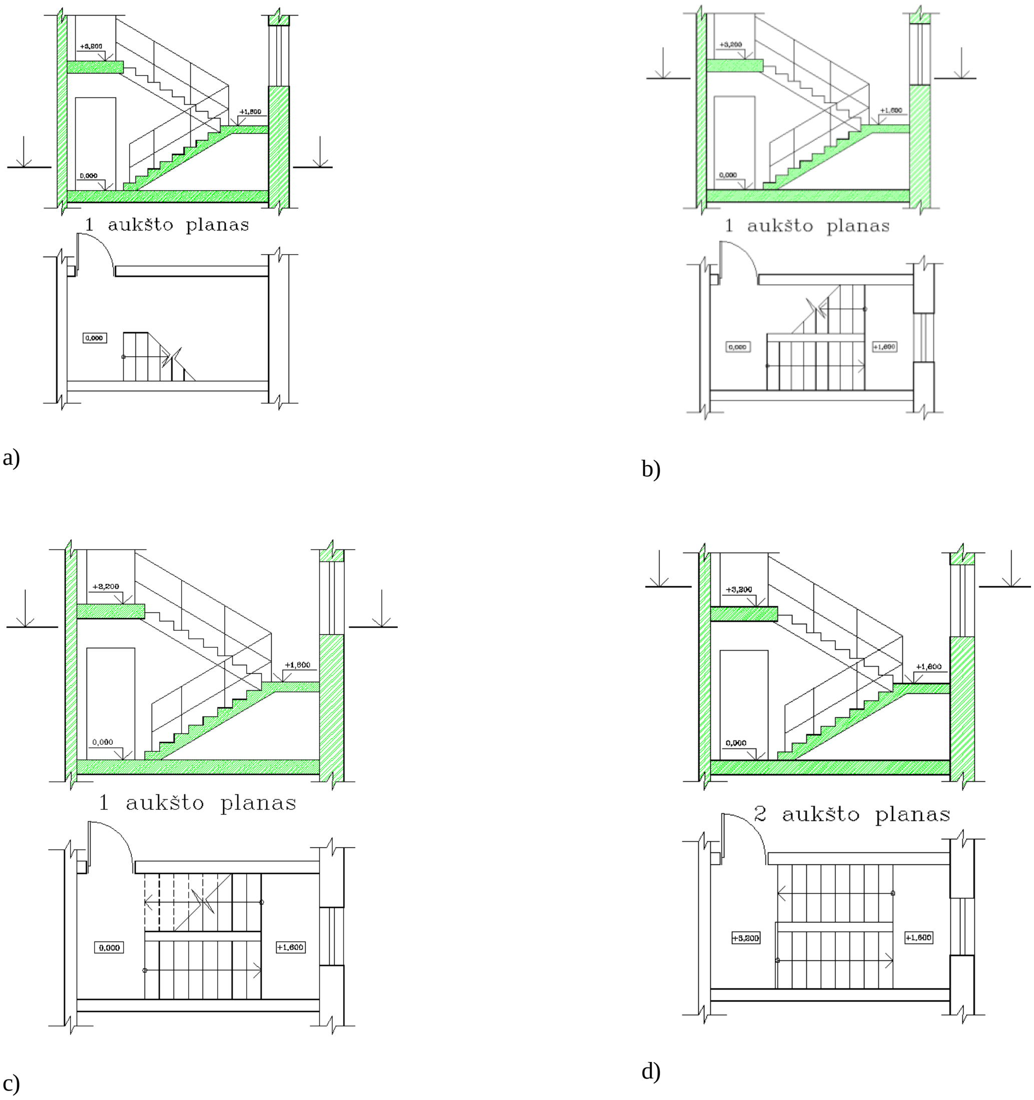
The comments (poster text part) of the sketch:

1. The horizontal projection of the first floor staircase can be displayed in three ways:
   - the cut plane intersects the stairways below the intermediate platform (Fig. 8 a),
   - the cut plane intersects the stairways above the intermediate platform (Fig. 8 b),
   - the cut plane intersects the stairways above the intermediate platform, but additional dotted lines of the flight of stairs lines outside the cut plane are shown (Fig. 8 c). Such stairway presentation is not reviewed in the legal documents, but is widely used in architectural design process.

2. Both the stairways are visible in the second floor stair projection (Fig. 8 d).

3. Vertical dimensions are necessary at the floor planes (Fig. 8).

It is not necessary to show all the information about stairs at the demonstration posters, because today teachers may load it into Moodle system of VGTU. As this learning platform gives effective online teaching it is easy to create various tests, learning experiences and teaching measures for peculiarities of staircase representation, for example 3D virtual images of various building could be presented in the learning material about stairs (Fig. 7).



a) b) c) d)

Fig. 8. The sketch of stairs connecting two floors

Conclusions

- First year students are not able to represent staircase projections correctly by themselves, after they have been taught the drawing rules. So it is necessary to give them the additional training information using demos.
- Demonstration posters should show the stages of drawing stairs, connecting stairways projections by construction lines and etc.
- Teachers can load the information about staircase forms, tests and various demos into Moodle system.
- All the Department staff should decide what training material must be printed in demonstration posters or be loaded into the information space.

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eISBN 978-609-457-835-9

MUTUAL SUPPORT AND USAGE OF CAD SYSTEMS

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Abstract. Usage of different CAD-systems for communication engineers- partners is a true reality, therefore it is very useful for a specialist to be able to use different programs. Modern graphic programs (AutoCAD, SolidEdge) have many similar opportunities, but they also have some differences. Knowledge of several drawing programs is necessary and reducing the amount of time for the skills development for usage of each CAD-system is a problem of a future engineer. In this article two different programs are compared and the possibility of using both CAD-systems for working with drawings.

Keywords: graphic program, CAD-system, AutoCAD, SolidEdge

Introduction

Speaking about modern higher education, we mean system of training which allows young specialists to quickly fit into the labour market. In other words, such specialists must be equipped with the necessary knowledge and skills, not only to do the job, but the foresight and thinking to do the job better.

After all, the process of creation of a concrete product consists not only of technological tasks and their decisions, this chain begins with searching for the order and communication with the customer, and comes to an end with payment and again communication with the customer. Positive reviews of a product is the best advertising!

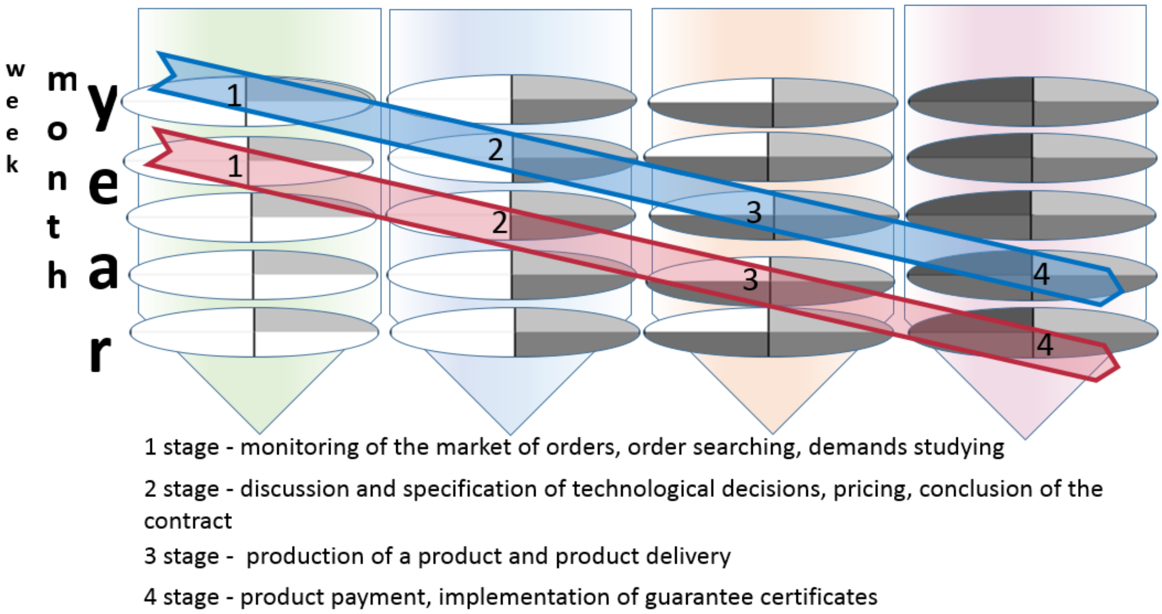


Fig. 1. The process of creation of a product

What link of this long chain a graduate of HIGHER EDUCATION INSTITUTION will become is hard to predict, after all it is only his choice. But a task of the Higher school is to provide a basic knowledge of product development, which will allow the young specialist to successfully work in the industry and keep growing. And certainly in this basic amount of knowledge there has to be an understanding of technical language - ability to understand and create technical drawings.

The value of this skill is very high – ability to see real objects behind laconic lines on a paper and vice verse – to explain an expanded object in a way any specialist and someone not familiar with the industry will understand.

Knowledge of this language allows to significantly reduce the time of transferring, additional processing and submission of information on any object – existing or planned.

If parameters of particular object are presented by necessary images – projections of types, reserves and the sizes – i.e. there is a drawing, than the expert reading this drawing can not only imagine this object in space from any foreshortening, but is able to transfer the expanded and dynamic idea of the object in the form of the sketch, the model or virtual computer model.

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.007

It is hard to find a better way to discuss the product with colleagues or present it to the customer because the best way humans interpret things is by visualizing. To show the model to a customer in shape and color (whether it is sketch or the computer model) means to get an advantage.

1. Basic information

The language of engineers is drawings. Computer drawings allow to reduce working hours significantly by their production, correction, transfer and saving. Therefore ability of the specialist to use those programs for work with drawings becomes necessary.

It may seem that computer is an expensive tool when used instead of a ruler and a compas but now the computer became a necessary communication tool in everyday life and of course for work. Itis a nesssesary tool when it comes to transferring, processing and archiving of information, regardless of the content of information - text, figures, formulas, photos, sketches or drawings.

Major programs made for computer designing are very powerful, those are programs that require good preparation both intellectually and financially.

Each developer tries to offer the potential user very interesting conditions of initial acquaintance and usage of the product.

The company Autodesk, Inc. is the world's largest supplier of the software for industrial and civil engineering, mechanical engineering and media market. And the software package of AutoCAD is most widespread. Since 1982 the Autodesk company has developed a wide range of decisions for experts of different industries allowing them to create digital models, to test model for interaction of its components and to make necessary changes.

Autodesc is offered to new users like students *free of charge to use it within 3 years*, it is a very good offer to users who are interested to examine opportunities of AutoCAD.

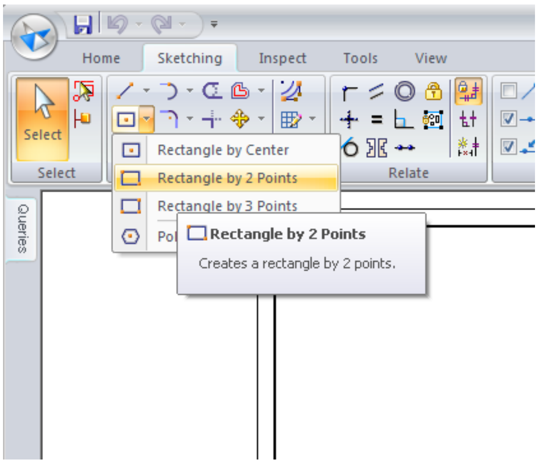
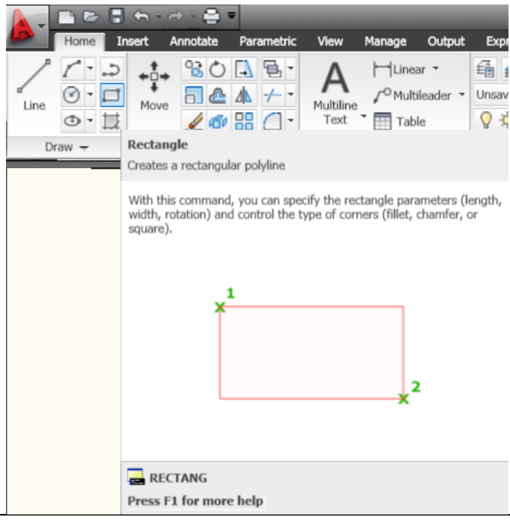
Also the online subscription to the license of a AutoCad package is offered - its value is low, and duration of usage begins from 1 month, which is very convenient to prolong via the Internet.

The Simens company - the owner and the SolidEdge developer – took a very reasonable step towards potential users: *the graphic part of the program* (2D - two-dimensional drawing*) is available free* of charge starting from 2006. There are links on a Simens website that will help to install free ST-7 (the name of the last SolidEdge version) or update the earlier installed program. This offer was very attractive and forced many experts in design industry to have a closer look at opportunities and advantages of 2D drawing in Solid Edge.

1.1. Comparison of opportunities: AutoCAD versus SolidEdge

Considering availability of two-dimensional drawing of SolidEdge, it is possible to say that now every company and every professional has an opportunity to significantly raise level of technical documentation and to reduce duration of its processing. It does not take too much time to learn the program and its updates.

And now we will consider similar opportunities of Solid Edge and AutoCAD in the comparative table which will help to assess the basic programm functions.

<table>
<tr><td></td><td>Solid Edge</td><td>AutoCAD</td></tr>
<tr><td>drawing</td><td>
</td><td>
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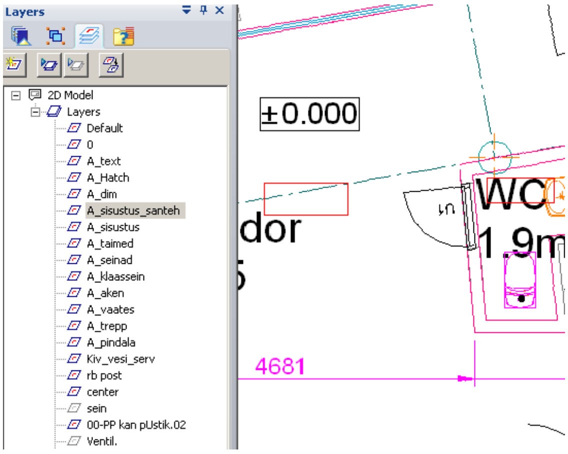
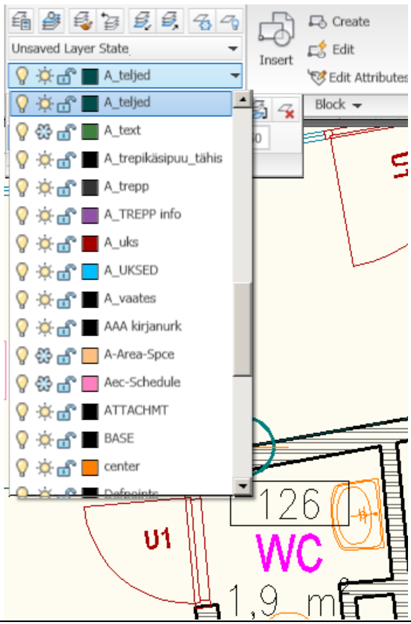
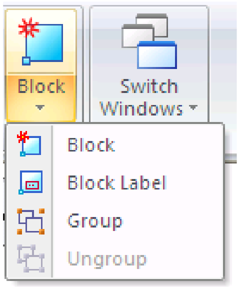
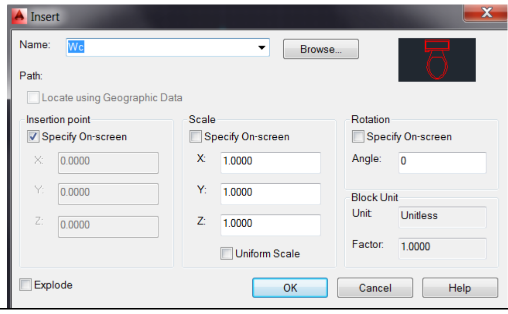
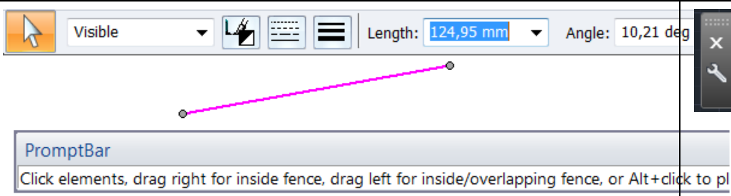
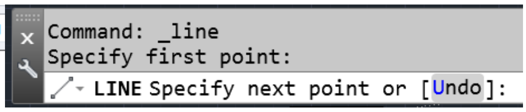
	Solid Edge	AutoCAD
layers		
blocks		
command line		

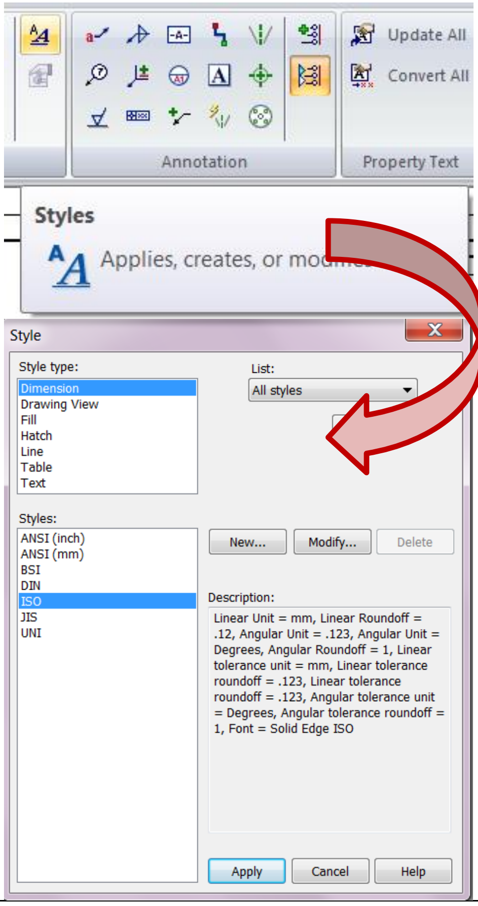
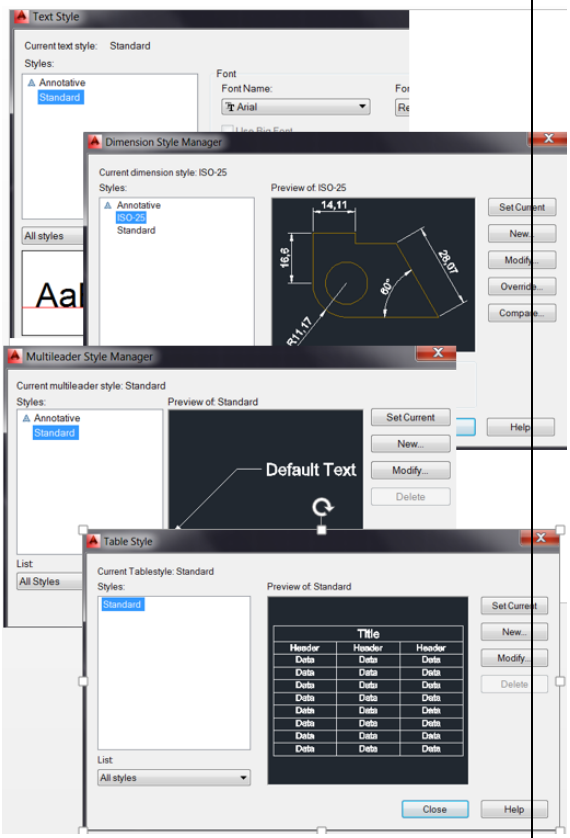
	Solid Edge	AutoCAD
styles of settings		

Fig. 2. Comparison of similar opportunities of systems

When comparing even some main functions of CAD-programs it becomes clear that the knowledge of work of one of them allows to master the use of other program enough quickly.

The comparative table is a little superficial, but nevertheless allows to see simplicity of Solid Edge in comparison with AutoCAD.

1.2. Convenience and availability: 2D environment of SolidEdge

Why do we need so little time to learn the SolidEdge program?

That is because of:

– appearance of the interface is familiar after using the most common programs (Microsoft Word for example),

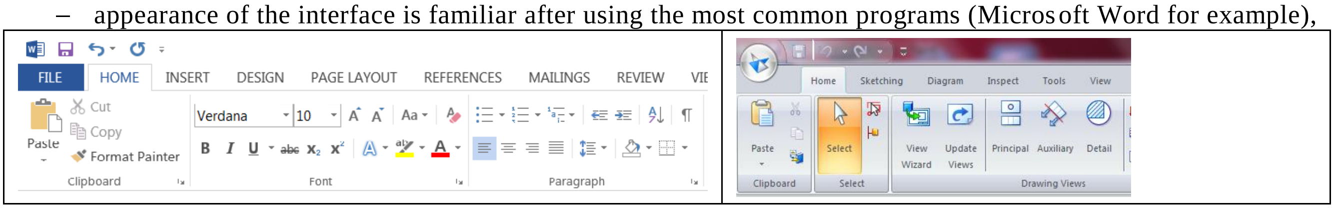


Fig. 3. Interfaces of Word and SolidEdge programs

– when getting familiar with the program for the first time the user does not find it difficult because there are not too many keys with pictograms and their amount is quite sufficient for a beginner. Placement of buttons with pictograms is memorized quickly enough because they are grouped according to their destination, built-in help system in a command line and pop-up menus help to successfully carry out process of creating or editing the drawing,

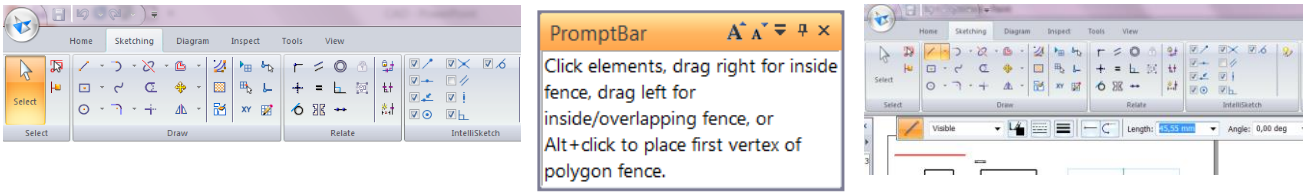


Fig. 4. Hidden options of plotting and editing of the program's drawings are in the menu

– there are options of saving the file in other formats – JPG, PDF, DWG, DXF -it allows working with different design systems, which means experts don't need to be retrained to edit or change drawings ,

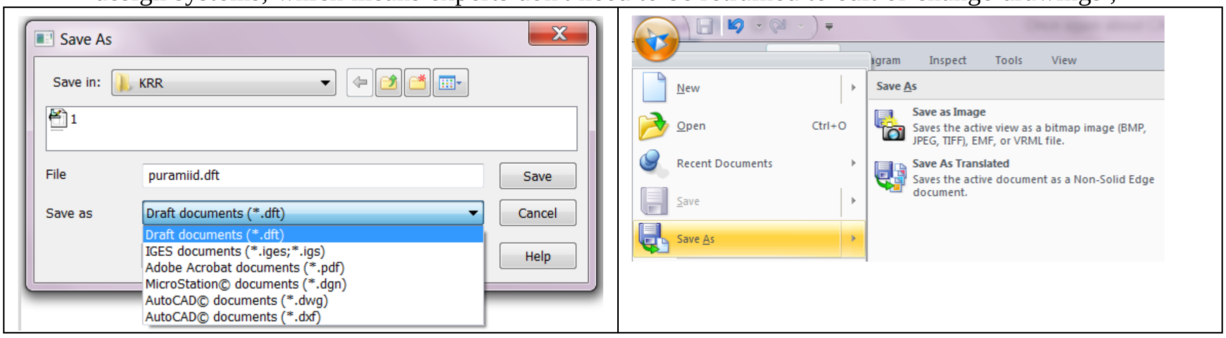


Fig. 5. SolidEdge's options of saving

– and of course the basic training of the specialist is very important. In this case – how well he can operate CAD/CAM program. There are also exercises for self-training with detailed instructions.

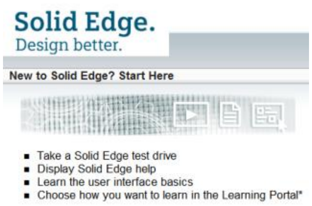


Fig. 6. Exercises for self-training

But if we speak about the joniour specialist – the university graduate - then ability to read drawings, thorough knowledge of one CAD/CAM system and ability to operate with similar functions of different systems considerably increases his competitiveness and success in the modern world.

Despite all powerful tools of design and visualization, the key moment in computer design is obtaining output documentation and its registration according to the accepted standards and that is considered an integral part of process of design. Settings of style of registration and of the plotting according to the international standards are provided in the program.

After learning Solid Edge 2D environment an expert can surely move to 3D modeling which makes it easier to obtain drawings of model and gives the chance to inspect parameters of virtual model and considerably improve them if necessary.

The Solid Edge system is designed for a wide range of users with different levels of computer knowledge and provides equally effective results both in 2D and 3D.

1.3. Usage of different CAD-systems in work with drawings

Solid Edge has one very essential inconvenience: if a document was created and saved in a new version (for example ST7), then it becomes incompatable with old versions – ST6 or ST5 etc.

In this case perhaps intermediate saving of the document in a DWG format which allows to open and edit the drawing with any version of Solid Edge.

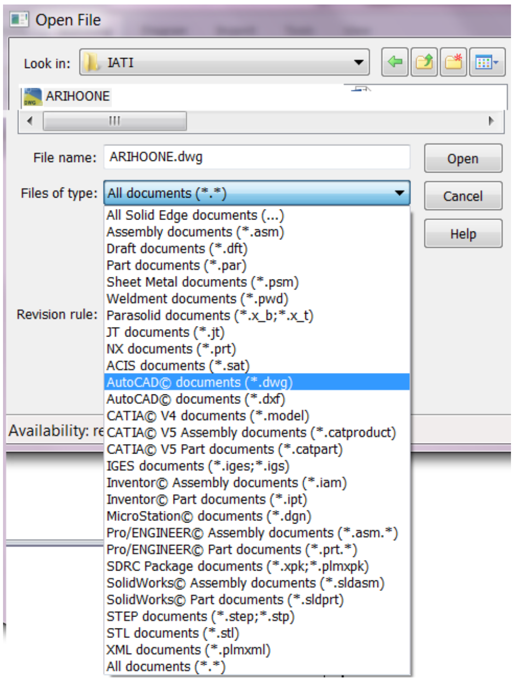


Fig.7. Usage of other programs for intermediate processing of the drawing with Solid Edge

Transfer of the drawing from dft into dwg and vice versa allows to use advantages of both programs in work as with 2d drawings and as with 3d models.

Conclusions

Considering availability of two-dimensional drawing of SolidEdge, it is possible to say that now every company and every professional has an opportunity to significantly raise the level of technical documentation and to reduce duration of its processing. It does not take too much time to learn the program and its updates.

It is very common nowadays that modern product equipment is not widely used because of the low level of training of the spesialist.

The task of the enterprise management it not only to provide production with the modern software product, but also to give to workers opportunity to increase the level of usage of the CAD-program and the equipment by providing specialized courses or at least self-preparation with exersises in the tutorials of CAD-systems.

And of course basic training of the spesialist is very important. In this case – how well he can operate CAD/CAM program. But if we speak about the junior specialist – the university graduate - then ability to read drawings, thorough knowledge of one CAD/CAM system and ability to operate with similar functions of different systems considerably increases his competitiveness and success in the modern world.

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SOFTWARE AGENT SYSTEM CONTROLS COMFORT SETTINGS IN THE HOUSE

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Abstract. A building can be called intelligent when it has the means for automatic control of all systems for life activities. Intelligent environments are able to support ever-changing environmental needs by automatically and dynamically adjusting their key parameters without explicit human intervention. An intelligent building can be defined as one that is able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt to the inhabitants and meet the goals of comfort and efficiency. Agents are software programs designed to act autonomously and adaptively to achieve goals defined by their human developers. These systems make use of a knowledge base and algorithms to carry out their responsibilities. This article analyses software agent system in the building environment. How does the agent control temperature and humidity in the house, how does it make decisions? The creation tasks of software agent system are solved with the help of Agent Unified Modelling Language. The collaboration diagram describes a particular situation and is useful to present objective range analysis results. Temperature and humidity measurement and access control appliances can interact with each other with defined functions. Fuzzy controller ensures the comfort situation in the room. Fuzzy logic rules in line with the method of choice are very important during system design. Study the conventional fuzzy control, which is also known as the creator of the first Mamdani fuzzy system. Logical description of the decision engine IF - THEN a rule set of fuzzy expert system to provide connections between the fuzzy variables in order to obtain the changes that occur in the input sensor. The computer program of fuzzy system is analysed. Obtained results are discussed and conclusions are made.

Keywords: agent unified modelling language, comfort, geometry, software agent system, fuzzy system

Introduction

Many ways, tools and concepts have been developed to determine performance indicators and criteria for healthy and comfortable buildings. The control of the indoor environmental factors has merely been focused on the prevention or curing of the different related observed physical effects in a mostly isolated way: thus trying to find solutions for thermal comfort, lighting quality, sound quality and air quality separately (Bluyssen 2010). A building can be called intelligent when it has the means for automatic control of all systems for life activities. Intelligent environments are able to support ever-changing environmental needs automatically and dynamically adjusting their key parameters without explicit human intervention. An intelligent building can be defined as one that is able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt to the inhabitants and meet the goals of comfort and efficiency (Nicol, Wilson 2011; Zhang *et al.* 2011; Sun *et al.* 2013). Advances in electronics and wireless communication bring smaller components with reduced power consumption and decreased prices, which enable the development of low-power and low-cost wireless sensing and control devices (Oksa *et al.* 2008).

Agents are software programs designed to act autonomously and adaptively to achieve goals defined by their human developers. These systems make use of a knowledge base and algorithms to carry out their responsibilities (Haynes *et al.* 2009). Agents control robot's hand (Britain *et al.* 2008), find way in the house (Sun, de Vries 2009). Agents create smart objects as wheelchair (Bielskis *et al.* 2009) or intelligent system in the house (Kaklauskas *et al.* 2010). The intelligent house is automated by using controllers and the current state is determined by using light, temperature, humidity, motion, and door/window/seat status sensors (Youngblood, Cook 2007). A fuzzy control is particularly suited for controlling systems that cannot be easily mathematically modeled, but can be described by experts. The linguistic description of the dynamic characteristics of a controlled process interpreted as a fuzzy model of the process. A set of fuzzy control rules can be derived using experimental knowledge (Dounis, Manolakis 2001; Eftekhari, Marjanovic 2003). A discussion of the advantages of fuzzy logic controller carried out, with the objective of showing how this controller can help to condition the air inside buildings (De Vries, Steins 2008; Lianzhong, Zaheeruddin 2008; Diaz *et al.* 2013).

Fuzzy controller consists of four main components: knowledge base, fuzzification, decision engine, defuzzification. Knowledge Base - a set of rules (IF-THEN) - an expert knowledge based on logic, linguistic fuzzy description of how to achieve good process control the best way. Fuzzification unit - converts controller inputs to fuzzy values in order to activate the indifferent mechanism and adapt the rules for decision making. The decision engine is indifferent mechanism to emulate an expert decision-making in interpreting and adapting a set of rules for information. Defuzzification unit – converts the indifferent mechanism of the decisions taken in resolution process designed to manage signals (Lee 2005).

Automated programming systems designers use object-oriented design methods. Based on this, Unified Modeling Language (UML) has been created, which is standard for describing system structure and principles of working. The Agent Unified Modeling Language (AUML) used for designing varied programs and systems with using agent technology (Odell *et al.* 2000).

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.008

This article analyses software agent systems in the building environment. The agent system manages the building's heating or conditioning, damping or ventilating settings. The creation tasks of software agent system have been solved with AUML.

1. AUML for modelling intelligent system

Collaboration of systems objects. Begin to analyze software agent system working in the house. Use case diagram, for designing such type of agent has the following cases: analysis of an environment and agent's integration into activity. If the user case diagrams describe the system at the end-user level, then collaboration diagram presents realization elements such as a class, objects and relationship among them. Collaboration diagram describes collection of objects, which in special situations work as united ensemble. The diagram presents ensemble's static (connections that link objects) and actions (sending messages). It accents the static ensemble structure. The messages in collaboration diagrams numbered for showing the sending order. Collaboration diagram describes a particular situation and is useful to present objective range analysis results, but is limited because we can show few messages in the diagram. In this collaboration diagram (Fig. 1) user controls the objects: sensors, agent, rules, and tools (heating, conditioning, damping and ventilating). After changing any parameter of the sensors, intelligent agent begins to self-operate. The agent automatically analyses the sensors information (temperature and humidity), begins decision making with fuzzy control system, begins heating or conditioning and damping or ventilating. The collaboration diagram presents the overall scheme of all objects belonging to the ensemble and their functions. It is possible that not all objects showing up in the collaboration diagram are going to end up in the final class structure.

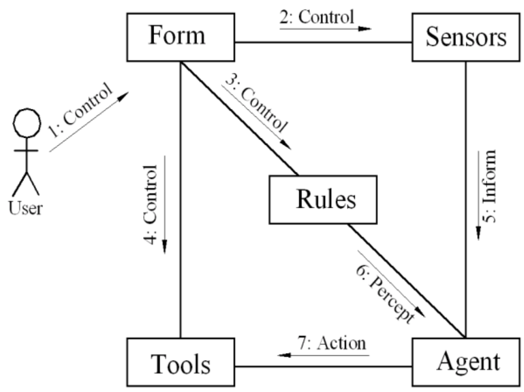

Fig. 1. System's collaboration diagram

The agent acts independently. It is not a called component; it is an active, monitoring its environment and responsive entity. The agent monitors its environment and is able to respond to changes in a manner to be able to continue to pursue the objectives of the task. State changes may happen because of inside transformations and actions from outside objects. Let's begin to analyze formation of an agent dynamics, of an agent state chart diagram (Fig. 2).

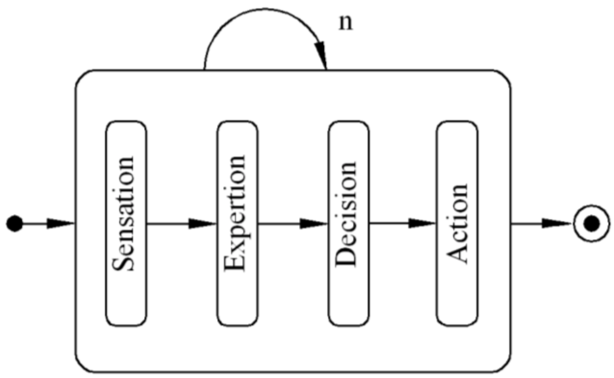

Fig. 2. Agent state chart diagram

A software agent has four states. These are integration states of the intelligent agent, which is iterated dependent on the number of sensors messages. The first state Sensation collects information about the sensors. The second state Expertion makes analysis of the sensors information. The third state Decision performs a fuzzy decision. The fourth state Action begins or not heating, or conditioning and damping or ventilating.

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2. Decision making with fuzzy control system

Unlike the classic elements of sets, fuzzy sets are the elements of the set where elements may partly depend on the heap with a certain degree of dependence and at the same time hold more than one set. The dependence function $\mu_a(x)$ for each element x of set X of attributes from the set A of fuzzy degree are membership between 0 and 1 (Zadeh 1988). Fuzzy set is fully characterized by the dependence functions. In practice, there are four most commonly used features of dependence, which are described by s certain mathematical formulas: triangular, trapezoidal, Gaussian and bell-shaped dependence function. We will use triangular dependence function. We will use the fuzzy control system of comfort situation in the room. The comfort situation control according to the humidity and temperature sensors is determined by heating or conditioning and damping or ventilating.

Input fuzzy sets. Let's say the comfort situation can be described in a variable *Humidity* with linguistic values of *Very dry, Dry, Normal, Wet, Very wet* and evaluating the linguistic variable *Temperature* with linguistic values *Cold, Cool, Good, Warm, Hot*. These linguistic variables are mapped to digital values (Fig. 3).

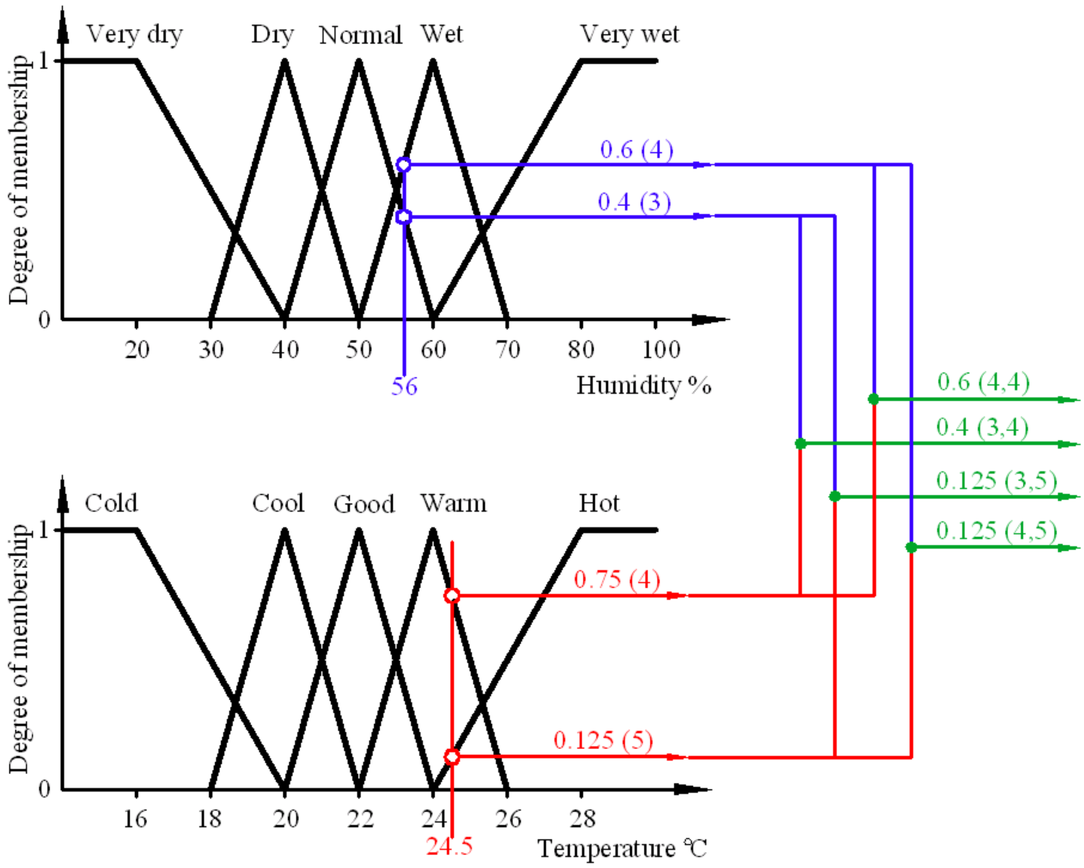

Fig. 3. Input fuzzy sets of Humidity and Temperature

Output fuzzy set. We have two output fuzzy sets of heating or conditioning with linguistic values of *heating* (H), *medium heating* (MH), *off heating and conditioning* (Off), *medium conditioning* (MC), *conditioning* (C) and damping or ventilating with linguistic values of *damping* (D), *medium damping* (MD), *off damping and ventilating* (Off), *medium ventilating* (MV), *ventilating* (V). These linguistic variables are mapped to digital values (Fig. 4, 5).

Knowledge representation with rules is most popular method used in the knowledge bases. In this method, the domain knowledge represented by a set of rules that were acquired through human experts' past long-term experience. Fuzzy system for decision-making on the basis of logical rules: IF premise THEN conclusion. Verbal rules describing the control system consists of two parts - conditions (between IF and THEN) and the effect of (after THEN). Fuzzy logic control based on the knowledge base of linguistic variables and logic control rules. For example:

- IF Humidity normal and Temperature good THEN tools off,
- IF Humidity dry and Temperature cold THEN heating and medium damping,
- IF Humidity wet and Temperature hot THEN conditioning and medium ventilating…

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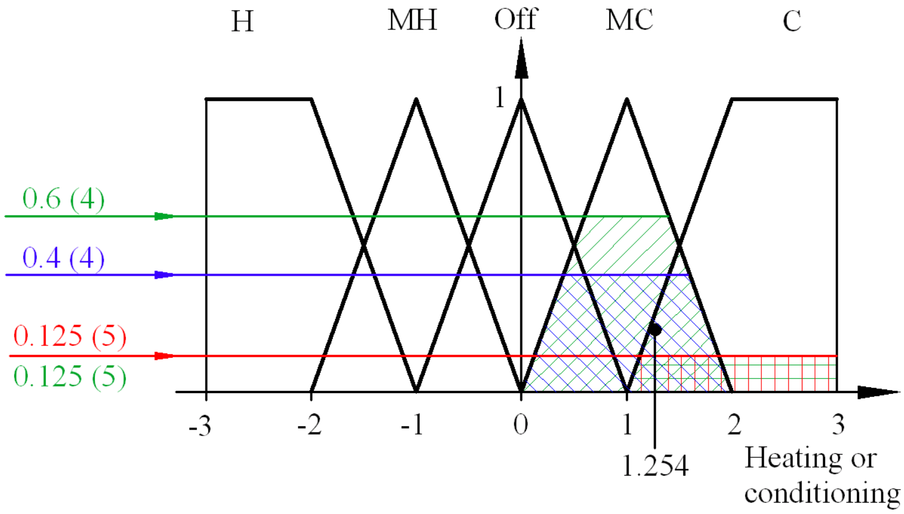

Fig. 4. Output fuzzy sets of heating or conditioning

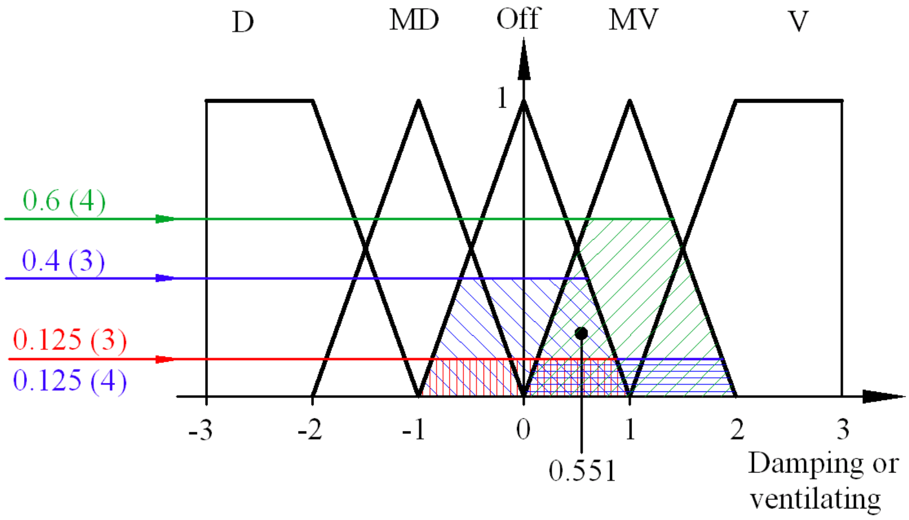

Fig. 5. Output fuzzy sets of and damping or ventilating

Fuzzy rules base is a simple set of rules that describe the relationship between input and output fuzzy sets. The fuzzy rule matrix for *Comfort* (Fig. 6) made according to these three graphs, whose rows are named after *Humidity* memberships and columns named after *Temperature* memberships, and the matrix is filled with the appropriate heating or conditioning and damping or ventilating values.

Comfort		Temperature				
		Cold	**Cool**	**Good**	**Warm**	**Hot**
Humidity	**Very dry**	H D	MH D	off D	MC D	C D
	Dry	H MD	MH MD	off MD	MC MD	C MD
	Normal	H off	MH off	off off	MC off	C off
	Wet	H MV	MH MV	off MV	MC MV	C MV
	Very wet	H V	MH V	off V	MC V	C V

Fig. 6. Comfort dependent from Humidity and Temperature

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This matrix allows to programmatically automate the entire process of fuzzification. We use matrix digital indexes and digital values when programming.

Fuzzification is the second stage of the logic of the system fuzzy calculation. During this stage the real world variables are converted into fuzzy inputs. This process is using fuzzification for variable conversion or monitoring. Variables used to convert the dependency function. In our case, we have the following two initial sequences of fuzzy graphs: *Humidity* and *Temperature* (Fig. 3). The number of rows in the dependency function matrix is equal to the number of linguistic values and the number of columns is only two because of linguistic values range of variation fixed in the row. For example, function *Miu1* takes variables from dependency function matrix of humidity [*DFH*] and specific parameter humidity *h*. The result of the function is a matrix [*MH*]. Analogously we use the other function *Miu2* which takes variables from dependency function matrix of temperature [*DFT*] and specific parameter temperature *t*. The result of the function is a matrix [*MT*]. Results of the functions are presented in (Fig. 7) and graphical presentation in (Fig. 3), where the fuzzy values and the linguistic values are serial numbers of dependency function.

20	40
30	50
40	60
50	70
60	80

16	20
18	22
20	24
22	26
24	28

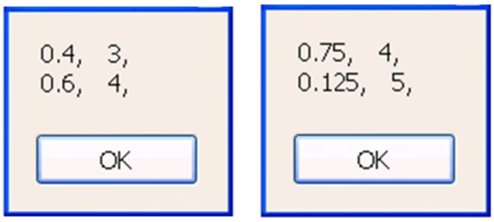

Fig. 7. Matrixes [*DFH*], [*DFT*] and results of fuzzification [*MH*] and [*MT*]

Decision engine is the main stage of the logic of the system fuzzy calculation. In general, in decision making logic part, we use four inference methods: Mamdani method, Larsen method, Tsukamoto method, and TSK method. Mamdani method uses minimum operator as a fuzzy implication operator (Mamdani, Assilian 1975; Mamdani 1977). We have four values and need to get one result. First, with the four values, we make four pairs of variables available and select members with minimum values (Fig. 3).

Defuzzification is the last phase of this methodology. Defuzzification is a reverse action, when the answer comes from fuzzy set to traditional mathematics numerical value. Defuzzification procedure operates withvague conclusion sets of the existing rules to find the perfect expression of the output value. Simply put fuzzy forced expressive values. The most commonly used two methods are: center of sums (CoS) and center of area (CoA) (Lee 2005). Other methods are center of maximum (CoM) and mean of maximum (MoM). Centre of sums (CoS) defuzzification method calculates the significance of the expression as follows:

$$x_c = \frac{\sum x_i A_i}{\sum A_i} \qquad (1)$$

Here A_i – μ values define separate areas of the graph, x_i – μ individual values defined by the center of area *x* coordinates.

3. Obtained results

Intellectual climate control system of the building is analyzed. It is an expert agent system based on fuzzy logic, which is designed to manage the building's devices. Sensors installed on premises transfer current environment settings to the system where they are processed according to the rules and an output data is calculated. The automated climate control system consists of two connected modules. The first module is designed to regulate ambient temperature; the second is designed to regulate ambient humidity levels. Each module runs two devices, which cannot operate simultaneously. For example, if an air conditioner turned on, the heater should be turned off and vice versa. At the same time, humidity level control equipment is operating. Modules are individual, but their performance is linked by the fact that their individual behavior affects the other. The rising temperature decreases indoor humidity and the like.

Let's examine a situation when the humidity is 56 % and the temperature is 24.5 °C. Graphically it can be shown very vividly: humidity dependency function consists of five parts and has five linguistic parameters (Fig. 3). At 56 % humidity dependency function is crossed at two points: the third part (*Normal*) at 0.4, and the fourth part (*Wet*) at 0.6. Temperature dependency function consists of five parts and has five linguistic settings. At a temperature of 24.5 C dependency function is crossed at two points: the fourth part (*Warm*) at the 0.75 and the fifth part (*Hot*) at 0.125 (Fig. 3).

All links can be seen in (Fig. 7) [*MH*] and [*MT*] matrices. The first row on the left has (0.4, 3) and the first row on the right has (0.75, 4). According to Mamdani system, it says to take minimum of the two numbers 0.4 and 0.75, and put the knowledge matrix cells (row = 3, column = 4) in the linguistic parameter „MC". After studying the other three pairs of values, we obtain

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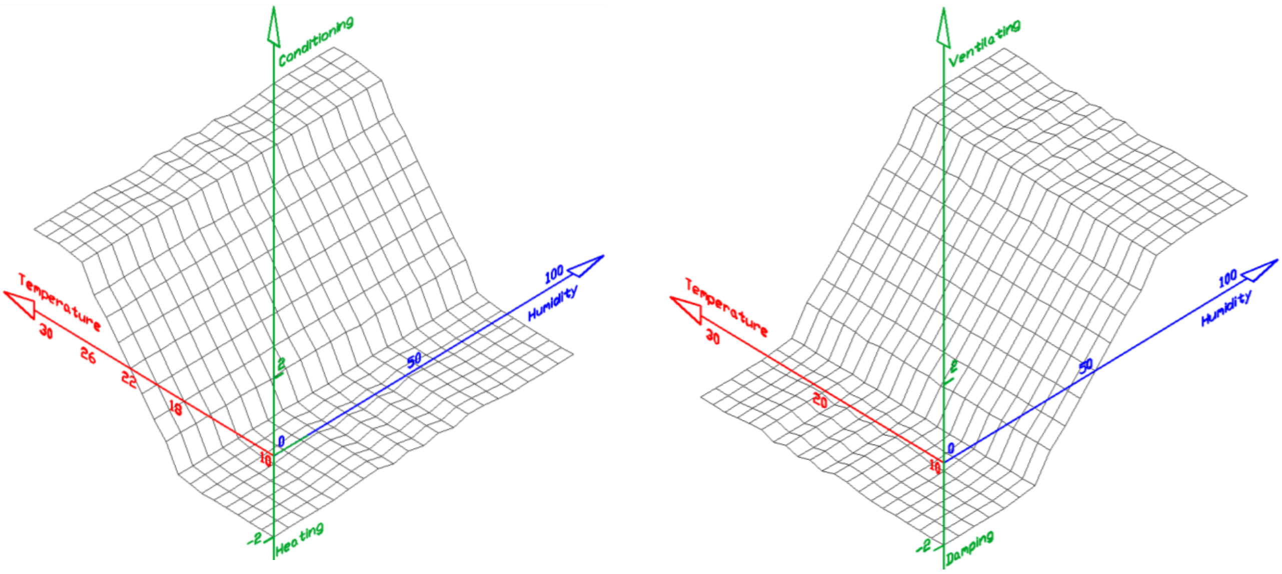
the graph heating or conditioning shaded area (Fig. 4). There we find the average area, which is equal to 1.254. This is the real meaning, which will consider the input humidity and temperature parameters of the system for finding the output parameter and entering the area 0.5 - 1.5, which means medium conditioning (MC). Adjacent areas (-0.499 – 0.499) refer to facilities deactivating (Off) and area (1.501 - 3.0) means conditioning (C). The entire response surface is presented in Fig. 8 a.

Analogously we obtain the shaded area in the graph damping or ventilating (Fig. 5), with the average area of 0.551 falling within 0.5 - 1.5, which means medium ventilating (MV). The entire response surface is presented in Fig. 8b.



a) b)

Fig. 8. Output fuzzy sets (a) of heating or conditioning, (b) of damping or ventilating

Conclusions

Intellectual climate control system of the building regulating ambient temperature and humidity depends on using four tools: heating or conditioning and damping or ventilating.

A utility is designed so that it allows to go deeper into the decision made by a computer program how an agent can find several parameters to make the right decision.

By merely programming we finally learned how to assess the two charts with four parameters and obtain only one value. The diagrams bound by matrices and functions provide a definitive answer.

When programming artificial intelligence systems, graphics programming is important, which can be easily managed by the geometrical features and to obtain other geometric characteristics.

A graphical environment and a working programming language in this environment are required for writing in such systems. For example, Visual Basic for Application programming language works with the AutoCAD environment.

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eISBN 978-609-457-835-9
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GEOMETRIC APPROACH TO THE REVITALIZATION PROCESS OF MEDIEVAL SERBIAN MONASTERIES

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Abstract. Among the standard approaches concerning cultural heritage preservation, the architectural point of view deserves particular attention. The special place in medieval Serbian history of architecture belongs to the world famous monastery complexes Studenica, Dečani and Gračanica. Beside them numerous significant monuments (churches and monasteries) exist as witnesses of the national testimony, currently in the state of ruins, archaeological sites, or damaged ones. A lot of them have adequate needs for revitalisation, where the start point is engineering documentation. The focus of the research is on the role of specific geometric and engineering graphics tasks when these areas are concerning. Monastery church devoted to Introduction of Holy Theotokos in village Slavkovica (near town Ljig), with three old sarcophaguses, dated back to 15th century, is presented and analysed from several aspects: measuring, architectural style characteristics - geometric design, 3D modelling (classical-CAD and terrestrial photogrammetric) with visualization and presentation. The attention was paid on preservation of authentic architectural style and medieval building techniques, which allow imperfections in realization. The opinion of experienced scientists and specialists involved in all the phases of monument's revitalisation has been followed as a guideline to the final result – a proposed geometric design of the revitalised church in Slavkovica.

Keywords: architectural geometric design, Serbian medieval monasteries, revitalization, 3D photogrammetric model, laser measurements, computer software, visualisation

Introduction

During the last decade, in the area of cultural heritage protection and revitalization significant improvements were accomplished in methodologies and processing, concerning data collecting (Author 2007), documentation (Schaich 2007, Zehetner and Studnicka 2007) and presentation (Bruno *et al.*2010, Horošavin 2010, Darilkova *et al*. 2005). Most of them use virtual reality i.e. 3D technology, which employs geometry and computer graphics(Stachel 2006) in the variety of software solutions.The results of laser scanning (El-Hakim 2003), radar surveying, or photogrametry methods (Ivanović and Nedeljković 2007,Pejić 2014)are high accurate point clouds, orthophotos,3D digital models with photo realistic textures and multi-media presentations. Constant growth of friendly software solutions initiated enrichment of digital city maps with 3D models of buildings available in the global informative space (Pejović 2011).CAD/CAM and CNC technologies enabled materialisation and mass production of archeological replicas in the form of 3D models (Polić-Radovanović *et al.* 2010, Author2011). The applications of all these techniques are wide ranging from small historical artefacts, such as artworks, to the monument complexes in several contexts: scientific, educational, historical, architectural, touristic or informative.

The other tasks concerning restoration and conservation require information about the original material. In the activities of surveying or temporary repairment of the monument, the role of widely applied laser techniques is highly important and confident.The small sample quantity of the material, characteristic of these techniques is sufficient for reliable results.Laser techniques, specially the ones with minimal destruction (such as LIBS- laser induced breakdown spectroscopy) are recognized for material identification in the area of restoration (Noll 2011).Current tendencies in measuring techniques are concerning nondestructive *in situ* measurings, microscopic samples and remote sensing where the lidar techniques and extensive experience offer precise description of the particular material (Author2015, Author2009, Casadio 2001).

The great part of Serbian history, culture and identity rely on monasteries and churches of the medieval time. Many of them were devastated or damaged during several wars on this territory and have an urgent need for revitalization. Revitalization process of a monastery is a specific and complex task demanding several points of view: dimensional analyses of the historical remains, style and building techniques analyses, material analyses, revitalisation and final presentation concept. The author's aim was to present the research carried out in the central Serbian region on the medieval monastery devoted to the Introduction of the Holy Theotokos (God's Mother) located in village Slavkovica near Ljig. Previous studieson revitalizations of monasteries and churches related to the same architectural style group and time of building (Nenadović 2003; Nešković 1984) had shown variety of interesting details in architectural design, which enlightened directions of the proposed design solution. Existing

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.009

technical documentation is supplemented by 3D digital model of the monument's current state, obtained by terrestrial photogrametry methods. The architectural design proposal of revitalised church is created in Auto CAD environment.

Some important educational aspects of 3D modelling applications were considered, since the students were involved in the research.

1. Historical overview

Serbian sacral medieval architecture characterizes a wide range of monuments (churches and monasteries) made of brick or stone, with plan patterns of inscribed cross, varying in styles, size, architectural "geometry" and decoration. These monuments are grouped in five time periods (due to ruling dynasties) and three style groups (with respect to architectural characteristics): *Moravian*, and *Byzantine* (Nenadović 1978). The most famous representatives of monastery complexes, world known Studenica, Gračanica and Dečani are renewed and very active in primary-spiritual, as well as secondary-pilgrimage and touristic functions. Since Serbian monasteries were educational and cultural medieval centers as well, these monuments or their remains were very important witnesses of *the time,* equally valuable as cultural, spiritual and other origins of the Serbian people. During several wars on Serbian territory numerous sacral objects were destroyed, along with the ravages of time. Some of them are in the state of archeological remains (foundations and partly walls), while the others are just partly damaged (roof, cupolas, etc.). Accordingly, there is a constant need to preserve and revitalize significant monuments and give them back functionality.

1.1. Preservation of the monastery complex in Slavkovica

Some investigations have shown that in the surroundings of mountain Rudnik, in the time period 13th - 18th century, more than 80 churches and monasteries were built. One of these is monastery in village Slavkovica, dedicated to the Introduction of Holy God's Mother, dated in 15th century. The church, built in Ras style had a rather simple one nave concept, deformed rectangular plan and a big apse on the east side, later anexed with the special purpose chapel. There is a reasonable assumption that the last Serbian dynasty ruler Đurađ Branković with his wife and son were buried there in three heavy stone sarcophaguses (Madas 1984). Interior of the church was divided into three parts with four pilasters, and over the central part there was a dome. In the time period 1972 – 1984 the archeologists (leading archaeologist D. Madas) investigated the location, church and necropolis arround, evaluated and started the restoration of the monument.

According to the Venetian Charter from 1964 (Nenadović 1980), it is possible to rebuilt particular parts of the monument (up to the defined height), based on reliable data, by restoration methods- using original foundings. This phase relied on experience of the experts and recognition of sand stone elements found in the location of Slavkovica monastery.A great part of the church was rebuilt in such way that the authenticity of the monument was not compromised,(Figs.1-2). Restored parts were propperly marked on the fasade with wide curved line – joint between stones.

The other missing parts can be added regarding analogy and typological characteristics of the monument's style group, in special building techniques (different from the original one), by recomposition methods (Nenadović 1980).

Fig. 1 South view of the church and chapel (current state photo)

Fig. 2 South-East view of the church corpus (current state photo)

2. Structural concept of the monument

One nave domed concept of the church, present on the Adriatic coast, dated from IX century - *prior roman* style, had a variety of solutions, i.e. complex typology (Vasov 2014). There wasa wide pallete of structural solutions concerning dome supporting and outer architecture of the *tambour*(cilindrical or polygonal) and its cubical postament.These solutions spread from the Jadran coast to the heartland of medieval Serbia. Although the churches classified in style group *Ras*were under the influence of the *roman* and *bizantyne* style, they had their own originality. In such circumstances almost each monument had its own solutions in structural concept, depending on masons imagery and skills (Pejić 2002). The investigation of closest sorroundings have shown typological similarities of the monument to the one in Slavkovica: church devoted to St. Dimitrios in the village Marko's church, (Figs. 3 - 4).

Fig. 3 South view of the Marko's church (15th century)
https://www.facebook.com/373615226108338/photos/a.373636166106244.1073741828.373615226108338/373638442772683/

Fig. 4 East view of the Marko's church (15th century)
https://www.flickr.com/photos/ljubar/2520829672/

The church in Slavkovica had rather modest dimensions (9.7 x 4.8 x 6.5 m), and it was simple in proportionality and functionality. The first one of the three aisles of the church was the best in time hardness. The remains of this part conducted in the first phase of restoration - definition of approximate heights of the arches and the voult, while the other two were restored up to the defined level in original stone material and old building techniques,(Figs. 5-7).

The central part of the church was rectangular (deformed) in the plan, supposingly with a dome, while the other two aisles were vaulted. The pilasters supported lateral (leaning) and transverse arcs composing summarized cross in the plan. Often the vaults and arcs in the interior had different radiuses and centers, even though that this irregularity made difficulties for the supportive structure (Nešković 1984). The pilasters on the outer side of the church are not aligned with interior ones, and it seems that they played just a decorative role.

Fig.5. The first vaulted aisle with arches

Fig.6. Approximate defined heights of the apse

Fig.7. Detail – joint marking the original parts

It was not unusual appearance of “irregular geometry” in the church medieval architecture, (Fig. 8) The lack of orthogonality, symmetry and precision was allowed concerning old building techniques where these factors were conducted by the masons's

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experience and skills (Nenadović 2003). Although very old building techniques applied on architectural archetypes (Colagreco 2014) had rather precise methods for obtaining rounded shapes, here the masons made significant distortions.

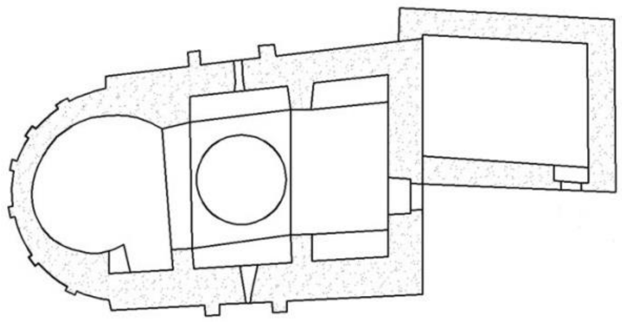

Fig. 8 Plan view (the state after of archaeological works) – irregular geometry of the church and chapel in Slavkovica

The main material for the church in Slavkovica was sand stone and lime mortar, where the thickness of the walls was approximately 90 cm. Building technique of the walls was *two faced*. Just outer and interior face of the wall stones were flat, while the inner layer was row and filled with smaller peaces of the stone joined with mortar (Madas 1984). The roof was covered with slate - thin rough plates of stone 2-3cm thick, since this area had a planty of stone exploited from two famous quarries, (Šekularac 2012).

3. 3D model presentations

Contemporary engineering documentation of any building requests 3D verification of the proposed design. Sometimes 2D drowings are made after 3D modeling phase, when concerning the architectural (design) approach. When the cultural heritage protection tasks are of the matter, the 3D model of the current state of the monument is equaly needed as the one offering renewed - proposed design. Both are valuable in the global informative space in monument's presentation to a world wide auditorium, such as in the Google Earth information platform (Pejić 2014).

3.1. Photogrammetric 3D model of the church in Slavkovica

Considering all the aspects involved in the restauration project there was a need for an accurate 3D digital model of the current state of the monument, for the purposes of documentation and further development. The semiautomatic terrestrial photogrametric method was applied. Computer software support here adopted was Agisoft Photo Scanand camera Canon EOS 5D (lens-Canon EF 24mm f 1:2:4). After a successful camera calibration process, aproximately 215 photos(65 of the interior space and 150 of the exterior) of the church were taken on the spot, in landscape position of the camera.

The specificity ot the case was that two separate point clouds had to be obtained (one for the interior of the monument and the oher for the exterior) and connected. Therefore four special purpose markers (on the metal plates) were positioned on the upper surface of the walls to be visible from the inner and outer space, to enable this connection. The point cloud of the monument's interior (Fig. 9), regarding the file size was made in one piece, while the exterior (Fig.10) needed several chunks.

Fig. 9. Interior space of the church model in *Agisoft PhotoScan*

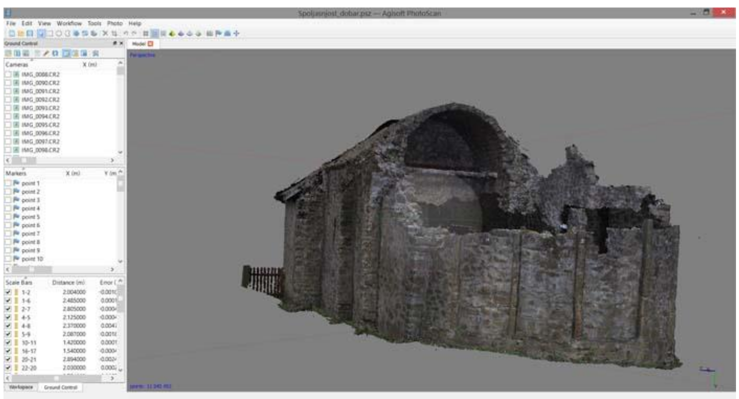

Fig. 10. Exterior space of the church model in *Agisoft PhotoScan*

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Whole monument was marked with 80 equal markers (reference points) and measured (the reliable distances of neighbor markers), regarding calculations and the prior shooting plan (Fig. 11). The distance of the camera from the target was approximately 3.5 m, while the distance between two neighbor shooting points was 1m horizontaly (calculated to obtain overlapping of images for 60 %). From each shooting point, at least two images were taken from the ground surface (1.2 m and 2.5 m height).

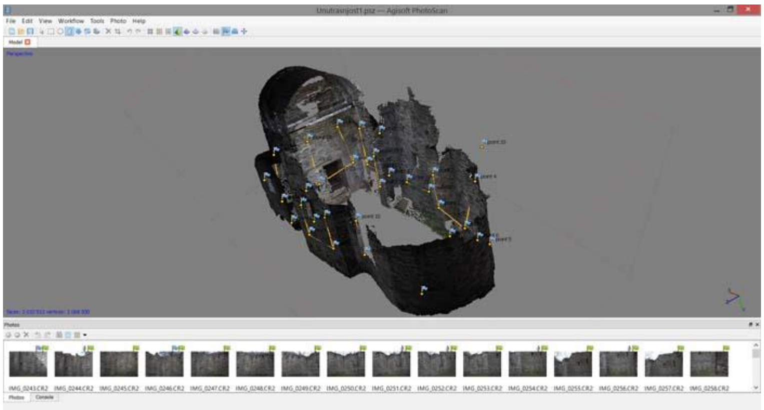

Fig. 11. Positions of the markers (yellow points with blue flags) and their measured distances in *Agisoft PhotoScan*

The advantages of Agisoft PhotoScan software application are concerning high accuracy, reliability and variety of products (3D model, orthophotos, point clouds), as well as variety of image file formats (*.tif, *.jpg, *.png, *.bmp, etc) supported. It allows the use of various amateur digital cameras and images from various positions of camera. Like in the other 3D software solutions, the manipulation in 3D surroundings allows even "passing through the walls" and obtaining view in detail, (Fig. 12).

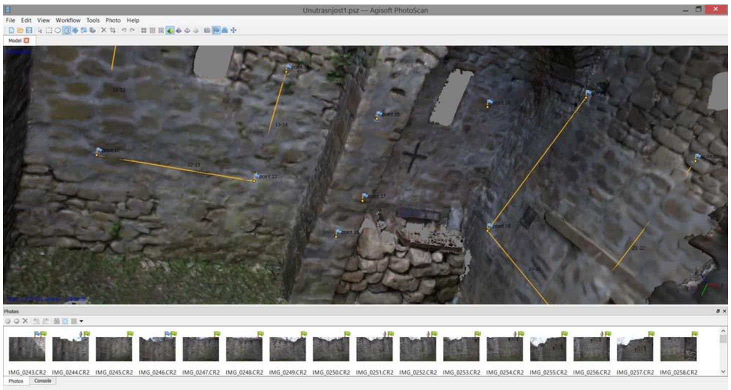

Fig. 12. Detail view of 3D interior model of the church in *Agisoft PhotoScan*

The inconvenience (when the number of images is higher) came from the necessity of data processing by very powerful computer hardware, and the time occupancy. The similar situation appears with exported files (eg. *.dxf files in Auto CAD).

3.2. 3D model of the proposed design solution

The design of the renewed Introduction church is presented by 3D virtual model, created in engineering software AutoCAD, as a one nave building with summarized cross shape in the plan. The model of the church has its complex outer and inner 3D geometries. The four pilasters divided the *innerspace* on three non equal parts – aisles (Fig. 13).The characteristic architectural-geometric solution offers medieval architectural concept: first and third aisle are vaulted (over the full width of the nave), while above the central one is the dome structure. Geometric design of the central dome structure has arisen from the rectangular shape of the plan, and it is not a common case in one nave concepts. The dome is supported by four arcs: two transverse and two elongated leaning arcs, and four pendentives (spherical triangles) in the lower level below the main vault as well. The cylindrical shaped form of the drum is lifted up over the pendentives towards the high positioned semi sphere of the dome. The third aisle is extended in the plan with prolonged semicircular apse. The walls of the abse are ended in spherical geometry, by half of the callote (Fig. 14).

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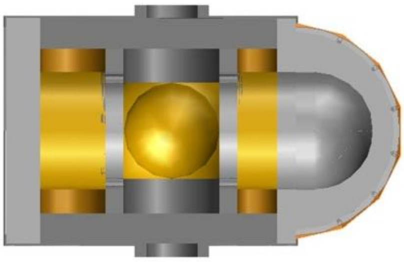

Fig. 13. Cruciform plan view of the church   Fig. 14. Longitudinal section of the church

The *outer* appearance of the central drum structure is prismatic –octagonal, with eight narrow and vaulted windows (Fig. 15). The dome is lowered in the interior of the prismatic "shell", in order to obtain the smaller roofslope in exterior space. The octogonal pyramidal shape of the roof is ended with the cross on the top. The whole structure is supported by prismatic (rectangular) pedestal.Waved roofs above the vaults and prolonged arcs repeat the cruciform shape of the plan in the external architecture of the church.

The facades are rather simple, triangular covering the vawed roofing, decorated only with string courses and two outer pilasters connected with the arc. Two windows (rectangular narrow holes expanded in the interior) are high positioned on the south and north façades. A big semicircular apse on the east side of the church is decorated with a sequence of colonettes on the round postament. In order to obtain as much authenticity as possible in this first-modeling phase, the other details are avoided (Fig. 16).

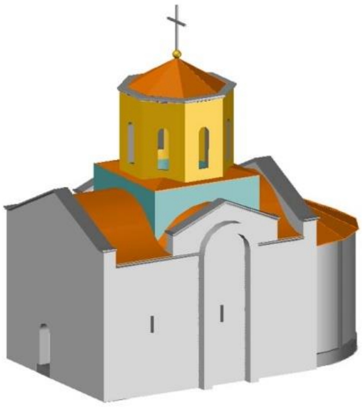

Fig. 15. South-west view of the church   Fig. 16. East view of the church

The presented modeling task solution required high spatial abilities of the modeler, adequate geometric education (Author 2006) as well as high skills and experience in manipulation with software tools(Author 2014), along with the adequate interpretation of competent resources (references in the field of sacral architecture). Although the authors offered one solution of the model, guided by the existing state of the monument, the conclusion is that there were other possibilities, which assumed the existence of some errors made during the conservation process. Although limited in materials and building techniques, medieval practice offered surprisingly original solutions of the masons. It is resonable to claim that solution of the model strongly depend on its author.

Conclusion

Based on the existing documentation, measurings, analysis of historical facts (building epoch andarchitectural style group characteristics) and photogrammetric recordings, the two 3D models of the sacral monument in Slavkovica village were created: the first one – photogrammetric, presenting the current state of preservation, and second one - architectural, offering a geometric concept of renovation. In the area of cultural heritage protection they have multiple values: documentational, informative, educational and creative.Digital image- based photogrammetric 3D model of the Monastery church devoted to the Introduction of Holy Theotokos in Slavkovica is precise documentation for the further process of the monument's revitalisation and simultaneously, data collection for students' practical research in photogrammetry.The architectural-geometric3D model is an

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example of the restoration of a specific medieval cultural heritage monument, complex in geometry and relations of geometric elements, which can be upgraded with materialization and utilized for visualization or presentation purposes. Its role in the final restoration design project of the monument, advertizing and realisation process is irreplaceable. Certainly, the educational purposes and its informative character should not be neglected.

Acknowledgements

Authors express their gratitude to all the associates included in the project: deacon *Dragan Ikonić*, for the support, informations and hospitality during field work in Slavkovica, *Department of Photogrammetry* and students *Jovana Đoković* and *Milena Nešić* from the Civil Engineering Faculty in Belgrade, for making 3D digital model of the Church in Slavkovica. This research is supported by the Ministary of Education, Sciences and Technological Development of the Republic of Serbiain the project No. TR 36008 entitled: *Development and application of scientific methods in design and building of high-economic structural systems by application of new technologies*.

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eISBN 978-609-457-835-9

BUMP MAPPING EFFECT APPLICATION ANALYSING

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Abstract. Bump mapping is an easy way to create the effect of the relief surface that allows a more detailed surface than a polygonal surface does. If there are bumps in surface, you can see light and dark place on surface. Flat surfaces reflect more light and bumpy surfaces reflect less. This effect is used in bump technology. OpenGL, WebGL and DirectX supports this bump technology. This realization is not difficult and is working fast. This is an implementation in pixel or fragment shader.

Keywords: bump mapping, normal mapping, pixel shader, textures, displacement mapping

Introduction

Bump mapping is a texturing technique in computer graphics that was introduced by James Blinn in 1978. Bump mapping is a technique for simulating wrinkles and bumps on the surface of an object. This texturing method is achieved by perturbing the surface normal of the object and further using the perturbed normal during lighting calculations. Although the surface of the underlying object is not really modified, the result is an apparently bumpy surface rather than a smooth surface. Normal mapping calculation is the most common variation of bump effect realization used.

1. Bump Mapping Theory

1.1. Bump Mapping foundation

There is data structure needed for texture maps. Each texel (pixel in a texture) can consist: of:

- colour map (RGB map, diffuse map) need a RGB colours;
- bump map (or normal map) need a normal;
- specular map need a specular coefficient;
- alpha map (or cutout texture) need a transparency coefficient;
- displacement map (or height texture) need a displacement of the vertices surface;
- light map, baked light texture need a precomputed, baked lighting.

Bump mapping is a texturing technique in computer graphics to make a rendered smooth surface look more realistic by simulating for visualization small displacements (wrinkles and bumps) of the object surface. However, unlike using displacement mapping method, the surface geometry (vertexes data) is not modified. Instead only the surface normal is modified as if the surface had been displaced. The modified surface normal is then used for lighting calculations (using, for example, the Phong or Gouraud reflection model). Silhouettes and shadows therefore remain unaffected, which is especially noticeable for larger simulated displacements. This limitation can be overcome by techniques including the displacement mapping where bumps are actually applied to the surface or using an isosurface (An Introduction to Bump Mapping 2010; Foley 2000; Guinot 2006).

This effect is giving the appearance of detail instead of a smooth surface. Bump mapping is much faster and consumes less resources for the same level of detail compared to displacement mapping because the geometry remains unchanged. There are also extensions which modify other surface features in addition to increasing the sense of depth. Parallax Mapping is one such extension.

The primary limitation with bump mapping is that it perturbs only the surface normals without changing the underlying surface itself (Tutorial 20 2013; Tutorial 26 2013; Zink, Pettineo, Hoxley 2011).

1.2. Bump Mapping methods

There are two primary methods to use bump mapping texturing technique. The first (displacement) method uses a height map for simulating the surface (Fig. 1) displacement yielding the modified normal. The steps of this method are summarized as follows (Fig. 2). Before a lighting calculation is performed for each visible point (or pixel) on the object's surface the following actions are to be done:

1. finding the height values in the heightmap;

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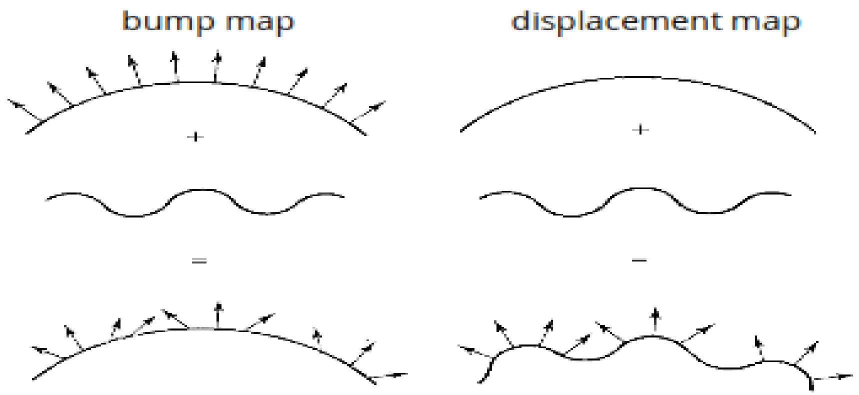
2. finding the corresponding height to each position on the surface;
3. using the mathematical method (typically the finite differences method) for calculating the surface normal of the heightmap;
4. calculating the surface normal directions from step two with the true ("geometric") surface normal so that the combined normal points (igautu) a new direction;
5. calculating the interaction of the new "bumpy" surface with lights in the scene, by using lights reflection methods (for example, the Gouraud or Phong) and new values of normal.

The result is a surface that appears to have a real depth. The algorithm also ensures that the surface appearance changes as lights in the scene are moved around (Fig. 1).

The other method is to specify a normal map which contains the modified normal for each point on the surface directly. Since the normal is specified directly instead of being derived from a height map, this method usually leads to more predictable results. This makes it easier for artists to work with, making it the most common method of bump mapping today (Fig. 2).



b

Fig. 1. Bump and displacement mapping comparison

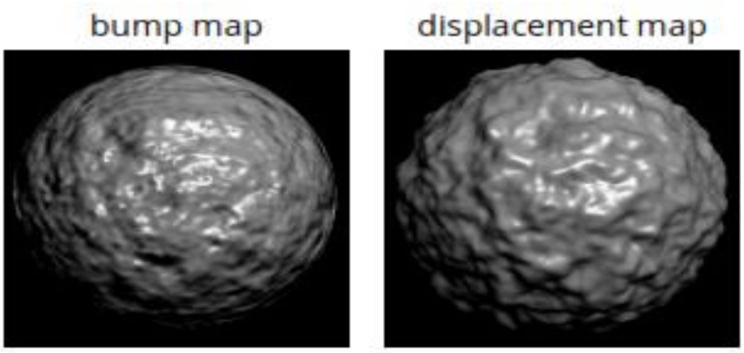


Fig. 2. Bump and displacement mapping result

2. Bump Mapping realization

Rendering a high polygon surface is a very expensive process. It would be cheaper to use bump mapping method, as we can get the same result and see the effect - a very realistic image.

The traditional and common way to create a normal map is first to produce a 3D model of the surface and then to get a normal map by applying a method to generate normal data from 3D model.

On the other hand we can use 2D textures processing to produce a somewhat decent normal map but it is obviously not as accurate as the 3D model version would be.

For normal maps creating use the x, y, z coordinates and translate them to color components (red, green, blue pixels). The intensity values of each color components represent the angle of the normal. The normal of our polygon surface is still calculated the same way as before. We use two normals (the tangent and binormal) for calculating requires the vertex and texture coordinates for that polygon surface. The Figure 3 below shows the direction of each normal:

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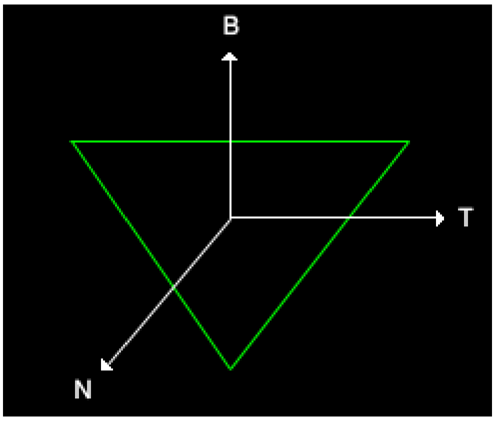

Fig. 3. Bump mapping in tangent space (Tangent Bitangent space)

The normal is still pointed straight out towards the viewer. The tangent and binormal however run across the surface of the polygon with the tangent going along the x-axis and the binormal going along the y-axis. These two normals then directly translate to the *tu* and *tv* texture coordinates of the normal map with the texture U coordinate mapping to the tangent and the texture V coordinate mapping to the binormal (Anyuru 2012; Cantor, Jones 2012; Danchilla 2012; Luna 2012; Matsuda, Lea 2013; Sherrod, Jones 2011; Tutorial 20 2013).

By using the normal and texture coordinates we must do some precalculation to determine the binormal and tangent vector. These calculations can be done in two ways: inside the shader and in a function in C++ code, that you will see to do this during the model loading. The second way is better, because it is fairly expensive with all the floating point math involved. Also if you are willing to use this effect on a large number of high polygon models it may be best to precalculate these different normals and store them in your model format. Once we have precalculated the tangent and binormal (1) we can use this equation to determine the bump normal at any pixel using the normal map:

$$bump_{Normal} = (bumpMap.x * input.\tan gent) + (bumpMap.y * input.binormal) + (bumpMap.z * input.normal). \quad (1)$$

Once we have the normal for that pixel we can then calculate against the light direction and multiply by the color value of the pixel from the color texture to get our final result (Tutorial 20 2013).

```
// Pixel Shader
float4 BumpMapPixelShader(PixelInputType input) : SV_TARGET
{
   float4 textureColor;
   float4 bumpMap;
   float3 bumpNormal;
   float3 lightDir;
   float lightIntensity;
   float4 color;

   // use the texture Sample for shading.
   textureColor = shaderTextures[0].Sample(SampleType, input.tex);

   // use the texture Sample for the bump map.
   bumpMap = shaderTextures[1].Sample(SampleType, input.tex);

   // Change the range of the normal value from (0, +1) to (-1, +1).
   bumpMap = (bumpMap * 2.0f) - 1.0f;

   // Calculate the normal from the data in the bump map.
   bumpNormal = (bumpMap.x * input.tangent) + (bumpMap.y * input.binormal) + (bumpMap.z * input.normal);
```


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```
// Normalize the resulting bump normal.
bumpNormal = normalize(bumpNormal);

// Invert the light direction for calculations.
lightDir = -lightDirection;

// Calculate the amount of light on this pixel based on the bump map normal value.
lightIntensity = saturate(dot(bumpNormal, lightDir));

// Determine the final diffuse color based on the ambient, diffuse, specular color and the amount of light intensity.
color = saturate(ambientColor * diffuseColor * specularColor * lightIntensity);

// Calculate the final bump light color with the texture color.
color = color * textureColor;

return color;
```

Conclusions

Texture Mapping- Bump Mapping is a modern computer graphics method. This technology adds roughness to surfaces for simulating wrinkles and bumps without changing real height values of the surface. It is a quick way to add detail to an object. The very important detail of bump mapping that polygon remains physically flat, but appears bumpy. This effect is achieved by perturbing surface normal. A common use of this technique is to take a low resolution model and by using tricks make it look like a higher resolution. This method is successfully realized by using DirectX platform using pixel shader.

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eISBN 978-609-457-835-9

FORMS USED FOR GRAPHIC REPRESENTATION OF AN OBJECT IN ENGINEERING GRAPHICS

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Abstract. A technical problem is identified and needs to be visualised through developing a graphic model and completing drawings. The basic knowledge of the writing and reading technical drawings is learnt in the Engineering Graphics course. In this paper drawings are treated as semiotic signs applying Peirce´s triadic model of representation. The representation of an object (future product) can take different forms: icons, indexes and symbols. On the other hand, for the image of an object, there must be three modes: iconic relation - firstness, indexical relation – secondness, and symbolic relation – thirdness. Various forms of graphic representation of the spur gear, i.e. icon, index and symbol, are presented.

Keywords: engineering graphics, representation, Peirce´s model, modes of being

Introduction

In the design process, a problem is identified and concepts and ideas are collected. The primary product is an „idea". Designers express their design ideas through planning a graphic model (engineering drawing as a visual tool together with its structural components, e.g. shape, colour etc.) according to which machine parts, structural elements or members (which are physical objects) can be manufactured and machines and buildings can be assembled. Designers apply complex knowledge: basic and graphic competence and professional competence in engineering and technology (manufacturing). The drawing as the image of a future object (engineering product) is dealt with in the course of Engineering Graphics which is included in the curricula of higher engineering education. This technical course for engineering students serves as a basis for their further engineering disciplines. After completing the engineering study course, the student has specialized in correctly completing simple drawings and engineering documentation, as well as in correctly reading and interpreting drawings and engineering documentation. Drawings can also be interpreted as signs and Peirce's triadic model can be applied for transferring the data of the design object. Representation of an object in the consequent interpretation can take different forms. According to Peirce, these are icons, indexes and symbols. Icons in our interpretation are three-dimensional (3D) models in axonometric and perspective drawings which bear external likeness to the object. Working drawings supplied with a specification and design documentation can be interpreted as indexes of the future object, i.e. constructed marks presenting the visible parameters as well as the nonvisible phenomena of the object. Symbols, i.e. highly schematized pictures, do not bear any physical resemblance to the object and are arbitrary. The modes of being of engineering drawings are: firstness - icons, secondness – indexes, and thirdness – symbols. Various forms of graphic representation i.e. icon, index and symbol, are presented on the example of the spur gear.

1. Background

1.1. The engineering drawing as a graphic representation of the identified object

A graphic model becomes an integral part of documenting observations, ideas and solutions (Bedward et al., 2009). The problem is identified and concepts and ideas are collected. The primary product is an "idea".

First, the idea assumes a graphic representation (visible graphics) through shape, which alone may be sufficient for recognizing a planned product with a naked eye. In Engineering Drawing a general term for visible graphics is the image with dimensions (view, section and cross-section) as well as with parameters (e.g. tolerance, roughness). It presumes that each object can be built from certain geometric primitives which can be seen as graphic variables (semiotics tools) in logical (structural) relationship. This system of internal relationships () is common for the object as well as for the image. Logical relationship is based on geometric variables, i.e. picture plane and line of sight.

eISBN 978-609-457-835-9
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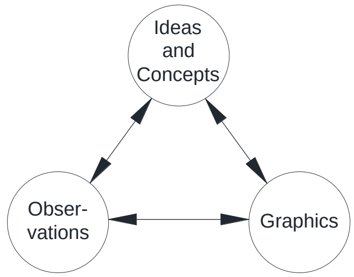

Fig. 1. Triangular model of observations, graphics and concepts

Technical drawings are supplied with a specification in which, depending on the choice of material, there emerge nonvisible phenomena. These are chemical composition and physical properties: density, coefficient of thermal expansion, thermal conductivity, electrical resistivity, module of elasticity, etc.; mechanical properties: tensile strength, tensile yield strength (point), percentage elongation, ultimate elongation. By final processing, surface quality, i.e. requirements for the final result (product) will be established. Integration of visible and nonvisible phenomena presumes an understanding of the core concepts of science and technology (Bedward et al., 2009). They are studied in the course of training in Mechanical Engineering: mechanical structure, machine mechanics, machine design, engineering measurements, mechanical engineering project, etc. At same time, it is known that not a single model accords fully with the engineering product, be it a 3D-printed prototype or even a pre-product. The engineering drawing is not only a model of the planned engineering product but also a device (design document) for engineering communication. From the viewpoint of learning, one may need to answer the question if a visual 3D model could replace the planned object. The 3D visual model offers a possibility to investigate the object quickly and flexibly from different angles and to design cross-sections from its different points. On the other hand, the desired final result of the design is not a visual image but a physical object.

The perception of an object is known to be the more effective; the more organs of the sensory system are involved in the process of cognition. In the case of a 3D printed prototype, mainly the eyes (vision) and the fingers (tactile perception) determine the result. However, perception of an object is more adequate in case also internal phenomena are taken into account. In psychology, when dealing with memory, the term "processing depth" is applied, this means that in superficial memorizing according to, e.g. external shape and colour, the result is worse than in "deep" memorizing with a focus on internal phenomena. In the learning process understanding is highly important in memorizing.

1.2. Peirce's triadic model and the three modes of being of the engineering drawing as a sign

A form of graphic analysis in semiotics is applied to analyse the relationship between the elements (i.e. signs) that make up a drawing. Hence the designer uses a semiotic device, i.e. the representation, which can be illustrated by means of Peirce's triadic model (Fig. 2) (Nadin, 1990).

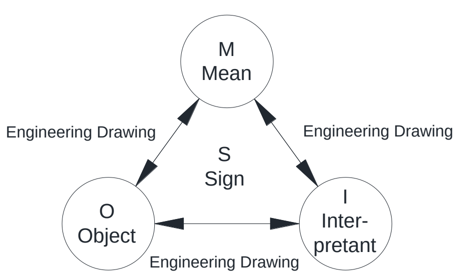

Fig. 2. Peirce's triadic model (edited by M. Bense, Bense, 1983) for transferring the data of the design object

The representation of an object (future product) can take different forms in the consequent interpretation (Fig. 2). According to Peirce, they are icons, indexes and symbols (Nadin, 1990; Deely, 2005). It is well known that the art in education lies in the interpretation of the problem.

The icon is a pictorial representation of likeness or resemblance with the object. The picture forms are well known axonometric projection and perspective. The index is directly related to the object through actual contact, environmental impact or marks of the

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object. In the present context, working drawings are constructed marks that stimulate to act, according to which the process of manufacturing details from the material by using various operations takes place. On the other hand, the working drawing is more complex and has several semiotic layers (above mentioned dimensions, words, symbols; chemical composition of the material; mechanical and physical parameters of the material). Through images indexes involve iconicity.

Symbols are conventional, related to the object; they are representations which act through codes and other regularities (ISO, 2002). Conventional graphic symbols are used in engineering drawings, diagrams, plans, maps and other documents of technical products. The different forms of the representation of an object are integrated in the semiotic bundle. (Sabena, 2008).

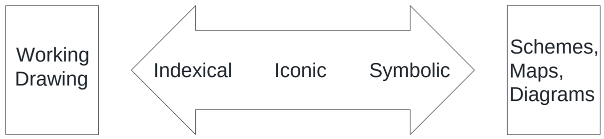
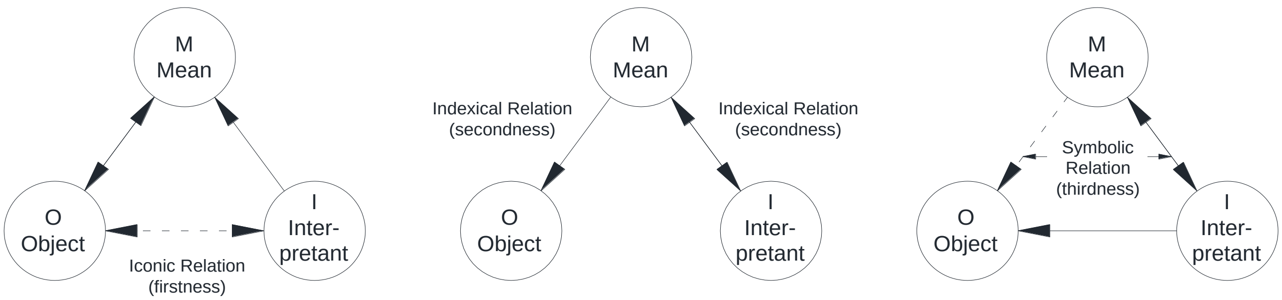


Fig. 3**.** The forms of representation as integrated in the semiotic bundle



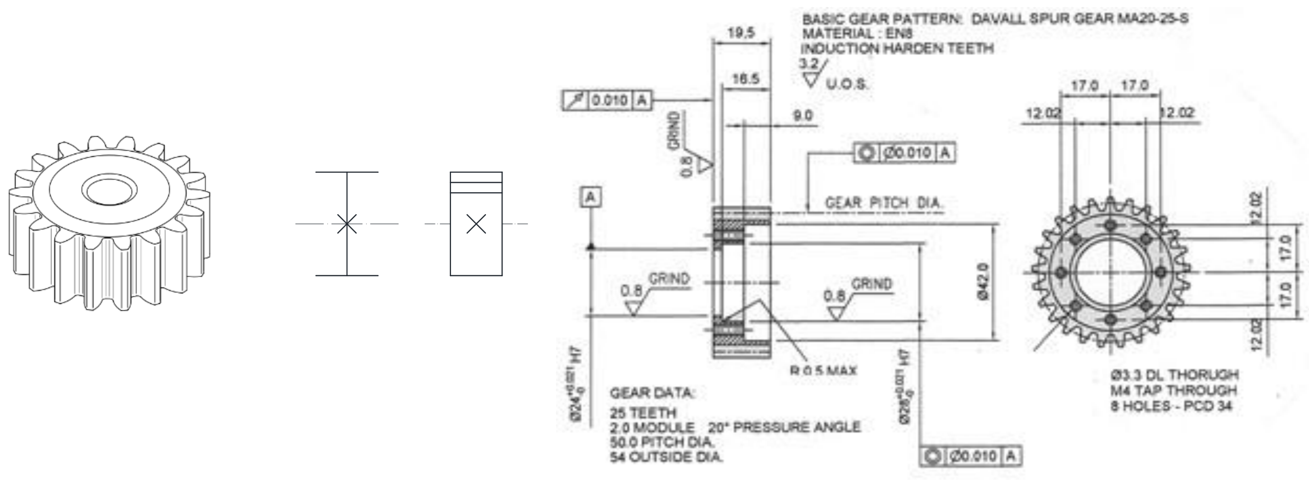
a) b) c)

Fig. 4. Relations of the Peirce's triadic model with the three modes of being: a) firstness, b) secondness, c) thirdness

According to Peirce, there are three modes of being: firstness, secondness and thirdness. Firstness concentrates on the object as a potential thing, Secondness is the realisation of the object according to the drawing, Thirdness is a symbolic image involving mediated interaction between the object and the interpretant (Skaggs, 2011). Analogical pictures resembling the object are established solely through functional similarity or structural correspondence. Realistic (or representational) pictures resemble their referents (objects) through physical similarity (shape, dimensions, tolerances, materials, colour, or motion). Logical pictures can be thought of as highly schematized pictures where the elements of the picture do not bear any physical resemblance to the object and are arbitrary (Scheiter et al., 2009).

2. Discussion

As an example, the possibilities of the technical drawing of the spur gear are presented for delivering engineering and product information through various forms of graphic representation, i.e. icon, index and symbol (Fig. 5).



a) b) c)

Fig. 5. Forms of representation of the spur gear: a) pictorial drawing (source: en.wikipedia.org), b) working drawing (source: www.davall.co.uk), c) graphic symbol

A detail (product) has different images, which allows to depict own identified idea and present it at the professional level.

Conclusions

A certain problem is identified and it is given a graphic representation using an engineering drawing in which the images and the object are connected through the same internal structural logic. Drawings are treated as semiotic signs applying well-known Peirce's triadic model. The representation of an object can take different forms in consequent interpretation: icons, indexes and symbols. The three modes of being of the engineering drawing are the following: firstness – iconic relation; secondness – indexical relation; thirdness – symbolic relation. A spur gear is presented in various forms of graphic representation: icon – pictorial image; index – working drawing; symbol – graphic symbol.

Acknowledgement

We would like to express our gratitude to Ms. Ester Jaigma for excellent linguistic help with this paper.

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eISBN 978-609-457-835-9

HOW TO PREPARE ENGINEERING DATA AND GRAPHIC SYSTEMS FOR SMART COUNTRY

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Abstract. Currently technologies reached the level which allows to create Smart Cities. And if all the cities, towns and villages become smart in this case, perhaps the whole country can be called a Smart Country. In a Smart City all infrastructure data is important but it is not enough, you need to know what to do with this data. Its purpose is to save money and to create additional value for the country.

Keywords: CAD;BIM; GeoBIM; GIS; geodesy; engineering graphics; land surveying; smart cities; smart country; cadastre; land registration; building information modelling

Introduction

Cities and communities around the world are facing significant challenges due to the ever growing urban population. It is getting harder to maintain good services for urban population and it is difficult for businesses to reach the clients. Information and technologies can help to make this growth sustainable. They can help connect people and businesses and enable innovations and new solutions that will improve the efficiency of physical infrastructure (Daniel & Doran 2013). If we implement such solutions into the city infrastructure it becomes smarter.

The drawing and design software represents the most prominent concerns of developers of computer systems, and is the development of several software that fall within the Computer Aided Design (CAD). This software solution are used in engineering fields such as mechanical or electrical or electronic, construction and architecture, some of which are advanced in the adoption of the principle of geometric modelling (Najy 2013). Editing one of 2D CAD views requires that all other views must be checked and updated, as well as an error-prone process that is one of the major causes of poor documentation (CRC for Construction Innovation 2007). Building Information Modelling (BIM) is technology and process that has quickly adopted CAD and transformed the way buildings are conceived, designed, constructed and operated. Although the roots of BIM can be traced back to the parametric modelling research conducted in USA and Europe in late 1970s and early 1980s, the Architecture-Engineering-Construction (AEC) industry practically started to implement it in projects from the mid-2000s (Azhar et al. 2012). BIM tools not only help in designing a building using 3D graphics, but also are capable of holding non-graphical information such as material properties related to the building elements, which are not available in CAD tools. This data can be retrieved to perform various analyzes of the building such as energy analysis, daylighting analysis, cost estimation and structural analysis (Kota et al. 2014). From the analysis of GIS software used for surveying and its participation in the digital construction process, it can be said that without surveying data starting and finishing of BIM project cycle may not be possible.

If all cities, towns and villages in country are connected and use smart solutions we can make an assumption that this is a Smart Country. Smart Cities become cost-effective. We can make an assumption that such cities optimally use their resources. If we want to create Smart City we need to prepare all the infrastructure for such a purpose. We need to think about criteria's which we will be monitoring, a database and its connections and the graphical interface which will show information to the interested parties. All starts from measuring the city. The main city components are its infrastructure and buildings. If we need to know all information about the city we need to have all cadastral, geotechnical and building information. Firs we need to analyze the current situation in the country and then we can start preparing the foundations for a Smart Country.

1. Cadastral data and graphical information exchange

1.1. Clients and contracts

When Lithuania re-established its independence, the land reform in the 1990-ies was launched to return the title to the lost land in Soviet times. Since 1996 a new coordinate system-LKS 94 was introduced in Lithuania, and geodesy network was connected to a common Baltic States geodesy network. These events have become the basis for the creation of a new geodesy and cadastral system in Lithuania. The role of the country is particularly high in the real estate measurements. After the independence and the emergence of new laws, broader prospects for the fields of Geodesy opened up. In earlier times measurements were performed using ropes and sticks, now they have been replaced by modern devices: total stations, laser scanners, GPS receivers and more.

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.012

Revival of surveyors in Lithuania resulted in the formation of companies and that has allowed the Government of Lithuania gradually to implement land reform. Although this reform has been continuing for more than 20 years, it has not yet been fully carried out. The execution of the land reform was and is one of the main commissions for geodesy companies.

Basically it can be said that any of the surveyors work is tied up with the government policy and the laws. Depending on the time of order execution can be distinguished as the main part of the project (Fig. 6), which must be completed in order to finish the project. At the beginning you need to consider the type of work and the client. There are several types of clients, from which contract details depends: physical, legal persons and public institutions.

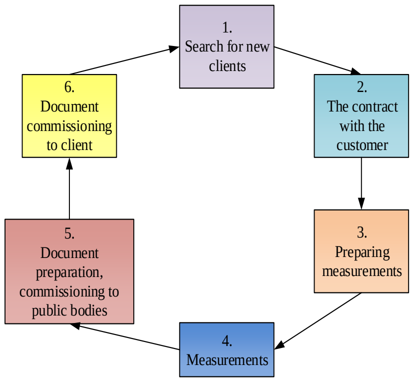

Fig. 6. Typical cadastral data and graphical information exchange system diagram in Lithuania

Natural persons tend to be oriented towards the following projects: geodesy cadastral measurements (including land embellishment), topography, land formation and conversion projects, rural development projects. All of these works are carried out in accordance with the laws issued by the government. When carrying out the projects you need to take into account the intended use of the land. Therefore, prior to preparation of the contract and committing to a client, it should be clarified if it is possible to make such a project. For example in the preparation of the project of conversion of the plot, everything depends on what kind of activity you want to perform on this plot. In any case, you first need to obtain permits for any restructuring of the land. Responsible for issuing authorizations, the National Land Service under the Ministry of agriculture, as well as a municipality, which is responsible for data collection. Legal person’s project orders are similar to physical persons. The biggest difference would probably be the size of the objects. Surveyor’s services in most cases are needed for legal persons who are engaged in construction activities, and they need to make topographic photos and measurements of the land, buildings and structures, engineering networks, control-geodetic photos and 3D laser scanning. All these operations must be carried out in order to build any kind of building. Public institutions not only monitor and supervise the work of the surveyors, but also make use of their services. Nature of the work is very varied, there may be geodetic measurements, cadastral, engineering networks, photogrammetric projects, renovation, 3D scanning, etc.

Impact on the restructurization of the land parcels is basically done by the country itself, which for the municipalities establishes and provides prospects for development of the city (country) General plans. The General plan is a comprehensive planning document in the territories. They take into account the spatial planning levels and tasks of the development territory, as well as the principles for the protection zones (Vilniaus miesto savivaldybė 2015). In the concept of the General city plan you can see city structures, residential areas, transportation systems, engineering infrastructure, natural and cultural values, and many other areas of the planned structures. Under such plans shaping of the land, constructing of buildings, building of roads, engineering communications are determined. So surveyor can’t always help the client with the project. Lithuania is dominated by agricultural lands, which are slowly changing to residential or commercial areas.

1.2. Preparing for measurements

Before starting measurements surveyor needs to collect some data about the land from the State National Land Register (Fig. 6). In Lithuania surveyor use internet portal “GeoMatininkas” which is administrated by VĮ „Registrų centras“. The surveyor can take cadastral information about land and its coordinates from the system. Vector data is downloaded in SHP or DXF formats. Other data, such as ownership of the land is available in PDF formats. In some regions digital data is not prepared and surveyor needs to take 2D pencil drawings (Fig. 7, a).When the data is collected, the surveyor can start measurement process.

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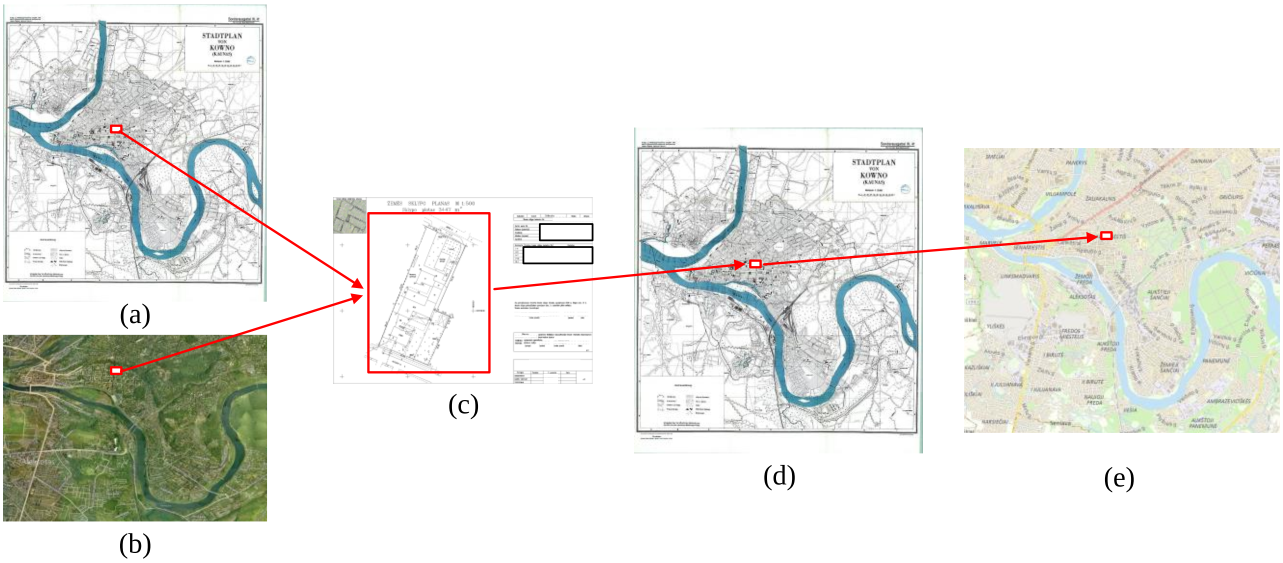


Fig. 7. Cadastral information workflow in Lithuania (a, b) surveyor takes information from 2D pencil drawing, cadastral register and measurements in the field, (c) surveyor makes 2D CAD drawing and documentation, (d) surveyor makes corrections in 2D pencil drawing, (e) public bodies make corrections in 2D GIS cadastral maps

1.3. Measurements

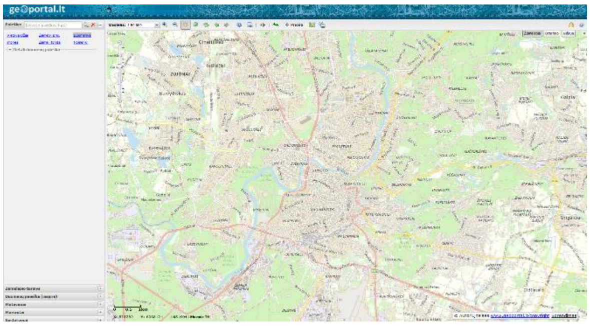
Measurements are very important stage of the project, because you take real information data from the field and use it to renew the old one (Fig. 6). Surveying is carried out via Total Station, GPS receivers, 3D scanners, Auto-leveling elevation measuring, distance measuring instruments, etc. it also uses textual and graphical information such as schemes, drawings, maps (Fig. 7, b). GPS technology is one of the best and fastest measurement methods. The position of each point is determined independently, this technology provides a completely new quality, which cannot be obtained using other devices. It is true that the GPS receiver in some cases is not enough, at this moment total station is used. In surveying practice these two devices complement one another (TOPCON GPS akademija 2000).After the measurements are done the surveyor obtains textual data, which is taken from the device in CSV format. After this you load the data into a software program and make required analysis and drawings (Fig. 7, c).

1.4. Document preparation, commissioning to public bodies

1.4.1. Commissioning to public bodies

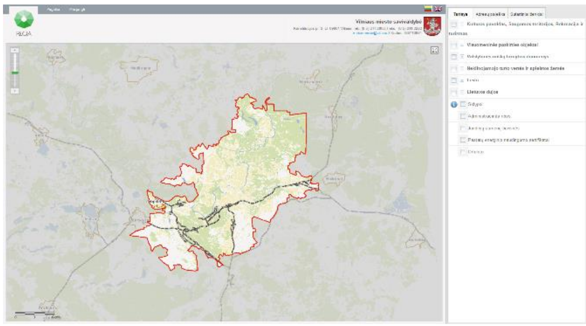
Cadastral surveying of land and buildings is carried out by public and private sectors represented by surveying companies and individual surveyors operating only through licenses issued by the National Land Service under the Ministry of Agriculture. Private surveying companies are also engaged in the topographical, geodetic, designing activities. Requirements for private surveyors are set forth by the licensing regulations, orders on cadastral surveying of real property objects. Supervision and control over cadastral surveying activities are exercised by two institutions – National Land Service under the Ministry of Agriculture, responsible for the issues related to formation of land parcels (Fig. 8, a), and the Ministry of Environment, responsible for preparation of territorial planning and supervision of construction works (Fig. 8, b).

Cadastral surveying of land is predominantly performed by private surveying companies, while surveys of buildings are mostly done by the public sector (Centre of Registers) (Fig. 8, c). For efficient administration of cadastral surveying of structures, the State Enterprise Centre of Registers has recently designed information system “Surveyor” (“Matininkas”) intended for surveyors of structures. Technically, a system “Surveyor” is based on Internet technologies and server–client architecture, and has a centralized database and server program. At his workplace, a user employs 2 programs – Internet browser and drawing program, which are both connected to the server program. A drawing program is a common program of Autodesk Inc. and the State Enterprise Centre of Registers designed with Autodesk technologies (VĮ Registrų Centras 2015). Municipal company "Vilnius plan" was founded in 1996. The company is working in two sections in general and detailed planning and GIS (Fig. 8, d). The first part consists of spatial planning, urban transport system, engineering infrastructure design, architectural design, small projects and projects of landscape management, topographical information in the engineering plans. The second part includes GIS data based map formation and digitalization of old 2D pencil drawings(SĮ Vilniaus planas 2015).

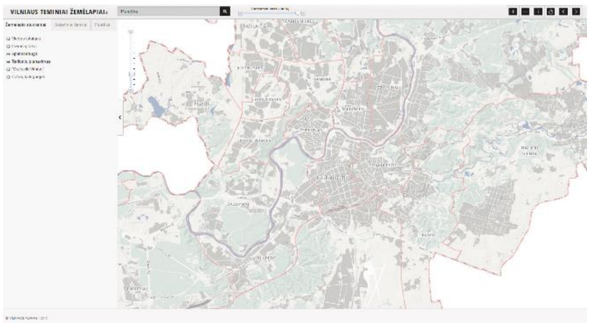


(a)

(b)



(c)



(d)

Fig. 8. Public bodies cadastral surveying of Vilnius city (a) (VĮ „GIS - Centras" 2015), (b) (Valstybinė teritorijų planavimo ir statybos inspekcija prie Aplinkos ministerijos 2015), (c) (VĮ Registrų Centras 2015), (d) (SĮ Vilniaus planas 2015)

Various public institutions have their own separate database, which are not connected. In this way, taxpayer's funds are used irrationally (Fig. 8). Only city municipalities and private companies, which are managing infrastructural objects, have common databases. In all these systems, the adjustment of information is mostly done by hand, i.e. the information is checked and modified in small parts, which often are not synchronized. There is no connection between the public and non-public databases. If we want to devolve Smart City or Smart Country concept, municipalities and private companies should connect and store that data in a single database. It would be convenient for users, if all the pickups and upgrades of information (graphic, textual, numeric) were carried out on the principle of a single window.

1.4.2. Tools for document preparation

The main tools for the preparation of cadastral documents are based on the CAD or GIS technology (Fig. 9). GIS by itself has sufficient body of knowledge on data representation, models, functions, tools, analysis methods, procedures, and methodologies, but still lacks the ability to optimally utilize the current resources and knowledge due to diversity of data formats, tools, platforms, developers, users, and researchers involved in various domains and applications (Karimi & Akinci 2009). The main differences between CAD and GIS software CAD are rooted in drafting and GIS in data management and combine multiple feature sets and databases together (Karimi & Akinci 2009).

The current geometric representation of cadastral information is usually based on very accurate but simple 2D representation of parcel descriptions with associated land information (Hassan et al. 2008). In the past decade we have witnessed an increasing of BIM technologies usage in building construction and infrastructure industries. The design and construction of built facilities is rapidly converting its design and documentation systems to three dimensional building information models. The primary benefit of this new technology is the change from a simple representation (2D drawings), to a semantic representation, that allows virtual prototyping, measurement of performance and multi-disciplinary life cycle collaboration (El-Mekawy & Östman 2012). All the BIM property information is in 3D and it is difficult to analyze building data in 2D cadastral database (Fig. 9). The standard design tools for buildings and civil engineering infrastructure – BIM are not prepared for working with real world subsurface information that originates from the 3D geological and geotechnical models – GeoBIM (Fig. 9). Also GIS standards (as the UGC standard in which data is defined in CityGML) or BIM standards (in which data is captured in formats as IFC, CAD) are not ready for that. BIM is used mainly in construction and is suitable for 3D modeling in a geometrically precise manner and with great detail and is used to model a limited location (e.g. a building). It is not used for larger areas, as is typical in GIS applications (ZOBL et al. 2011). At this moment there is an increasing demand of 3D cadaster data which is compatible with 3D building information.

eISBN 978-609-457-835-9

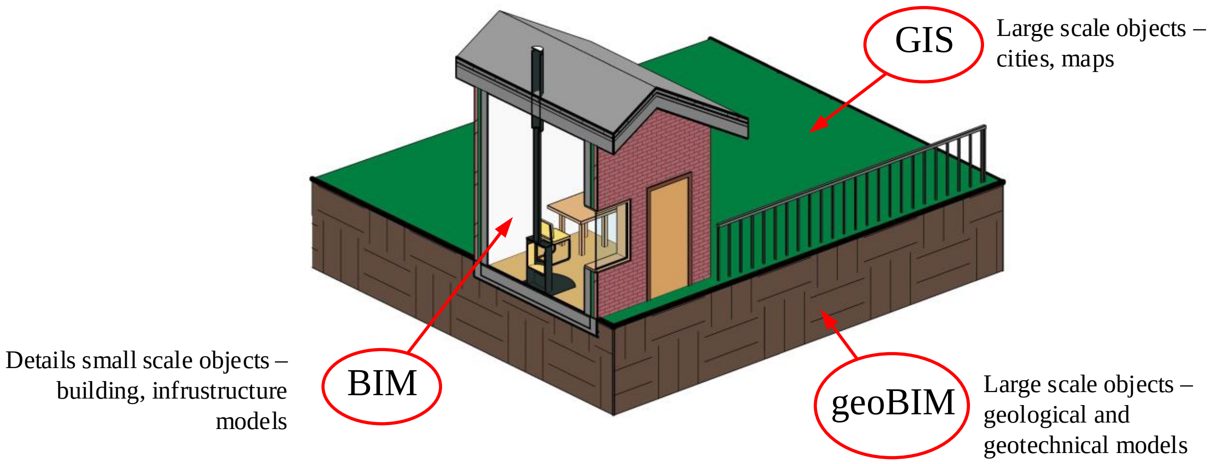


Fig. 9. Information management technologies used to collect and present different data formats

1.5. Document commissioning to client

After the completion of the contract work, the client is usually given a paper and a digital version of the documents. Information is usually given in original version with signatures, but if the client requests, copies can be made. But sometimes original documents are not given to a client, depending on the project type and laws. If a project is topographical or control-geodetic, the original documents may remain with the surveyor, because the original version is only one and it can be required by other companies which are making different parts of the project for the client (for example, if you build a house you need this data for the engineering networking or other project designers). Public authorities collect documents for archivation purpose in some cases, depending on the type of a project. City municipalities don't collect original topographical drawings, because they get the needed information from the surveyor when he is preparing project documents. In some municipalities digital drawings are transferred to the digital database. For example in "SĮ Vilniaus planas" if information of land is digitalized, the information is renewed in digital format, if not, the information is transferred on to metal plate covered with a thick card (Fig. 7, d). When project cadastral measurements are done, one original version of a document is for the client and the other is for National Land Service under the Ministry of Agriculture. When the project is prepared, the surveyor renews VĮ Registrų Centras data base by registering the new data. The renewed data is available for registered users for a fee.

Conclusions

The Smart Country solution installation is relevant, because these technologies help to more efficiently use country resources and distribute to the population. If these solutions are not implemented, the country experiences various losses, for which residents are paying. In order to apply this type of technological solutions in Lithuania, it is necessary to create an appropriate platform. Works must be carried out at national level in formation of the country laws, the detailed plans of cities, towns and villages. All the objects and activities in the country can be mapped to the cadastral system. One of the most important elements in the country is advanced infrastructure. For its representation we can use building information modeling, GeoBIM and 3D cadastral. So the state municipalities need to prepare a simple system for various data (GIS, BIM, and GeoBIM) exchange and a graphical representation of information for different type of users.

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eISBN 978-609-457-835-9

PRODUCTION-INTEGRATED QUALITY-CONTROL USING OPTICAL MEASUREMENT TECHNIQUES

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Abstract. In today's manufacturing processes, optical measurement techniques are becoming increasingly popular for on-line quality control. This fast and cheap technique enables manufacturers to not only check single points given by an inspection plan, but entire surfaces. This paradigm change brings new possibilities as well as new challenges to the inspection process. We devised software and technologies that achieve a seamless integration of optical measurement techniques into the existing workflow in the production process from design and prototyping up to series production. These techniques go far beyond the simple measuring of structural dimensions. The system permits the management and storage of the complete history of measurements. Hence, trends in deviations from the desired quality or functionality can be determined early and easily. This helps to implement corrective actions even before the produced structures fail to meet the specifications. Using a safe and decentralized server architecture using https, all data is available across business units and plants. Additionally, we developed highly interactive visualization and data exploration tools which enable expert users to fast and easily evaluate the measured data. With these techniques and visualization tools, we combine the advantages of optical measurements with the established evaluation of tactile measurements.

Keywords: Visualization, quality control, optical measurements, measurement evaluation, error analysis

Introduction

In manufacturing, quality control plays an important role in all stages of production (Yao, 2005). To guarantee compliance with the high quality standard expected by the customers, produced parts have to be examined in every step of the assembly sequence. While this has been done mainly by tactile measurements, in recent years optical measurement devices, such as stereoscopic cameras or handheld laser scanners, have become increasingly popular (Martínez et al., 2010). The most obvious advantage of these systems is that not only single points on predefined inspection plans are measured, but the surface as a whole. Additionally, those systems are fast and cheap. One disadvantage is e.g. the measurement of deep holes with small diameters, as there is a lack of information in there (Gapinski et al., 2014) and highly increased data size. While tactile measurement results contain three to six values per part for each feature on a predefined inspection plan, optical measurements result in triangulated point clouds which can easily contain several million triangles (Fabio, 2003).

To profit from the possibilities arising from the detailed measurement of the surface, the measurements need to be evaluated in a timely manner and presented to the expert user in a visually pleasing and informative way. Furthermore, the evaluation has to be automated in most parts and be integrated into the existing workflow, so that no relevant time overhead arises. Other challenges, such as the accessibility of the data across production sites, from within a measurement data management (MDM) system, secure transmission and compression of the data has to be considered as well.

In this paper, we present the different modules of the software we developed to efficiently evaluate, visualize and examine optical measurement data gathered in the manufacturing process from prototyping to series production.

1. Related Work

1.1. Other Commercial Frameworks

The following description of commercially available software for (not only) optical measurement data is in no way complete, nor is the description of the mentioned software. The intention of this paragraph is to point out the niche our software fills.

In industry, every company selling optical sensors, such as e. g. the Gesellschaft für optische Messtechnik (GOM, www.gom.com) and Steinbichler Optotechnik (www.steinbichler.de) have developed their own inspection software, namely GOM Inspect and Steinbichler Inspect. Also, there is a variety of commercial software that offers similar and extended functionality, such as e. g. PolyWorks by InnovMetric Software Inc. (http://www.innovmetric.com/). All of these software suites

baltgraf.vgtu.lt
eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.013

provide a huge variety of different functionality, starting from basic geometry editing and format changing to slicing and comparison of geometries. Tools for surface reconstruction and other advanced techniques are also available.

While these systems are extremely powerful and useful, our focus is the integration of the evaluation into the existing on-line workflow. This means that from the start of the measurement process in prototyping to the finished report of series production measurements, our software performs all necessary tasks so that time-consuming loading, evaluating and documentation of the measurements one by one will not be necessary anymore. While it will still be vital to use other (commercial) software in addition to our software suite for specialized tasks, such as reverse engineering, performing measurement hardware specific tasks and the first alignment of the measured data, our software provides the means to efficiently manage, visualize and evaluate the given data.

1.2. Optical Measurements

Optical measurement techniques are used in a huge spectrum of applications, ranging from the preservation (Yastikli, 2007) and monitoring (Risbøl et al., 2015) of cultural heritage over the monitoring of forests (Montaghi et al., 2013) to applications in industry, such as reverse engineering (Sansoni et al., 2004) and quality control (Akinci et al., 2006; Bosché, 2010).

There are many different optical measurement devices, such as stereoscopic camera systems (Winkler et al, 2013), (handheld) laser scanners (Martínez et al., 2010) and structured light systems (Valkenburg et al., 1998). The output of those devices is unstructured point data which is combined to a smooth surface. Doing so while preserving the topology of the scanned object has been researched for several years (Fabio, 2003), with great success. The measurement software available today produces high quality nets with high reproducibility even under suboptimal viewing angles. The triangulated and aligned meshes, that are the result of these processes, are the starting point for this work.

1.3. Visualization

“Visualization and visual analysis play important roles in exploring, analyzing, and presenting scientific data.” (Kehrer et al., 2013). To bring visualization to good use, many aspects of the intended application, audience and technical system used have to be considered (Hughes et al., 2013). For the application in the manufacturing industry, as in other application areas, it is important that the visualization fits the demands of the users (Fuchs et al., 2009).

The data produced by optical measurement devices are mainly triangle meshes, stemming from the triangulation of unstructured point clouds. By calculating the distance between each point on the nominal geometry to the measured geometry (see section 4.1 for details), we generate multiple scalar fields over a common, unstructured grid. We therefore applied scalar visualization techniques (Telea, 2014) as well as topological methods, and statistical methods.

Other visualization techniques, as are described in Kehrer et al. (Kehrer et al., 2013) and others will be considered in future work.

2. Overview

In this section we will give an overview over the measurement process for tactile measurements as well as for optical measurements. Following that, we describe the main evaluation steps for both methods. At the end of this chapter we compare them directly. Our main focus here is to point out the differences between optical and tactile measurements as well as highlighting the advantages of both methods, respectively.

2.1. Measurement Data Management (MDM)

Taking a measurement is useless if it is not thoroughly documented. Every measurement has to be stored and combined with its related metadata. This metadata contains, but is not limited to, the actual part the measurement was performed on, the feature for which the measurement was taken, the machine and the measurement device with which it was performed, the user supervising the measurements and the inspection plan in use. The management of these metadata is the main purpose of the MDM system. On every step from the first prototype to the end of series production, unforeseen problems may arise, making a revision of the geometry, the inspection plan, or both necessary. Therefore, another important function of the MDM is to correctly version and archive the respective geometries and inspection plans.

To truly assess the quality of the produced part, the raw measurement data has to be evaluated. This evaluation process is a complex task and is dependent on a variety of factors, that all have to be taken into account. Performing these evaluation steps is another main task of the MDM.

In industry applications, like car manufacturing, symmetry plays an important role. Most exterior parts are completely symmetrical. Therefore, inspection plans for symmetrical parts are only designed for one side of the car, typically the driver’s

eISBN 978-609-457-835-9

side and mirrored on the fly. Measurements, however, have to be performed and managed for both sides. Evaluating those measurements with respect to each other yields a measure for the achieved symmetry.

For the purpose of 3D Visualization, the nominal geometries have to be obtained. Therefore, the system also needs to communicate with the Product Data Management (PDM) system of the respective Original Equipment Manufacturer (OEM).

For a better understanding of the data and a better overview, as well as to fulfill legislative demands, the evaluated measurement results have to be documented in a printout report, e.g. as a pdf document. Moreover, all measurements have to be stored and documented for about ten years, depending on national legislation. Archiving of measurements and evaluations can also be a part of the MDM system. The generation of such documents can be cumbersome. To facilitate automated report generation, the MDM system has to apply cumulative and statistical methods to the measured and evaluated values as well as formatting and displaying it in a visually pleasing way. For best understanding, the evaluated measurement results are to be displayed in relation to their spatial context, meaning that e.g. a diagram showing the progression of a features deviation should be displayed next to a rendering of the part where the feature is actually visible. The association of features with their respective measurement results always has to be clear. For the automated generation of such documents, scenes are created by an expert user, defining the exact viewpoint, colors and features which are to be shown. From these scenes, pictures are automatically rendered for the report. The generation of tables and graphs as well as appropriate page headers and footers are also done according to the examined parts.

2.2. Measurement Process

The measurement process begins with the measurement planning. For every geometry that is constructed, an inspection plan has to be devised. This inspection plan contains inspection plan elements, called features, such as e.g. round holes. These features have got several properties like a spatial location, normal direction and/or touching direction as well as nominal values for, e.g., a diameter. Additionally, to truly assess the quality of the produced parts as well as the assemblage, tolerances can be defined for every feature and every nominal value. Derived features, such as distances and angles between certain sets of points may also be defined there.

For every step of the assembly, a new inspection plan is created, accounting for additional constraints that arise at the respective step. For instance, some features on the single part may not be measurable any more or may be more/less important on the assembly. Therefore, it may be adequate to add or remove certain features as well as set different tolerances to other features in different steps of the assembly.

Along with the inspection plan, the measurement modalities are specified. This might be anything ranging from a high-precision probe on a robot arm for Coordinate Measurement Machine (CMM) measurements, via over a worker with a caliper, up to large scale measurement methods such as tachymeter measurements (e.g. in ship construction). For actual measurements, metadata regarding the used measuring machine or device also have to be stored. With them, it is possible to, e.g., identify measurements which were performed with a malfunctioning measurement device as well as automatically incorporate the device specific precision into the evaluation process.

2.2.1 Tactile Measurement Workflow

Tactile CMM measurements are mostly taken by high precision robot arms using small probes with a defined touching force. For CMM robots as well as the probes, there exist numerous hardware and software vendors with even more different models of both. These robot arms have to be controlled. For that task, from every inspection plan, several measurement programs are developed and run on one or more measurement machines, either in parallel, if possible, or consecutively until all features have been measured. The result of each measurement is, e.g., an absolute three dimensional point value, which then has to be evaluated by the MDM.

With inspection plans containing up to several thousand features, this method, while highly precise, is slow and, therefore, expensive to use. Systematic errors occurring during those measurements, such as suboptimal alignment of the part, or prestress of the clamped part, have to be accounted for, e.g., by realignment of the part either by the MDM, the CMM or other specialized evaluation software.

The measured values are then stored to a measurement database, tagged with the actual part they were measured on, as well as the nominal geometry and inspection plan version used and other metadata.

2.2.2 Optical Measurement Workflow

Optical measurements are usually taken using e.g. a robot arm holding a stereoscopic camera. Depending on the application, the entire surface or only parts of it are scanned. Depending on the stage of assembly, the measurement may be of a single part or an assembled structure. Measuring a complex surface may require multiple measurements from multiple viewpoints which have to be combined, processed, thinned out and connected to form one triangulated mesh. This mesh is the starting point for our investigations.

The triangulated mesh is given e.g. as a binary file using the “Surface Tessellation Language” (STL). The MDM system now performs several tasks. Firstly, it ensures that the mesh is mapped to the correct measurement, meaning the right car model, part and version etc. and, therefore, inspection plan. Secondly, it compresses the given data as described below. The server now finds the corresponding quota (nominal) geometry to perform a deviation calculation. For this purpose, the quota may either be the triangulated geometry as given by the CAD model or an arbitrary user-defined geometry.

To compress the triangle meshes, we use the Open Compressed Triangle Mesh (CTM) method and format, which yields very small file sizes, i.e. good compression rates, especially when compared to standard binary STL files. For this, we first have to remove duplicate vertices, which naturally occur in STL files. While this process and the CTM encoding take some time, loading of CTM files is quite fast. Conversions from formats that are already indexed, such as the Polyworks (.pol) format or the GOM (.g3d) format, can be done directly.

2.2.3 Evaluation Process

The evaluation of tactile measurements is a multistep algorithm. The actual values gathered from the devices have to be corrected, depending on the alignment of the part and other factors. In subsequent steps, this value might have to be corrected again to account, e.g., for deviations from the nominal geometry due to deformation by gravity while it is spanned in a tenner. These changes can either be done by correcting the measured value or by changing the tolerances along the corresponding axes, e.g. by shifting the tolerance band in a defined manner. Further calculations and optimizations may be needed.

The evaluation of optical measurements on the other hand is divided into two steps. In the first step, for every feature on the inspection plan, the corresponding point on the measured surface has to be determined or, in cases such as round holes, to be calculated. Fitting algorithms for all types of features have to be developed and combined with evaluation strategies, which can stem from, e.g., the OEMs. In the second step, a comparison of the whole surface is performed. This can either be done by comparing the actual data against the original CAD surface or against a geometry chosen by an expert user.

We propose the usage of the so-called "Bemessungsfreigabe" as the quota geometry. It is a produced part that has been defined as reference geometry by the measurement experts. Since the actual parts may differ from the constructed CAD geometry in various ways and for many different reasons, comparison against this geometry might not be the optimal choice. Deformation because of gravity or stress, e.g. as a result of an assembly step, which might as well be planned, but is not accounted for in the original CAD model, would lead to large distances between the measurement and the CAD model. The "Bemessungsfreigabe", however, is proven to be excellent and, since it is processed and measured in the same way as all other parts in the series process, seems to be the optimal choice.

The actual calculation of the differences is a computationally expensive task that should be done only once.

2.2.4 Comparison

While tactile measurements are the necessary basis for quality control in the manufacturing process due to their high accuracy, which is needed at important locations on the surface, optical measurements can be an important and valuable addition to the quality control process. For quality control, the strongest argument for optical measurements is the possibility to analyze the complete surface at once, while from a processing point of view, the superior speed compared to CMMs is most important. For most purposes, especially in exterior design, the achieved accuracy is more than adequate. Therefore, tactile and optical measurements complement each other well. Although these measurements use much storage space and their evaluation is computationally expensive, it is worthwhile to perform it to create more accurate and, in the end, higher quality parts.

3. Software Features

In this chapter, we give an overview on the different functions and analysis tools we implemented to enable an expert user to explore and evaluate the given optical measurement data. We discriminate between per-vertex-(visualization)-modes, where every vertex is assigned one discrete value, which is then displayed as a color map on the quota and other visualization techniques, as well as data exploration functionality.

The selected modes and views, along with a variety of different parameters, can be configured individually for every geometry within the view. All of these parameters can then be stored in scenes, which are used for automated report generation. This holds true for all of the described visualization techniques.

By integrating all these features into an existing MDM software suite that already incorporates nearly all aspects of tactile measurements, we take one step on the way to the synthesis of optical and tactile measurements.

3.1. Client-Server Architecture

For tactile measurements, the amount of data for a single measurement is moderate. Therefore it is feasible and sensible to store them in a monolithic database e.g. at the headquarter of the customer. For optical measurements, data size is a serious problem. STL meshes from optical measurement easily reach sizes in the GB range, which calls for a different approach to the server architecture. To find an optimal way, we hypothesize on several principles:

6. *Local importance*, meaning that measurements performed in one plant, will most likely only be needed at that site.
7. *Global access*, meaning that it has to be possible to view the measurements from any plant.

8. *Small data packages*, meaning the effort to minimize the network traffic footprint of the application.
9. *Secure transfer*, meaning that the data sent must be protected from theft.

Measurements are taken where the parts are produced. Evaluating them on-site therefore would be sensible. When the parts are transported to another site, for instance, for assembly, only the evaluated measurement results or a statistical report will be sufficient for quality control.

While we hypothesize that this holds true for most cases, the data should still be available everywhere it is needed, which motivates principle two.

Despite the great efforts of politicians and telecommunication companies around the world, high speed internet connections cannot be considered a standard everywhere. This, as well as realizing that the given capacities have to be shared with other applications, makes the compressing data before transfers a mandatory task.

Data security and data theft are a serious problem in modern industry. Securing ones data against unauthorized recording makes the encryption of all sent packages mandatory. For that reason, we use secure https connections for both, server-server as well as client-server connections.

3.1.1. Server Architecture

Following the first principle, the data measured in one plant has to be accessible fast and easily from within that plant. Therefore, we implemented a local server, called the Vaulting Server, for every production site. Every optical measurement performed in the respective plant will be uploaded and stored in a compressed form on its vaulting server. Additionally, the vaulting server performs the comparison between the specified and the actually measured values and stores the results. This task is described in detail below. Furthermore, in future work, the server will evaluate the geometry according to the inspection plan and store the evaluation results separately into the measurement database, so that, depending on the user's needs, not even the comparison file has to be downloaded. A local user then can easily access both, the comparison results as well as the stored inspection plan evaluation data from within the MDM at high speed.

For users from remote facilities, the necessary download data volume is minimized by the fact, that the measurement comparison has already been performed. The remote user requests the measurement results at his or her local vaulting server, which will then request the corresponding comparison files on the remote vaulting server. Instead of downloading all the measurements, only the precalculated comparison results and the quota geometry have to be loaded. If the quota geometry is equivalent to the CAD geometry, this step might be unnecessary as well. The requested results can be cached on the local vaulting server, so that multiple transfers of the same file are avoided.

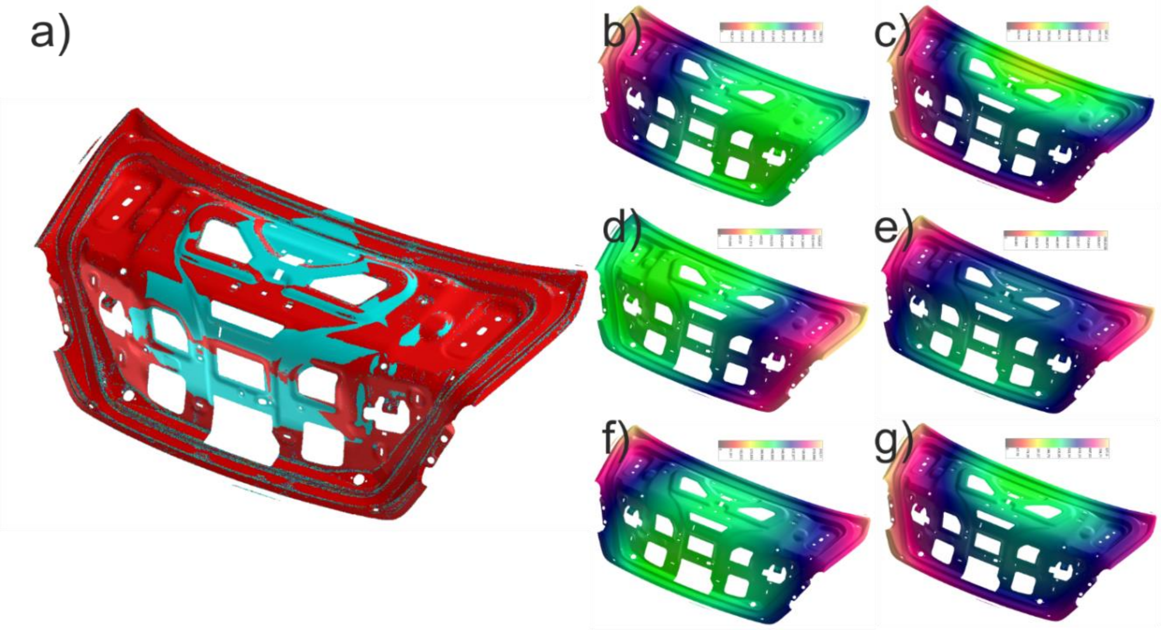

Fig. 1. Pareto View: a) shows the result of the Pareto calculation after Hüttenberger et al, calculated from the computer-generated scalar fileds shown in b) to g). For details regarding the interpretation see subsection 3.2.1 as well Hüttenberger et al.

eISBN 978-609-457-835-9

3.1.2. Client Architecture

The upload of measurements onto the server is performed in two steps. First, to minimize the data size for https uploads, the measurement files, mostly given in the binary STL file format, are compressed. After compression, the file is uploaded to the server for evaluation and archiving. Simultaneously, a new measurement entry is generated in the MDM database, referencing the newly uploaded measured geometry as well as the calculated comparison file as soon as the calculation finishes.

The client is connected to both the vaulting server and the MDM server. To download the optical measurement data, the files referenced by the measurement received from the MDM database are requested from the vaulting server. Analogously to server-server download requests, the downloaded comparison results and quota geometries can be cached locally to avoid unnecessary traffic.

3.2. Per-Vertex-Modes

As mentioned before, in these viewing modes, every vertex on the triangulated surface is assigned one discrete value, which is then color-coded to highlight regions which require special attention. The color scale used for the visualization can be customized in real time. Custom color scales can be saved and loaded. Allowing parts of the scale to be “rejected”, meaning that vertices with values in a certain range will not be displayed, isoline rendering becomes possible as well as trivial. A legend can be added to the view if needed. Of course, it is also possible to simply show the triangulated geometry without any color mapping. Per-vertex-modes can be selected and configured individually for all displayed parts. The calculations, depending on the per-vertex-mode selected, may require some calculation time (several seconds in some cases), once the values are computed, however, the rendering will always be fluent.

Exemplary calculation results for different per-vertex-modes are shown in Fig. 2 and Fig. 3.

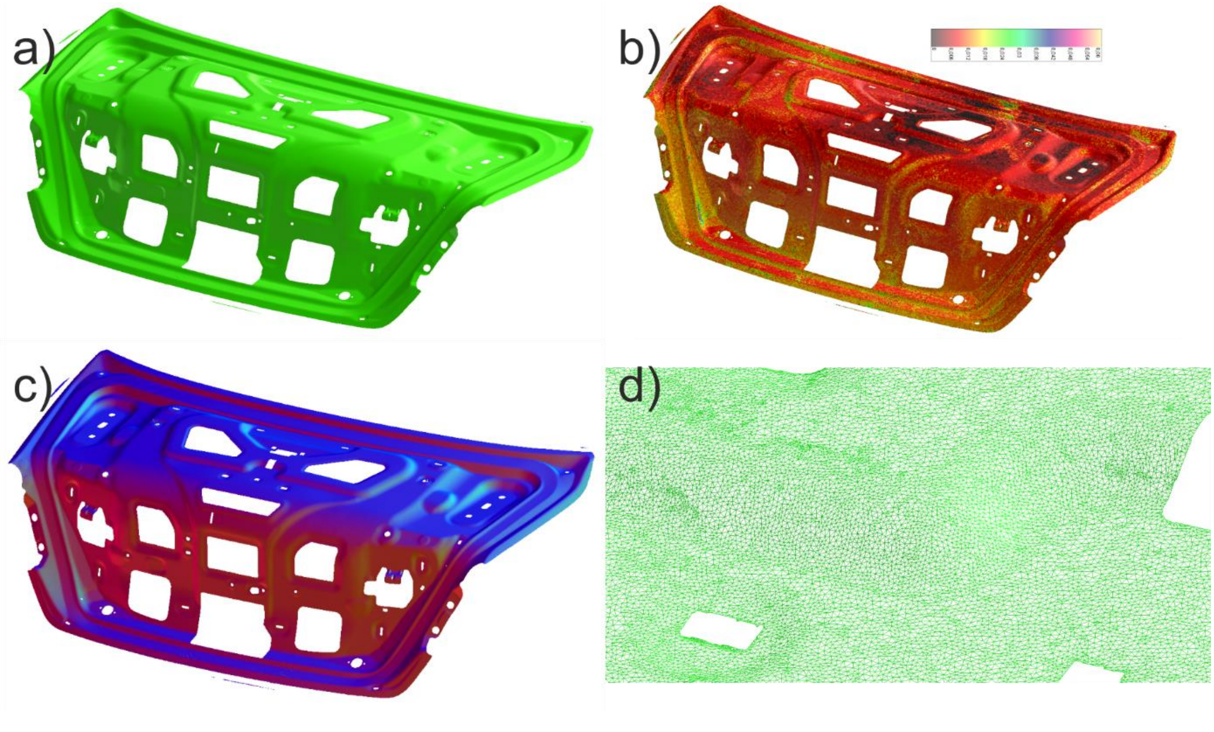

Fig. 2. Basic views. a) shows the rendered and shaded demo quota geometry, b) shows the results of a standard deviation calculation, c) shows the normal direction as RGB values and d) is a close-up rendering of the wireframe model.

3.2.1. Pareto

The software allows a Pareto-analysis of multiple measured parts, as was proposed by Hüttenberger et al. (Hüttenberger, 2015). With this technique it is possible to find areas on the triangulated surface, where systematic errors occur. We plan on dynamically adjusting the inspection plan based on a user-driven evaluation of the Pareto-analyzed surface. This means, that after the Pareto calculation was performed, we aggregate bigger pareto-optimal regions and proactively ask the expert user whether or not he wants to add a feature to the inspection plan at this particular location. Figure 1 shows a sample calculation for 6 computergenerated examples. These were computed by calculating and averaging the distance from five random points within the geometry’s bounding box for each vertex. The partial images b) to g) have maxima at different locations, leading to extended regions where the functions agree that there is a local maximum inside of them, meaning that all functions have large deviations inside this surface patch. For details see Hüttenberger et al.

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3.2.2. Average

When one or more measurements are selected, this mode shows the average deviation at each vertex. Using the well-known formulas for adding and removing elements from an average, this can be recomputed fast and easily if single measurements are added or removed, i.e. if the configuration changes. Results of the average calculation are shown in Figure 3 a), c) and d) as well as most other examples shown throughout this chapter.

3.2.3. Difference

When two measurements are selected, the difference between the values at each vertex can be displayed. The results of those calculations is shown in Figure 3 b). This might be especially useful in prototyping, where a lower number of parts is produced and the part-to-part changes are of extreme importance to the overall process.

3.2.4. Standard Deviation

Similarly to averaging, it is possible to calculate and display the standard deviation over several measurements. Also, with the known formulas for calculating the average, it is easily possible to update the computed values when the configuration changes. For an example of the standard deviation calculation see Figure 2 b).

3.2.5. Curvature

Our software allows the user to calculate the curvature on the triangulated surface. While the main curvature directions are displayed using curvature glyphs, the absolute values for Gaussian curvature as well as for κ_1 und κ_2 may be displayed as a per-vertex-mode. Curvature calculation is done according to Theisel et al. (Theisel et al., 2004).

3.2.6. Normal

In this mode, the vector components of the normal at each vertex, namely the x-, y-, and z-component, are mapped to the red, green and blue color component, respectively. This shows the orientation of the surface and helps to identify errors in the triangle mesh. The example shown in Figure 2 c) shows smooth color transitions around the whole surface, indicating a well triangulated mesh.

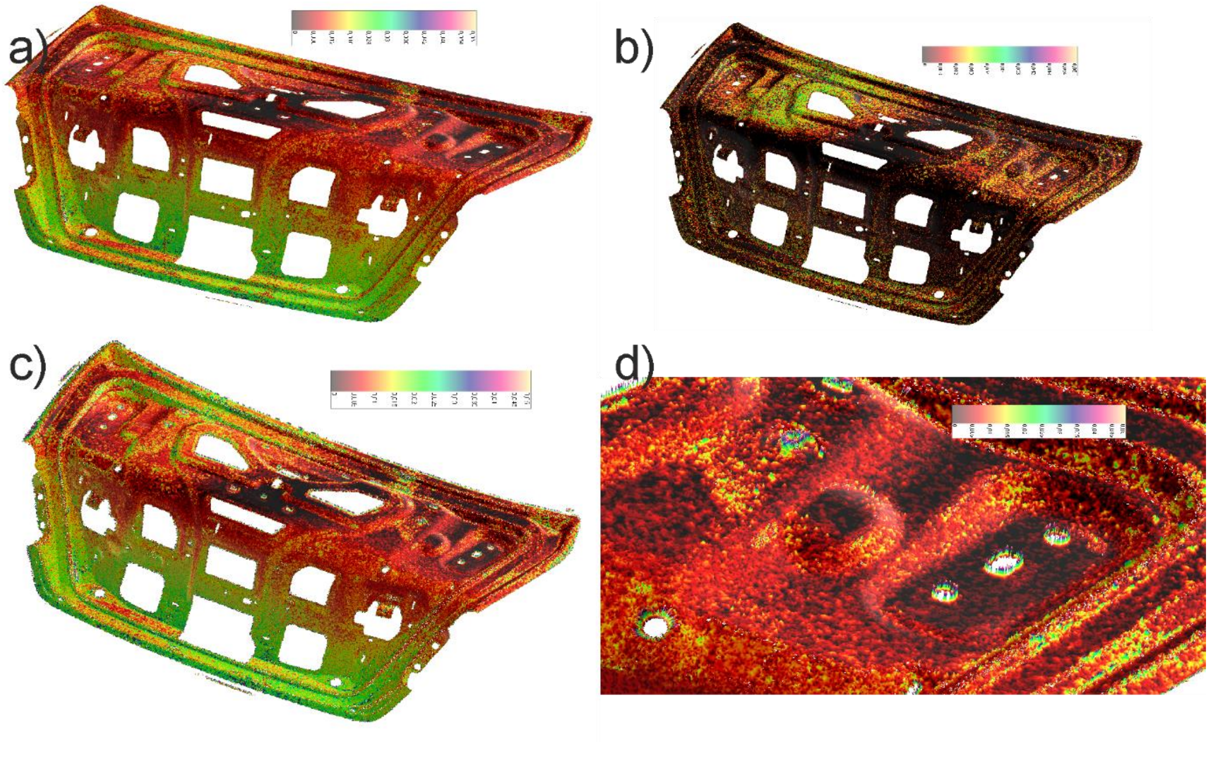

Fig. 3. Cumulative Views. a) shows the average over some measurements, b) shows the difference between two measurements, c) shows the average over some measurements with activated vertex dislocation and d) shows a close-up of the dislocated averages. The vertex dislocation introduced small artifacts as can be seen in c) and d). In d) it is easily observable, that the deviations are especially large around holes.

3.2.7. Easy expansion

Other per-vertex-modes, such as other statistical or summarizing aggregations can easily be added by implementing the given interface. We plan on implementing C_p/C_{pk} (Wu et al., 2009) calculation, besides other measures.

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3.3. Additional Visualization Techniques

The following utility visualization modes can be enabled or disabled at any time during data exploration.

3.3.1. Curvature Glyphs

Displays the curvature of the surface as cross-shaped glyphs. The arms of the cross point in the direction of greatest curvature and in the direction of smallest curvature, respectively. Those directions correspond to the eigenvectors of the curvature tensor for the smallest and biggest eigenvalues. The arms of the cross are colored red and green, respectively. Curvature calculation, again, is done according to Theisel et al. (Theisel et al., 2004). The glyphs are shown in Figure 4 a) as an overview and in Figure 4 b) as a close-up of the surface. As can be seen, the glyphs overlap strongly because of the high triangle density not only on curved parts of the surface. We plan on implementing other methods for curvature calculation in the future.

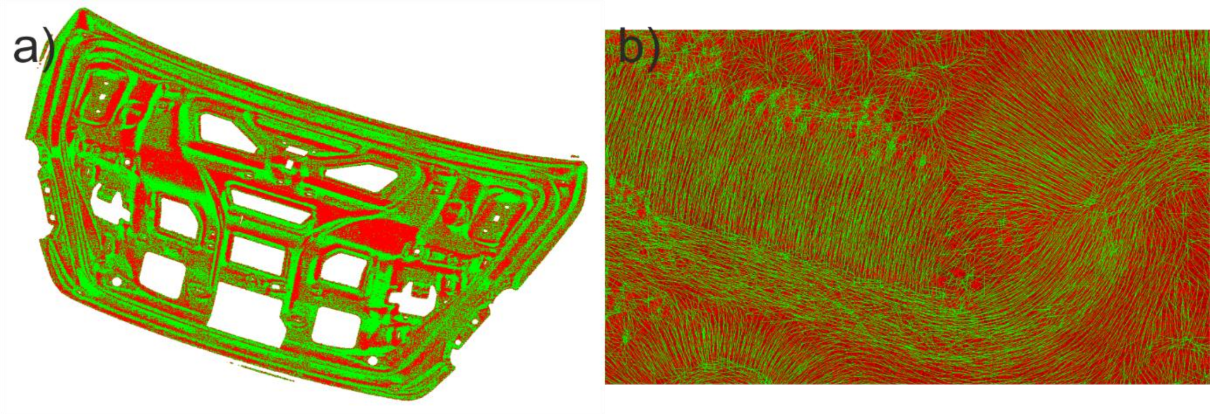


Fig. 4. Curvature Glyphs. a) shows the very dense glyphs displayed for every triangle, b) shows a close-up of the glyph display.

3.3.2. Wireframe View

Displays only the edges of the triangle mesh. The edges are color-coded according to the current per-vertex-values and color scale. The example in Fig. 2 d) shows a close-up of the surface with no per-vertex-mode active. While simple, the wireframe view enables the user to check the net quality and see through surfaces. This is also useful for viewing otherwise occluded parts of the view without losing the spatial context.

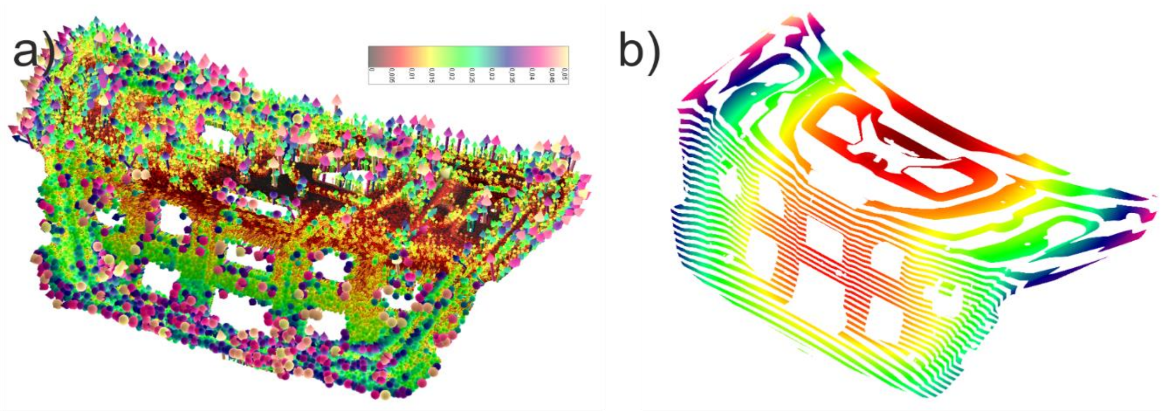


Fig. 5. Auxiliary Views. a) shows the hedgehog view of the average calculation for some selected measurements. b) shows another average calculation with a stripe-pattern projected on top.

3.3.3. Vertex Displacement

To better emphasize the meaning of the measurements as deviations from the original form, it is possible to displace all vertices along their normal direction. This can easily be done by dragging a slider. The results are shown in Fig. 3, c and d. The actual displacement depends on the current color scale and the scaling factor set with the slider. At the moment, this introduces small but visible artifacts in the overall surface, which will be eliminated in future work. Note, however, that the larger deviations around the holes are readily observable.

3.3.4. Hedgehog View

The hedgehog view visualizes the value at a given vertex on the surface by drawing an arrow pointing towards the normal direction at that point. The hedgehog view always visualizes the current per-vertex-data, with respect to the current color scale and value range. Arrow size and color indicate the respective value. The arrow density on the surface as well as the overall arrow size can be adjusted by the user. Changes to the color scale will affect the hedgehog view immediately. The hedgehog view is presented in Fig 5, a. As can clearly be seen, this view, strongly dependent on the configuration, may appear cluttered.

3.3.5. Projectors

As a tool to visually analyze the measured surface, we implemented projectors, which can be placed anywhere in the view. Projectors can cast an arbitrary image on the surface of a set of selected geometries. The projection is either displayed on top of the current per-vertex-mode or instead of it, using a solid color as background for the calculation.

In the overall view, the projector is represented by a small camera with a tripod attached to it. Dragging the arrows of the tripod allows for moving of the projector along the arrow axis, while right-dragging them rotates the tripod around this arrow. The projection is either an orthogonal projection or a natural projection. The pattern is repeated in both directions orthogonal to the viewing direction of the projector. The projection parameters, like the opening angles (in both directions perpendicular to the projection direction) and the brightness can easily and independently be adjusted to account for small and large patterns or images, respectively. Of course, all changes to the position of the projector as well as to the projected pattern or image are immediately displayed in the scene. Figure 5 b) shows a very bright natural projection of a stripe-pattern from the back of the car onto the geometry. The per-vertex-values are the averaging results from the (artificial) measurement results used for the Pareto-calculation.

This feature can be used in several ways. First of all, it can be used to project a pattern onto the surface similar to, e. g., an array of neon tubes or structured light projection which are used by some optical measurement devices. If positional data of the measurements device is stored together with the other metadata, the user will be able to see exactly how the measurement was performed. This may be helpful in evaluating if the area the user is analyzing was well captured.

Secondly, this may be used to create watermarks on the surfaces of parts for reports or marketing purposes.

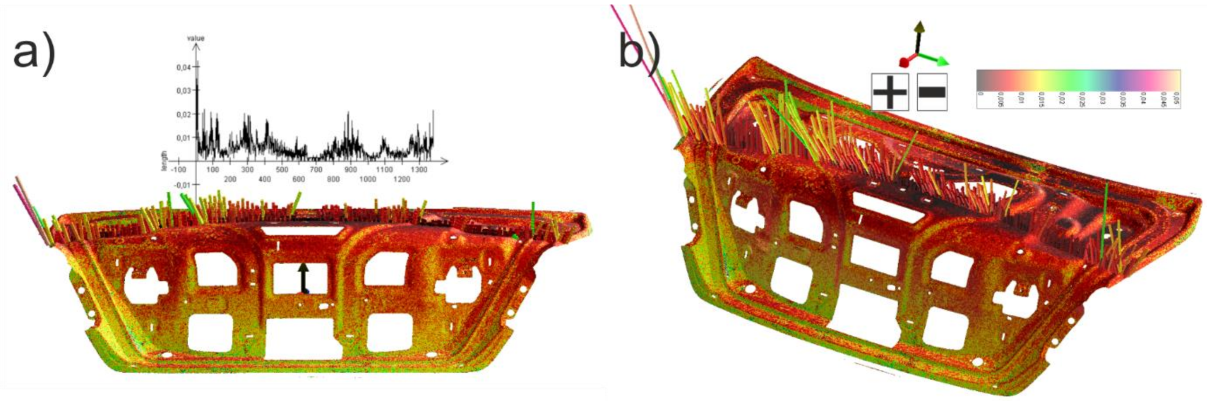


Fig. 6. Linehog styles. a) shows a set of linehogs with a linehog diagram, while b) shows a set of linehogs with buttons and scale. Note the green sphere near the right end of a), which is the marker for the mouse position. Both partial images show the linehogs in boxmode. Also note, that, although we calculate and display five cutlines and linehogs in both images, only one of these cutlines is used for the calculation of the diagram.

3.4. Data Exploration Techniques

In the following, we describe some more sophisticated data exploration tools and their usage.

3.4.1. Multiple Realtime Cutplanes and Linehogs

Our software enables the user to define and manipulate cutting planes. Cut planes are either a part of an inspection plan or can be added to the view by the user. It is also possible to define exactly which geometries are to be cut by these planes. The cut lines are automatically calculated and displayed. Additionally, it is possible to create multiple parallel planes with a defined distance to each other. These planes are connected and can be altered as a group. Each group can be configured individually to vary e.g. the distance of consecutive planes by using a slider. Adding and removing connected cut planes to or from the selected group is done with two buttons, displaying a "+" or a "-", respectively. To change the position of the planes, a tripod is displayed. Both, the tripod and the buttons can be seen in Fig. 6, b. With a left-click drag on one of the arrows, it is possible to move the group in that direction while with a right-click drag, the planes are rotated around that arrow, similar to the controls of the projector. Since all the calculations are done in real-time, the mouse interface allows for a smooth interaction.

The cuts can either be displayed directly on the geometry surface, which is shown in Fig. 7, a and b, or be dragged away from it, as can be seen in Fig. 7, a, to allow for an unperturbed exploration. The lines are color-coded according to the currently selected color scale. Values on the line are interpolated linearly and can also be displayed as “Linehogs”.

Linehogs visualize the error by displaying a geometry analogous to the hedgehog view. Linehogs come in two different modes: arrowmode and boxmode. The arrowmode is similar to the Hedgehog view, displaying arrows scaling with the current per-vertex-value and color-coded for the same value. In boxmode, the values are displayed as a stack of boxes, each one representing a defined value, e.g. 0.1 mm deviation from the quota geometry. Additionally, the boxes are color-coded correctly. The size of the boxes and the error per box as well as the density of stacks across the linehog can be adjusted individually for each linehog or cumulatively in realtime.

Furthermore, we implemented a diagram view for the cutlines. The diagram displays the value of the current per-vertex-mode as a function of the length of the cut curve. This diagram is then shown over the cutline. Hovering over the diagram with the mouse pointer highlights the selected position on the cutline. This helps finding special features on the cutline without optical clutter. This is shown in Fig 7, a.

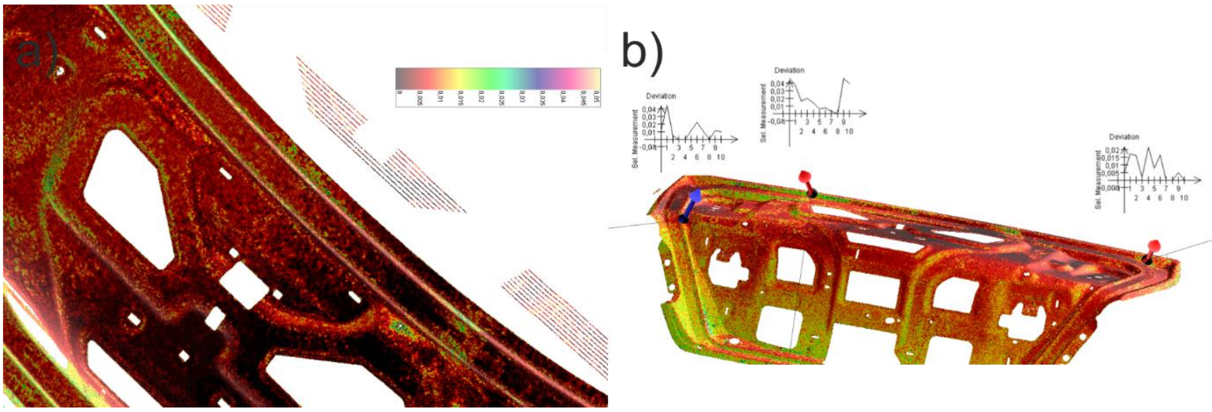


Fig. 7. Utility functions. a) shows the cutlines being displayed next to the actual geometry and b) shows three temporary features along with their respective graphs. The lines leaving the feature basepoints are connected to their respective feature description labels, which have been cropped out of the image.

3.4.2. Multiview Display

To gain insight into the three dimensional structure of a geometry, it is helpful to see it from multiple angles. Therefore, we implemented multiple viewports to facilitate just that. The user can switch between one, two (horizontal or vertical split) and four viewports. The viewport sizes can be adjusted by dragging their respective borders, as is common for many CAD and 3D design tools.

The views can either be coupled, using a predefined angle to the main viewport or decoupled, making it possible to have four completely different and explorable views. Furthermore, every view is configurable to only display certain elements of the scene, e.g. only cutlines. This is either done by clicking on the settings button displayed in the lower right corner of every viewport and selecting in the appearing dialog the types of elements that the user wants to see or by dragging an element from one viewport into another, which allows for a more fine-grained selection of the displayed elements.

3.4.3. Multi-Instance-View

Depending on the per-vertex-mode selected, only an aggregated view of the measured errors on the part is shown. To understand where, e.g., big values in the average stem from, it is useful to be able to see those measurements the average was calculated from at the same time.

To make this possible, we devised a multi-instance-view. The part showing the current per-vertex-mode is displayed in the main view, while up to six tiles on the right-hand-side of the viewport display the single measurements used to calculate the current per-vertex-view. These tiles can either be displayed as an overlay, being in front of the current main view and possibly occluding it, as an underlay, possibly being occluded by the main view, or decoupled, displaying it next to the main view. The viewport of the multi-instance-tiles is always the same as it is in the main view, making direct comparisons easier. Figure 8 shows a multi-instance-view. The main view shows the results from an average calculation while the five views on the right show the single distance maps for the measurements the average was calculated from.

While each tile only shows one part, it can be configured to show a hedgehog view, tactile features, cutlines and linehogs. We consider this feature highly useful for the automated report generation as well as for prototyping, where every measurement is of high importance.

The current implementation suffers from the fact that the tiles are not labeled according to the measurements they are showing. This will be changed in future work.

3.4.4. Triangle diagram

By clicking on the geometry, it is possible to create temporary features, which, when selected, display a diagram containing the distance values at the selected triangle for all selected measurements. These features can then be dragged around on the surface to show the respective diagram for another triangle. For this, the values for the three vertices making up the triangle are averaged for every measurement. Although it would be possible to do this on a per-vertex-basis, we theorize that, since for high resolution scans each triangle is far smaller than a pixel, per-triangle values are less noisy and sufficiently accurate. These temporary features can either be stored in a scene for automated report creation or be added to the inspection plan as new features. That way, interesting findings in the analysis process can be directly integrated into the report generation and documentation process. Fig. 7, b shows three temporary features with their respective distance graph.

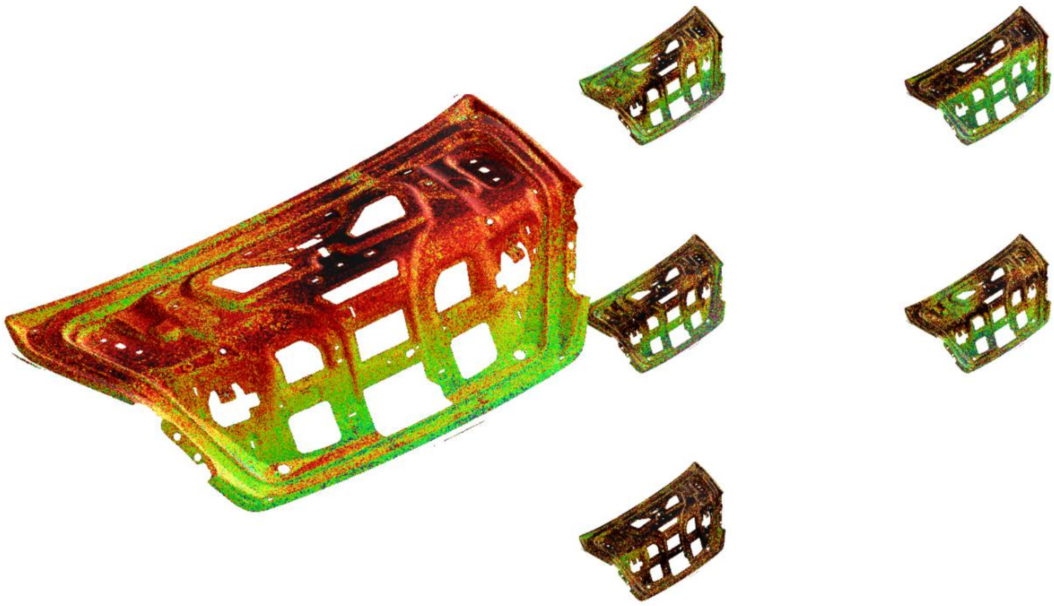


Fig. 8. Multi-Instance-View. On the left, the results of an average calculation are shown, calculated from the five measurements shown on the right hand side of the picture.

4. Implementation Details

The whole program is implemented in Java. For our implementation we used several open source libraries. For the cutlines as well as for the computation of the distances of the quota to the actual data described in this paper, we used the CGAL library. For rendering, we used OpenGL 4 (www.opengl.org) and JOGL (http://jogamp.org/jogl/www/).

In the following section, we give some detail about the implementation of some of the features described above.

4.1. Comparison between target and measured values

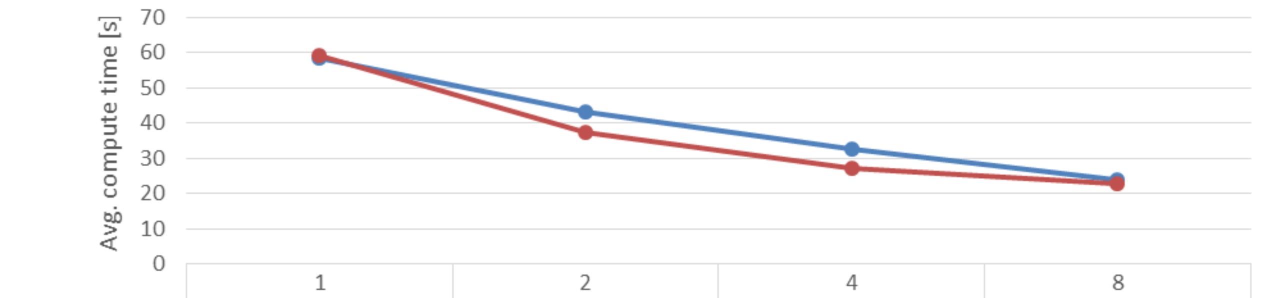
For the comparison of the quota geometry to the actual geometry, we use the Axis Aligned Bounding Box (AABB) tree for fast intersection and distance calculations (Alliez et al., 2015), from the CGAL library. With it, for every vertex on the actual geometry, we find the closest point to the actual vertex on the quota geometry as well as its respective triangle. With this information, we calculate the absolute distance of the vertex to the triangulation as well as the signed distance projected along the normal of the triangle. For that triangle, we find the vertex closest to the actual vertex and map the distance value to that vertex. If more than one distance value is mapped to the same vertex, the average is computed. This process is parallelized, which gives a strong performance boost. A test series was performed on a machine with an Intel Core i7-4700MQ @ 2.40 GHz and 16GB DDR3-1600MHz RAM. For our test, we used a quota geometry with approximately 3.38million vertices and 6.64 million triangles. We performed ten successive comparisons with one, two, four and eight parallel threads. Each worker thread takes his work in “chunks” of specific size from a controller. The average calculation time depending on the number of active threads and the size of these chunks is shown in Figure 9. As actual data, ten measurements of the same part with roughly the same number of vertices as the quota were used (ranging from 3.37 million to 3.56 million vertices, averaging 3.39 million vertices).

The results show a very limited dependence on the actual chunk size, while the dependence on the number of threads is very strong. The results show a decreasing gain in performance by doubling the number of threads with growing thread count.

Therefore, the comparison will never be done on more than eight threads in parallel. Another finding, is that the first distance calculation always takes significantly longer than consecutive calculations, while the calculation time afterwards stays mostly constant. While this might be a Java-related issue, in future work the server will hold a thread for each actual part that is currently produced, for a faster distance computation. This also eliminates the need to reload the quota geometry every time a new comparison is scheduled.

Calculating the difference from the actual geometry to the nominal geometry has several benefits compared to performing the comparison the other way around. One is, that every measured vertex is considered and its value stored. Secondly, it is possible to store one discrete distance value for each vertex of the nominal geometry, which, in turn, makes it possible to save the results of each measurement in a single, small file. These files, in conjunction with the nominal geometry, store all relevant information for the analyzing process. This eliminates the need to download the actual measured geometry from the vaulting server.

To guarantee compliance with the nominal data, the actual data has to be aligned and cropped correctly, meaning that, e.g., triangles belonging to the tenter are removed before the comparison starts. Cropping and aligning is done by the measurement software itself.



	1	2	4	8
50000	58,3	43,1	32,8	24,1
100000	59,2	37,2	27,2	23

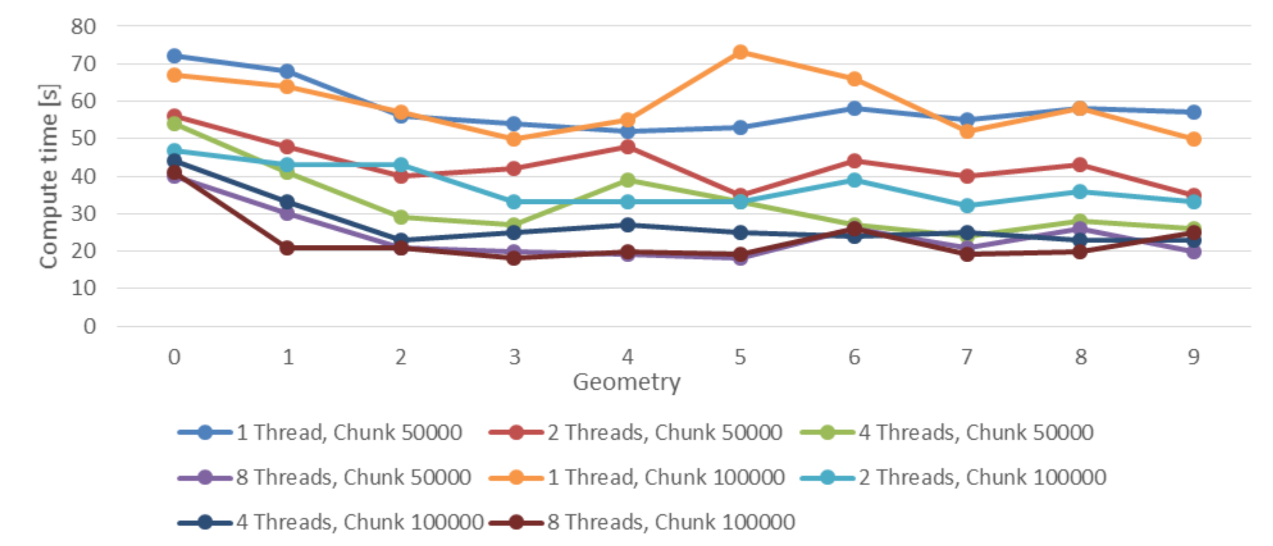


Fig. 9. Computation times. The upper graph shows the average computation time over ten consecutively calculated comparisons in dependence of the respective number of threads active. The lower graph shows the actual computation times for the different geometries. It is easy to see, that the first computation always takes significantly more time to finish than the subsequent ones, except for the orange graph.

Other distance calculation methods, as were proposed by e.g. Guezlec et al. (Guezlec, 2001) might be considered in the future.

4.2. Per-Vertex-Modes

A set of measurements is called a configuration. We implemented an interface which allows the easy storage and loading of per-vertex-computation results for different parameters and configurations. The interface uses the current configuration of its corresponding geometry and facilitates tasks such as adding and removing measurements from the selected mode on demand, meaning that only the current per-vertex-mode is updated and thereby avoids unnecessary calculations while maintaining a permanently up-to-date view. On the other hand, this improves the performance of some tasks, like calculating the average over several measurements, significantly by only performing “add” and “remove” operations, which for most per-vertex-modes does not trigger a recalculation over all measurements.

4.3. Cutlines

To calculate the cutlines, we use the CGAL library. Each cutline calculation is performed in a different thread, providing high performance even for multiple cuts, allowing for a smooth user interaction while moving or rotating the cutplane groups even for high cutplane counts.

The result of the intersection calculation is a list of line segments, combined with their respective triangle number. For each line segment, and, therefore, triangle cut, we perform barycentric interpolation to receive the value at the intersection points. The cuts are only performed once, then stored on the graphics hardware, together with their respective values, to achieve smooth rendering performance. Since the user can only alter one set of cutplanes at once, only one set of cuts has to be calculated at a time, allowing for a nearly arbitrary number of cuts to be shown at the same time.

4.4. Linehog Diagrams

Linehogs are calculated from the cutlines, obtained as mentioned before. The result of this operation is a list of line segments. We order the segments by pairwise identification of their start- and endpoints. For a smooth surface, this results in a set of piecewise linear curves. These curves are then ordered in a way that results in the shortest total length from start to end. The length of the curve is calculated by integrating the distance between two consecutive vertices. If there is a hole in the surface, the distance between the end of one curve and the beginning of the next curve will also be integrated. We then display the integrated distance on the x-axis and the interpolated values on the y-axis in a diagram. This results in a visually pleasing and highly intuitive view on the data. To further enhance the exploration, we included a mouse interaction scheme.

For technical reasons, every vertex on the line is mapped onto a discrete Pixel in the diagram along the x-axis. We store this mapping, averaging the position of the vertices for each pixel, to mark the position on the cutline while the user is hovering the cursor over the diagram.

The diagram itself is drawn as an off-screen image, which is then stored as a texture on the graphics hardware. Therefore, it can efficiently be rendered and, since the image has a small memory footprint, easily be replaced. If the cutplane changes, the diagram is recalculated immediately, which allows for smooth interaction.

4.5. Multi-Instance-View Implementation

For the multi-instance-view implementation the geometry, along with their current per-vertex-view is, as usual, rendered directly into the scene. For up to six selected measurements, the corresponding distance map is rendered into several different textures. These textures are then displayed to the right of the view. This induces a severe loss in performance, as rendering large geometries up to seven times (once for the main view and up to six times for the currently selected optical measurements) per frame is very expensive. We circumvent this bottleneck in performance by two measures: first, while the multi-instance-view is enabled, only the currently selected geometry is displayed, which obviously is a performance gain. Second, the different textures are updated on different frames. We render one of the textures anew every n frames ($n \in \mathbb{N}$, $n \geq 1$). This way, the maximal rendering overhead is 100% of the normal rendering process. The number n can be adjusted on the fly to cope with framerate drops.

Rendering the multi-instance-views as textures also has got the advantage that we can easily bring them to the front or the back of the view for better visibility or less occlusion, respectively.

Conclusions

We present an interactive framework for the analysis and evaluation of optical measurements integrated into an existing Measurement Data Management software. With that, we achieve seamless integration into the existing measurement, evaluation and documentation process. The implemented visualization and interaction tools enable the users to fast and easily explore and analyze the given data. We propose the usage of one specifically measured part that has been defined as a reference part, the so-called “Bemessungsfreigabe” as the quota geometry, because it is the actual part that fits best for its desired purpose.

However, some research regarding performance as well as testing with real world data still has to be done.

For performance optimization, level-of-detail approaches for high resolution quota geometries have to be explored. Additionally, mesh simplification algorithms, as described in (Cignoni, Montani, & Scopigno, 1998) and later, for the quota geometry have to be tested, especially if the “Bemessungsfreigabe” is used, since the vertex count might be extremely high.

To better archive the optical measurement data, which, although compressed, still accumulate to big amounts of data, we will enable the server to perform selective thinning of the archived meshes. For that, we are working on an importance- and age-based weighting algorithm to determine, which meshes can be simplified. In this step, it is vital that important regions, e.g. around features, are preserved, so that later evaluations will still yield the same results.

For further and more in-depth analysis of the measured data, more per-vertex-modes and visualization tools have to be developed.

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eISBN 978-609-457-835-9

TEXTURE MAPPING AND LIGHTING EFFECTS

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Abstract. The light mapping is a texturing method. It is useful because the common lighting required more computer recourses and various difficult calculations. All lighting and shading methods required powerful computers. In order to solve this problem we can use the light mapping. For this method we need two textures: first texture for surface detail and second texture for fighting simulation. The multitexturing is the best way to realise the combination of the two textures. All three graphics programing platforms (DirectX, OpenGL and WebGL) have the opportunity to implement a light mapping. WebGL is a special branch of OpenGL that is responsible while using the Internet. All of these platforms allow Multitexturing. Its realization is analogous. But light mapping requires few resources to extract the lighting effects. It is therefore interesting to realize light mapping WebGL platform. Realization is successful and the code is running in real time. The result is the lighting effect, which looks like a really calculated lighting.

Keywords: light mapping, texturing, blending, blending effects, blending operators, WebGL realization

Introduction

The primary idea of the lighting mapping is the use of two textures. The first texture is the lighting image and the second represents the surface detail. The effect can capture various lighting components (diffuse and specular). Light mapping has some highlights. Eliminated lighting calculation saves computer resources. Light maps are low resolution and thus it facilitates and reduces lighting calculations. Actually, the light maps used in this method can be applied to multiple textures.

1. Light mapping foundation

Lighting with a lightmap is a modern computer graphics technology. This method allows local light and it is affected by surface color and lighting texture (An Introduction to Bump Mapping 2010; Foley 2000). In order to achieve results we must add locally lit image to the scene. This image is created by combining the modulate texture surfaces with lightmap. In fact, initially we use two textures, followed by multitexturing, which allows the use of multiple textures at one time. (Fig. 1).

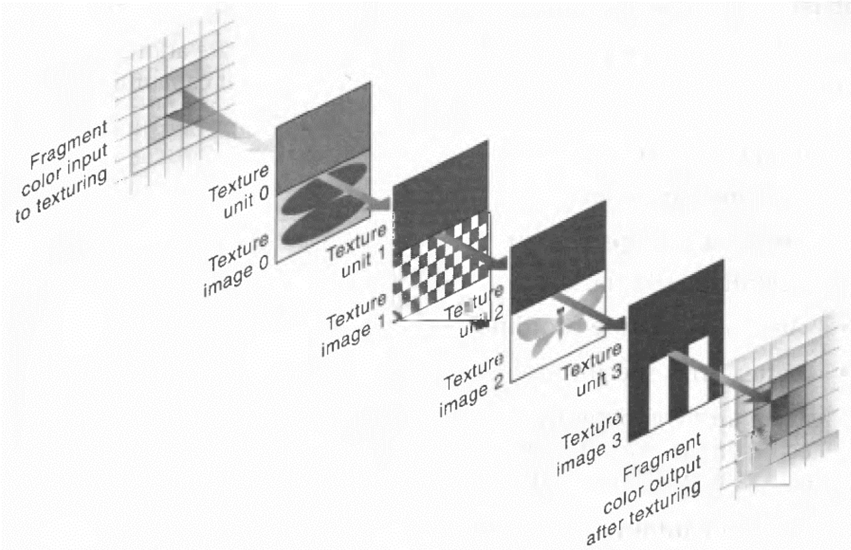

Fig. 1: Multitexturing in fragment shader

The best way for light mapping implementation is the use of the blend effect. Suppose, that we want to multiply a source pixel with its corresponding destination pixel (Fig. 2).

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eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.014

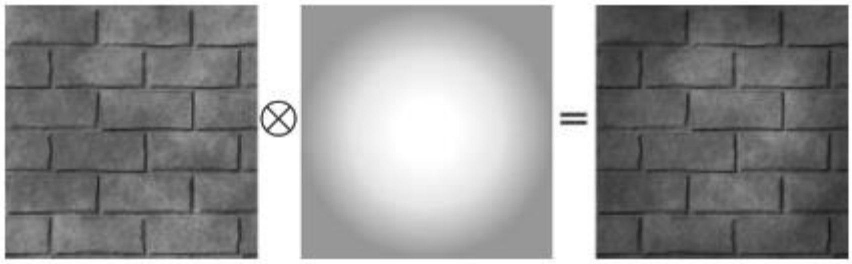

Fig. 2: Multiplying source colour and destination colour.

To do this, we set the source blend factor (Luna 2012; Sherrod, Jones 2011; Zink, Pettineo, Hoxley 2011) to *D3D11_BLEND_ZERO*, the destination blend factor to *D3D11_BLEND_SRC_COLOR*, and the blend operator to *D3D10_BLEND_OP_ADD* (1). With this setup, the blending equation reduces to:

$C_{final} = C_{src} \otimes F_{src} \oplus C_{dst} \otimes F_{dst}).$

$$C_{final} = C_{src} \otimes (0,0,0) + C_{dst} \otimes C_{src}. \qquad (1)$$

$C_{final} = C_{dst} \otimes C_{src}.$

Where C_{final} – final color after alpha blending;

C_{src} – source pixel color;

F_{src} – source pixel blend factor;

C_{dst} – destination pixel color;

F_{dst} – destination pixel blend factor;

$\otimes$ – operator means componentwise multiplication for colour vectors;

$\oplus$ – operator may be any of the binary blending operators.

Light mapping process requires little computer resources. Therefore, this method implementation for WebGL is very successful. The steps for texturing process in WebGl are described below (Guinot 2006; Multitexturing 2010).

1. We must describe a new variable to hold the texture at the top of the script block and add this statement:

var newtexture = null;

2. We need to supplement the vertex and pixel shaders with the texture-describing code. The new attribute and varying are added to the vertex shader by declaring the variables:

attribute vec2 aVertexTextureCoords;

varying vec2 vTextureCoords;

3. And at the end of the vertex shader's main function, we have to make sure to copy the texture coordinate attribute into the varying so that the fragment shader can access it:

vTextureCoord = aVertexTextureCoords;

4. We need to supplement the fragment shader with two new variable declarations: the sampler uniform and the varying from the vertex shader.

uniform sampler2D uSampler;

varying vec2 vertexTextureCoord;

5. We need to call texture2D with the sampler and the texture coordinates to access the texture color. As we want the textured surface to retain the lighting that was calculated, we will multiply the lighting color and the texture color together, that will give us the following line to calculate the fragment color:

gl_FragColor = vertexColor * texture2D(uSampler, vertexTextureCoord);

6. Then, at the bottom of the configure function, we add the following code, which creates the texture object, loads an image, and sets the image as the texture data. In this case, we will use a PNG image with the WebGL logo on it as our texture.

7. After that we must create a new texture object:

//To create the texture object:

newtexture = gl.createTexture( );

8. For texturing we must load our image

// Load an image

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var image = new Image();
image.onload = function(){
9. To set the image as the texture data:
gl.bindTexture(gl.TEXTURE_2D, texture);
   gl.texImage2D(gl.TEXTURE_2D, 0, gl.RGBA, gl.RGBA, gl.UNSIGNED_
BYTE, image);
   gl.texParameteri(gl.TEXTURE_2D, gl.TEXTURE_MAG_FILTER,
gl.NEAREST);
   gl.texParameteri(gl.TEXTURE_2D, gl.TEXTURE_MIN_FILTER,
gl.NEAREST);
   gl.bindTexture(gl.TEXTURE_2D, null);
}
image.src = 'textures/webgl.png';
10. Next, we need to expose the texture coordinate attribute to the shader:
if (object.texture_coords){
gl.enableVertexAttribArray(Program.aVertexTextureCoords);
gl.bindBuffer(gl.ARRAY_BUFFER, object.tbo);
gl.vertexAttribPointer(Program.aVertexTextureCoords, 2,
gl.FLOAT, false, 0, 0);
}
11. Next, we need to bind the texture to the shader sampler uniform:
sampler uniform:
gl.activeTexture(gl.TEXTURE0);
gl.bindTexture(gl.TEXTURE_2D, texture);
gl.uniform1i(Program.uSampler, 0);

2. Light mapping in WebGL

For realization in WebGL we need to do these actions: at the top of the script block, we add two textures variables for texture representing surface details and lighting texture (Anyuru 2012; Cantor, Jones 2012; Danchilla 2012; Matsuda, Lea 2013; Tutorial 18, 2013, Tutorial 26, 2013).

var texture = null;
var textureLighting = null;

The next step is to add the code to load the two textures for surface details (*texture*) and lighting (*textureLighting*).

The code is as follows:

texture = new Texture();
texture.setImage('......./texture.png');
textureLighting = new Texture();
textureLighting.setImage('......./light.png');

In the scene draw function, that binds the first and second textures, we add the following to expose the two new textures to the shader:

for surface details texture:
gl.activeTexture(gl.TEXTURE0);
gl.bindTexture(gl.TEXTURE_2D, texture);
gl.uniform1i(Program.uSampler, 0);
for lighting texture:
gl.activeTexture(gl.TEXTURE1);
gl.bindTexture(gl.TEXTURE_2D, textureLighting);

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```
gl.uniform1i(Program.uSamplerLighting, 1);
```

Next, we need to add the new sampler uniform to the fragment shader:

```
uniform sampler2D uSampler;
uniform sampler2D uSamplerLighting;
```

Finally, we add the code to sample the lighting texture value and blend it with the first surface texture. In this case, since we want the second texture to simulate a light, we multiply the two values together:

```
gl_FragColor = texture2D(uSampler, vTextureCoord) * texture2D(uSampler1, vTextureCoord)
```

Conclusions

Light mapping process requires a few computer resources and simple calculations. Therefore, implementation of this method for WebGL is very successful. WebGL is created especially for the Internet and it is a siding of OpenGL. Such modern graphics libraries as DirectX, OpenGL and WebGL have powerful opportunities to implement a light mapping. Multitexturing allows all of these platforms. Its realization is analogous. But light mapping requires few resources to extract the lighting effects. It is therefore interesting to realize light mapping WebGL platform. Realization is successful and the code is running in the real time. The result is the lighting effect, which looks like a really calculated lighting.

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eISBN 978-609-457-835-9

ENGINEERING AND COMPUTER-AIDED DESIGN IN TEACHING BIOTECHNOLOGY

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Abstract. Knowledge in engineering design is currently indispensable in many fields including bioengineering. The students attending the lecture course Engineering and Computer-Aided Design acquire the basic knowledge and skills in a very important language – graphics language. Understanding the objectives, purpose and fundamentals of the symbols and rules used in engineering design will be useful in studying other courses as well as will enable the students to apply this knowledge and skills in their professional work.

Keywords: engineering and computer graphics, bioengineering studies, knowledge

Introduction

The aim of bioengineering studies is to prepare a highly qualified professional who is able to work and do research in the fields of biotechnology, bioengineering, biochemistry and others. Students of bioengineering like other students, are studying fundamental technical subjects that can be used purposefully in the future. Industry of "chemical engineering", recognized already in the last century, (Sentani et al) needs professionals with basic math, graphics and programming knowledge.

MATLAB is widely used for complex calculations, has the appropriate functions, is attractive for the construction of utility design software, and is implemented in biochemical and chemical engineering education. (Rahman et al, Stamoua et al). A computational MATLAB Tool with examples based on typical Chemical Engineering problems has been designed and students indicate that the Tool motivates the use of MATLAB in upper-year courses. (Cress at al).

The project of the Hong Kong University of Science and Technology (HKUST) aims to initiate the teaching of user-friendly Excel Visual Basic for Application (VBA) programming in chemical engineering with the emphasis on relevant examples selected from chemical engineering core courses. The course is designed with the emphasis on not only how to program, but also on problem solving and how to convert a chemical engineering problem into a working program (Wong et al).

Among the other fundamental subjects, "Engineering and Computer Graphics" introduces students not only with fundamentals of engineering graphics, but also enables the student to use the knowledge with the help of IT (Information Technology) tools. The acquired knowledge and experience can be used to master new software environments. Computer-aided learning packages can be a useful tool in supporting the development of these skills, as they enable students to explore and gain experience of new software environments in subject specific context (Glasseya et al) and simulation models (Kuriyan et al).

AutoCAD design program is popular in many technical areas, so the use of this software is significant in bioengineering studies also to develop a dynamic simulation of chemical processes (Cartaxo et al).

Information technologies are only technologies that require people who are able to manage them. Engineering graphic studies develop spatial imagination and teach graphic literacy, while IT is an integral part of the field enabling the execution of joint multidisciplinary work become more efficient.

1. Bioengineering, drawings, history

Bioengineering is the application of engineering principles and knowledge to medical problems and biological systems. The field of Bioscience is developed not only abroad, but also in Lithuania. In addition, according to scientists, it is one of the most promising professions in the twenty-first century. This field not only teaches biology and medicine but also engineering.

Drawings are used not only in production, design or construction, sometimes they are used in an invisible process, e. g., atomic nucleus, power plant work or to illustrate the structure of the universe and express ideas for alternative object's shape.

Drawings have been used for centuries before our era in the construction of the Egyptian, Babylonian, Indian, Chinese cities. They are found in the walls of pyramids of Egypt and old frescoes. It should be noted that the drawings were understandable for later generations without any explanation, while the ancient writings, e.g., Egyptian hieroglyphics were deciphered only in the beginning of the nineteenth century. Authors that explored chemistry and graphics fusion historically emphasize that these things are linked from the era of Renaissance to the present days (Sentani et al).

eISBN 978-609-457-835-9
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http://doi.org/10.3846/baltgraf.2015.015

Graphical expression in the first prehistoric paintings, related to the Greek alchemy, helps to interpret the structure of petroleum products and chemical reactions (Fig. 1).

Bioengineering professionals acquainted with CAD systems can participate in the development of devices and equipment and do research in fields like artificial joints, cardio stimulators, bioengineered skin prostheses, liver dialysis, etc.

Fig. 1. Representation in exploded perspective of a sulfur sublimation setup. Geber Smith exhibition. Venice 1544.

2. „Engineering and computer graphics" in Bioengineering studies

Bioengineering students learn Engineering graphics during the theoretical lectures, exercises and laboratory work (5 ECTS) (Fig. 2).

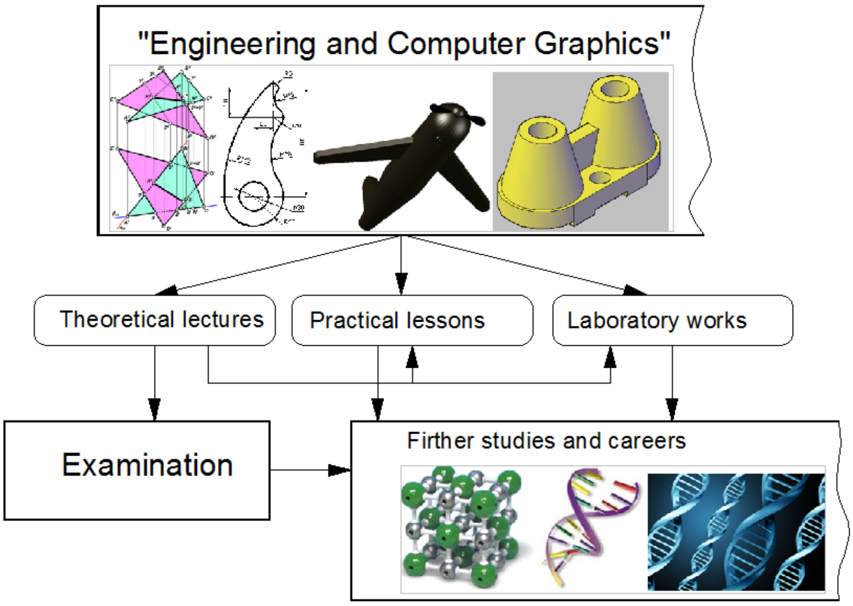

Fig. 2 Structure of the subject "Engineering and Computer Graphics"

During the theoretical lectures, students are introduced to the basic theoretical principles of engineering graphics and related tasks. The resulting knowledge develops spatial imagination and is adapted during exercises and laboratory works. In addition, students learn about the preparation of the technical documents and rules for performing various engineering tasks.

Standardized symbols and rules in drawings help to express objects uniquely: define the size, texture, surface and the material of the object, as well as other parameters.

Standards are required not only for drawings, but also in many other areas of life, including bioengineering. In graphics, drawing sheets are standardized in sizes, lines, font, size designation, arrows, scales, images (projections) layout, cutting, marking and imaging, etc.

The old Chinese proverb says, “What I hear, I forget. What I see - I remember. What I do, I understand.” Therefore, pencil drawn images of non-complicate parts help to assimilate Lithuanian standards with the theory as well. During those exercises, students are first aware of the drawing as a graphical language, which is an equivalent to linguistic, musical, plastic and other forms of expression.

AutoCAD computer program is used to convey graphic knowledge during the laboratory works. In the laboratory works, students learn to use AutoCAD program while modeling the different configuration of two-dimensional contours. Mastered AutoCAD drawing, editing, ribbing and the other options can help students in their professional work (Figure 3): interaction of enzymes and substrates (catalytic reaction), which forms an enzyme and substrate complex (ES complex) and graphically visible active sites of the enzyme. The computer program is used to represent the structure of organic molecules or imitate the visible atomic ratios, types of bonds, bond angles, length between atoms, space filling or ball-and-stick models of the molecules.

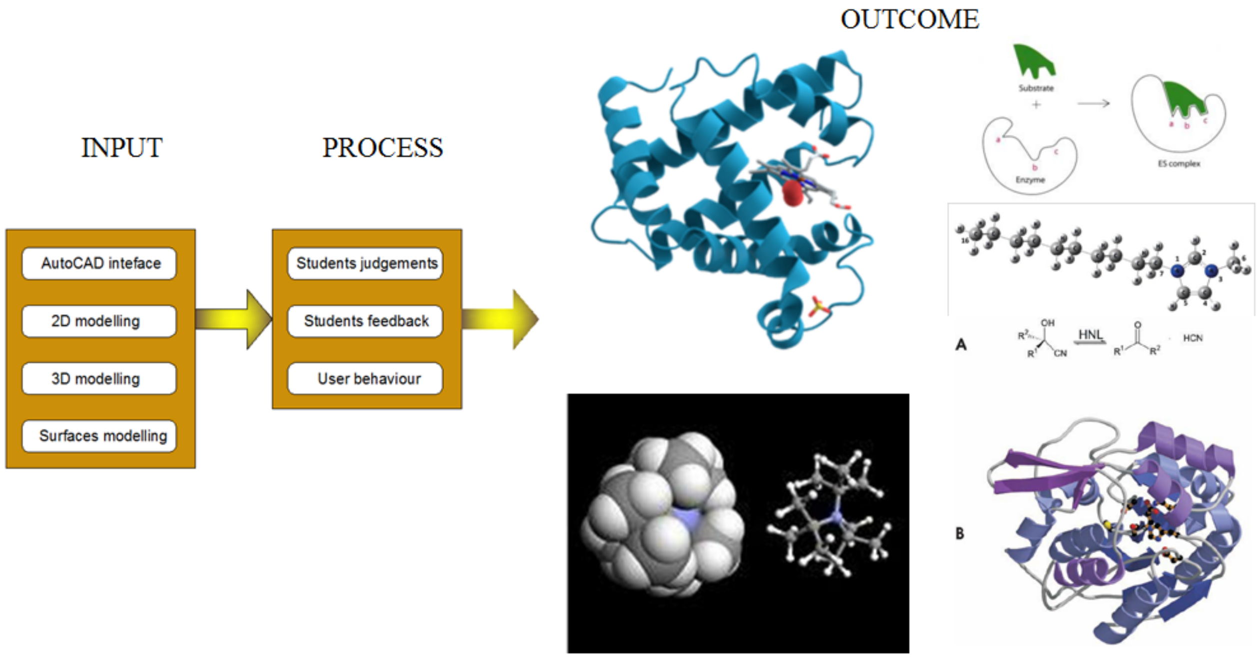

Fig. 3 Model of learning and applying Engineering Graphics

Modeling three-dimensional objects in AutoCAD program could be adapted for studying protein chemistry, examining the primary, secondary, tertiary and quaternary structures of proteins, the representation of the three-dimensional structure of the protein folding or protein modeling or in similar professional tasks. In enzyme studies students can simulate e.g., Hydroxynitrile lyase from Hevea brasiliensis (rubber tree) spatial structure. Imaging and graphic presentation of the three-dimensional complex structure of the chemical elements helps students to consolidate their theoretical knowledge and carry out experimental work.

Like in all fields of studies, students of bioengineering studies have diverse abilities. Therefore, those who are most interested in engineering graphics, are offered additional surface modeling work (Fig. 4), which is the technique that helps to develop models and adapt knowledge in "Chemical Engineering" development.

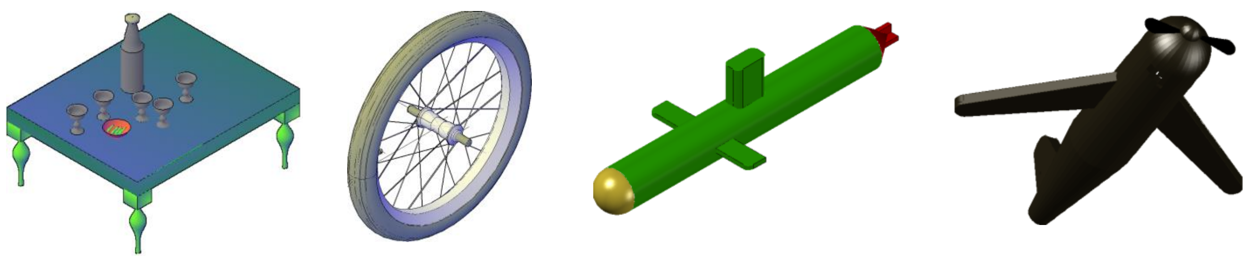

Fig. 4 AutoCAD program additional surface modeling work

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Conclusions

The interference between theoretical instruction and practical application is perceived gradually, so students learn not only to depict the spatial objects in two-dimensional space, but can perceive the connection between them. Tasks, performed in AutoCAD program during “Engineering and Computer Graphics” lectures, will teach how to develop higher quality and more imaginative bioengineering-related images.

Most of the students have a difficulty in learning the subject of graphic. Therefore, the task of the faculty is to constantly improve the learning process, applying new forms and methods of teaching. In order to successfully tackle the challenges of graphic works, it is necessary to analyze the students' learning process, collect feedback information to properly assess and manage the teaching process.

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eISBN 978-609-457-835-9

SKEW QUADRILATERAL MEMBRANE FOLDING FOR LAMPSHADE DESIGN

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Abstract. Historically, Japanese traditional lampstand 'Andon', was manufactured from paper. And paper folding method was adopted into some Andon or western lampshade design. For example, Yoshimura/Diamond pattern, known as a structure of crashed cylinder, or a structure of building roof, that has been of beneficial use in commercial lampshade products. Yoshimura pattern structure includes a set of skew quadrilaterals which are not on a plane surface and each quadrilateral is constructed with 2 planar triangles. Development of Yoshimura pattern is constructed by one set of horizontal parallel lines at even intervals for valley fold and two sets of oblique parallel lines at even intervals for mountain fold. The author found that similar shape can be constructed from development which includes only mountain fold lines of Yoshimura pattern and this method has various applications. With proposed paper folding method, each skew quadrilateral is constructed by single curved surface. In this paper, the author first defined the principle of the proposed paper folding method, second, explained the. Features of the shape made by the proposed method and the luminance distribution on the shape, third, indicated examples of applications of the proposed method. Finally, examples of application of the shape made by SQMF in the field of education are explained.

Keywords: Paper folding, Skew Quadrilateral, Lampshade, Andon, Luminance Distribution, Differential Geometry

Introduction

Historically, Japanese traditional lampstand 'Andon', was manufactured from paper. And paper folding method was adopted into some Andon or western lampshade (Shimazaki 2003). If we put non-flat texture on the surface of such lampshade by paper folding method, nonuniform luminance distribution appears on the surface, according to basic laws of illuminance. Such nonuniform luminance on the surface of lampshade contributes to easier recognition of its shape and a more attractive appearance. Yoshimura/Diamond pattern (Yoshimura 1951) is one of the most typical paper folding methods in the field of lampshade design. This pattern is known as a structure of crashed cylinder and structure of building roof, and has been of beneficial use in commercial lampshade products. Yoshimura pattern structure includes a set of skew quadrilaterals which are not on a plane surface and each quadrilateral is constructed by 2 planar triangles. Consequently, lampshades manufactured with Yoshimura pattern have nonuniform luminance distribution overall, however, luminance distribution within a skew quadrilateral unit is discontinuous at boundary of two planar triangles which compose a skew quadrilateral unit. The author found that similar shape can be constructed by modified Yoshimura pattern and developed the method of ‘Skew Quadrilateral Membrane Folding’. In this paper, the author first defined the principle of the proposed paper folding method., second, explained the.features of the shape made by the proposed method and the luminance distribution on the shape, third, indicated examples of applications of the proposed method. Finally, examples of application of the shape made by SQMF in the field of education are explained.

1. Principle of the paper folding method ‘Skew Quadrilateral Membrane Folding’

Paper folding method ‘Skew Quadrilateral Membrane Folding’ is one of the construction methods of developable surface. As shown in Fig. 1, curved surfaces are classified into four classes from the viewpoint of differential geometry (Isoda, Suzuki 1986).

- Curved Surface
  - Ruled Surface
    - Developable Surface
      - Conical Surface, Cylindrical Surface
      - Tangent Surface
    - Warped Surface
      - e.g. Hyperboloid of Revolution, Hyperbolic Paraboloid, Helicoid
  - Double Curved Surface
    - Surface of Revolution
      - e.g. Sphere, Torus
    - Double Curved Surface in General

Fig. 1. Classification of Curved Surface from viewpoint of Differential Geometry

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http://doi.org/10.3846/baltgraf.2015.016

At first, all curved surfaces are classified into ruled surface and double curved surface. Ruled surface can be described as locus of a straight line movement. Double curved surface, including sphere and torus, cannot be described this way. Double curved surface is not developable and cannot be made from plane surface. Ruled surface is classified into developable surface and warped surface. Developable surface is including conical surface, cylindrical surface and tangent surface, and can be made from plane surface by bending the surface. Warped surface is including hyperboloid of revolution, hyperbolic paraboloid and helicoid.

Manufacturing of developable surfaces is very easy, though designing of the surfaces has many restrictions. Therefore a lot of researches have been conducted to increase the freedom of shape design. These researches are classified into two categories: researches which enable approximation of given curved surface with combination of developable surfaces and researches which enable easy designing.

Concerning researches for approximation, Mitani et al. proposed the method of approximation with plane triangles (Mitani et al. 2004), Shatz et al. proposed the method of approximation with conical surfaces and planes (Shatz et al. 2006), Massarwi et al. proposed the method of approximation with tubes which are constructed by triangles (Massarwi et al. 2007), Pottman et al. proposed the method of approximation with developable strips (Pottman et al. 2008) and Mitani proposed manufacturing method of approximated solid of revolution by paper folding (Mitani, 2009).

As far as researches for easy designing are concerned, Rose et al. proposed a method of 3 dimensional shape generation from 2 dimensional perspective drawing (Rose et al. 2007), Kilian et al. proposed a method of shape generation with repetition of curved line folding (Kilian et al. 2008), Suzuki proposed a method of shape generation with combination of tangent surfaces (Suzuki 2010) and Suzuki extended the tangent surface method with hermite curve (Suzuki 2012). Suzuki also proposed a method of shape generation with manipulation of curved line to generate connected developable surfaces (Suzuki 2014a), Suzuki implemented the design method on CG freeware POV-Ray making use of affine transformation and locus diagram (Suzuki 2014b) and Suzuki et al. introduced the curved line manipulation method into graphic science education for designing and manufacturing of lampshade to evaluate the proposed method and developed interface (Suzuki, Sakaki, Yasufuku, Matsumoto 2015). The method proposed in this paper is considered as a research for easy designing and designing with the proposed method is far easier comparing to existing researches, though freedom of designing by this method is smaller.

Lampshade designing is an appropriate subject to learn the relationship between the shape and light in the field of graphic science education. Suzuki introduced lampshade design assignment to educational course of graphic science. (Suzuki 2006). He also introduced paper folding lampshade design assignment to the course (Suzuki 2011). The proposed paper folding method has a high potential for assignment of descriptive geometry as well.

The proposed paper folding method, 'Skew Quadrilateral Membrane Folding', is based on Yoshimura pattern (Yoshimura 1951). Yoshimura pattern is one of the famous paper folding methods. The Yoshimura pattern has been applied to the structure of building roof (Salvadori 1979) and cylindrical Yoshimura pattern was considered as approximation of buckling of a circular cylindrical shell (Yoshimura 1951). Besides cylindrical Yoshimura pattern, dome Yoshimura pattern (Miyazaki 2000) has been proposed as well. As shown in Fig.2, development of cylindrical Yoshimura pattern has two sets of oblique parallel lines at even intervals for mountain fold and one set of horizontal parallel lines at even intervals for valley fold.

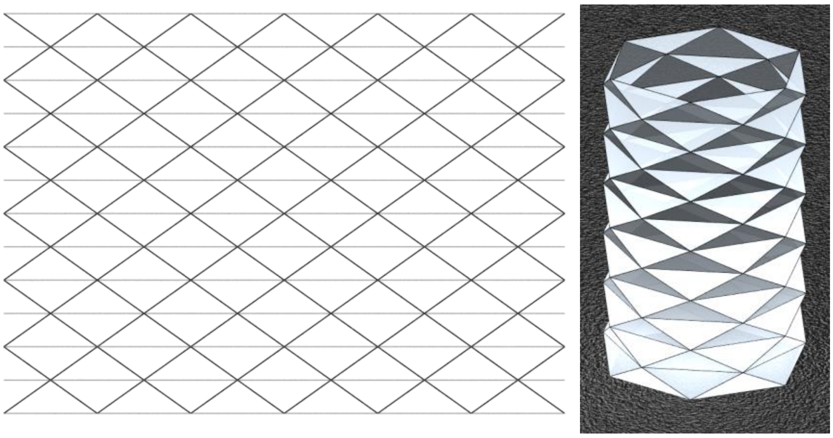

Fig. 2. A development of cylindrical Yoshimura pattern (left, black lines for mountain fold and grey lines for valley fold) and cylindrical shape made from the development (right)

Cylindrical shape shown in Fig. 2. appears after folding the development along with the lines drawn in the development and bending the development to attach bilateral sides without gap and overlap. In case of the shape made from cylindrical Yoshimura pattern, each diamond on the development changes its shape to skew quadrilateral unit and the unit is constructed by two planer triangles. Consequently, luminance distribution in the area of the unit is discontinuous at the boundary of the two triangles.

As shown in Fig. 3., a similar shape appears after folding the development shown in Fig. 2. along with only lines for mountain fold and bending it. The author named the shape constructed by skew quadrilaterals with mountain folds as 'Skew Quadrilateral Membrane Folding' (here after SQMF). The shape shown in Fig. 3. is constructed by cylindrical SQMF method.

Fig. 3. A shape made by cylindrical SQMF method with point light source.

In case of the shape made from cylindrical SQMF, each skew quadrilateral is constructed by continuous curved surface and illuminance distribution is continuous within the area of a quadrilateral unit as shown in Fig. 3. From the viewpoint of shape, difference between two shapes is trivial, however, from the viewpoint of illuminance distribution, difference between two shapes is significant. Though luminance on diffuse transmitting surface measured from outside is decided by direct illuminance and indirect illuminance of the corresponding inner point, contribution of direct illuminance is higher considering relative variation of luminance distribution. Direct illuminance given by point light source can be calculated by basic illuminance laws described in Fig. 4.

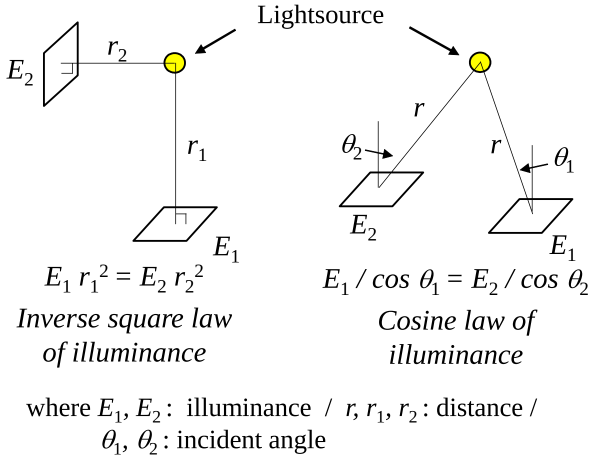

Fig. 4. Basic laws of illuminance distribution

The luminance distribution shown in Fig. 3 is mainly based on these basic laws of illuminance.

2. Features of the shape made by SQMF method and the luminance distribution on the shape

As described in chapter 1, skew quadrilateral units constructing the shape made by SQMF are constructed by a curved surface. The curved surface for SQMF shape must be a developable surface, if there is no warp in the curved surface. Fig. 5. is a photograph of the shape made by SQMF method taken from the same direction as that from the right side point of a skew quadrilateral unit to the left side point of the unit. As shown in Fig. 5, almost all part of the curved surface is a cylindrical surface.

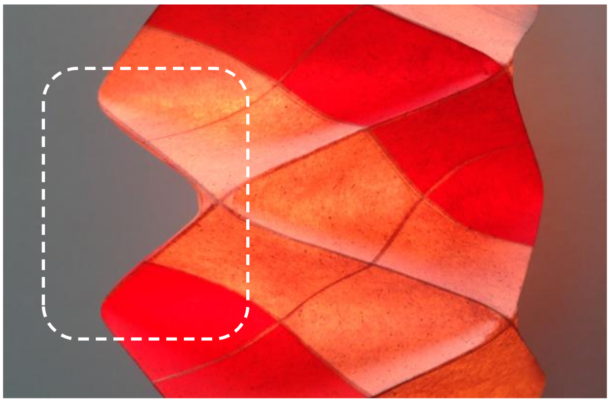

Fig. 5. Photograph of shape made by SQMF method taken from the direction same as that from right side point of a skew quadrilateral unit to left side point of the unit.

Fig. 6 shows measured luminance distribution on the surface of the shape made by SQMF method. The luminance distribution is already explained in chapter 1 and continuous distribution is intuitively recognized from the figure.

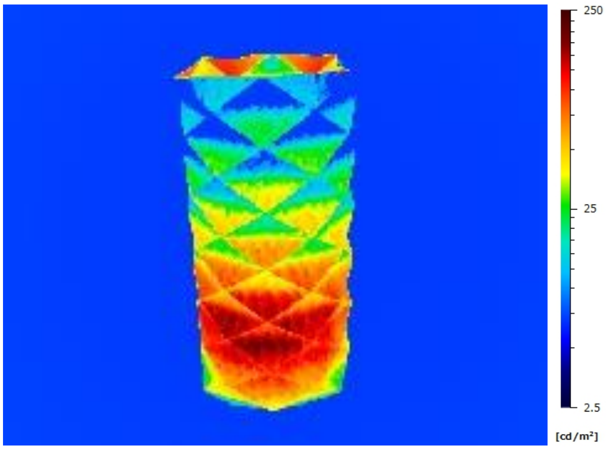

Fig. 6. Photograph of shape made by SQMF method taken from the same direction as that from the right side point of a skew quadrilateral unit to the left side point of the unit.

However, a more precise recognition is possible with Fig. 6. At almost all quadrilateral units, luminance values of the upper side and that of the lower side are quite different and buffer zone exists between the upper side and the lower side to connect values of the upper and lower side continuously. In this experiment, LED lamp which can be considered as point light source was used as a light source of the shape. If a bigger light source is used, change of luminance distribution becomes unclear, because the inner illuminance distribution of the shape does not follow the basic illuminance laws for point light source.

3. Variations of SQMF method

As explained in chapter 1, if unit diamonds with valley fold line are located radially, dome shape can be obtained. Dome type Yoshimura pattern is a variation of cylindrical Yoshimura pattern. The same way as the Dome type Yoshimura pattern, the Dome shape can be obtained by the dome type SQMF method. As shown in Fig. 7, development of the dome type SQMF is made by diamonds without valley fold located radially from the center. And after folding and bending of the development, the dome shape can be obtained as shown in Fig. 7. The same way as the shape made by the cylindrical SQMF method, each quadrilateral unit of the shape made by the dome type SQMF method is covered by curved surface.

eISBN 978-609-457-835-9

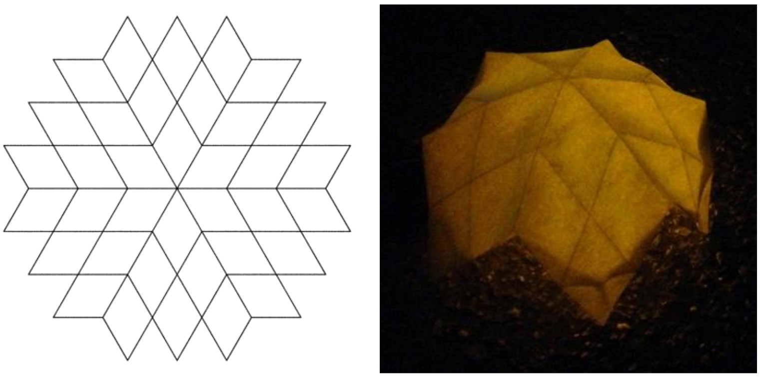

Fig. 7. An example of development of dome type SQMF (left) and the shape made from the development (right).

Fig. 8 shows an example of development of a conical SQMF and the shape made from the development. As shown in the figure, conical SQMF is also a variation of SQMF. In this case, paper should be bent to make conical shape after folding. Each quadrilateral unit is covered by a curved surface as well.

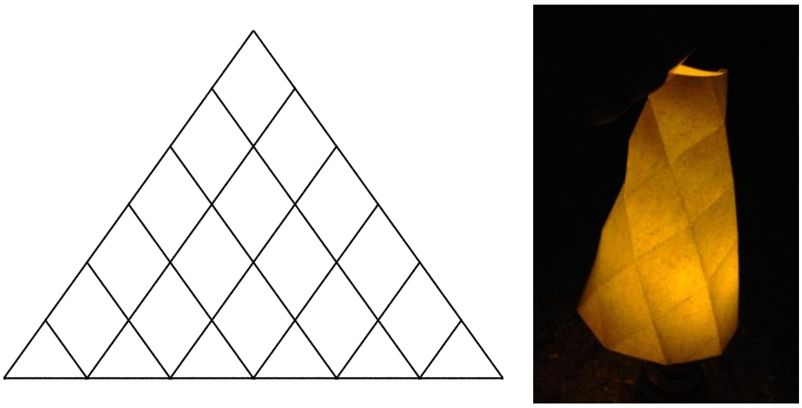

Fig. 8. An example of a development of a conical SQMF (left) and the shape made from the development (right) (After bending, the top and the bottom of the conical shape with non-flat texture are cut off horizontally).

In the case shown in Fig. 8, corresponding fold lines which meet on attached edges are not jointing smoothly because fold lines are not designed to be jointed smoothly. However, it is possible to design corresponding lines to be jointed smoothly. Fig. 9. is an example of non-parallel SQMF and corresponding fold lines which meet on attached edges are designed to be jointed smoothly.

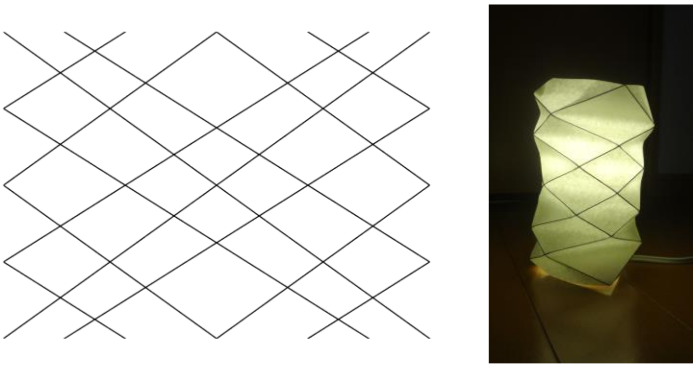

Fig. 9. An example of development of non-parallel SQMF (left) and the shape made from the development (right).

When the angles between fold lines and the edge are the same, if the fold lines are corresponding, corresponding lines can be jointed smoothly. As shown in the figure, non-parallel SQMF is one of variations of SQMF.

Fig. 10 shows an example of a development of left-right asymmetry SQMF method and the shape made from the development.

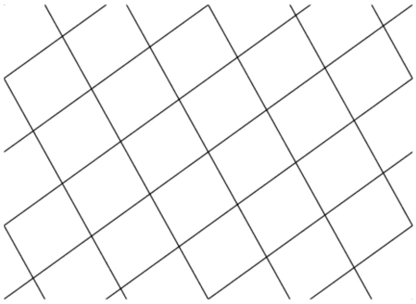 

Fig. 10. An example of a development of left-right asymmetry SQMF (left) and the shape made from the development (right).

As shown in the figure, two set of lines which construct quadrilateral are not limited to be left-right symmetry.

4. Examples of application of the shape made by SQMF in the field of education.

As the manufacturing process of the shape made by SQMF method is simple enough, SQMF has a large potential in the field of education. On 12th December 2014, a special lecture for high school students was held at the department of engineering, Kobe University. 13 high school students joined the lecture. The lecture started with the explanation of the basis of differential geometry with the figure similar to Fig. 1. Then the students were requested to manufacture lampshades made by cylindrical SQMF by themselves. Finally, basic laws for illuminance were explained and the students put their own lampshades around the candle fire to prove the laws. As the manufacturing process of lampshades is extremely simple, all participating students could easily construct the lampshades and all the lecture together with the practical exercise took 75 minutes in total. Fig. 11 shows an example of the lampshades manufactured by a participating student.

Fig. 11. An example of lampshade with a candle light manufactured by a high school student who participated at a special lecture in Kobe University.

And the shapes made by SQMF method can be shapes of assignment for exercises of hand writing descriptive geometry. Fig. 12 shows an example of submitted works in the class of descriptive geometry exercise in Kobe university.

eISBN 978-609-457-835-9

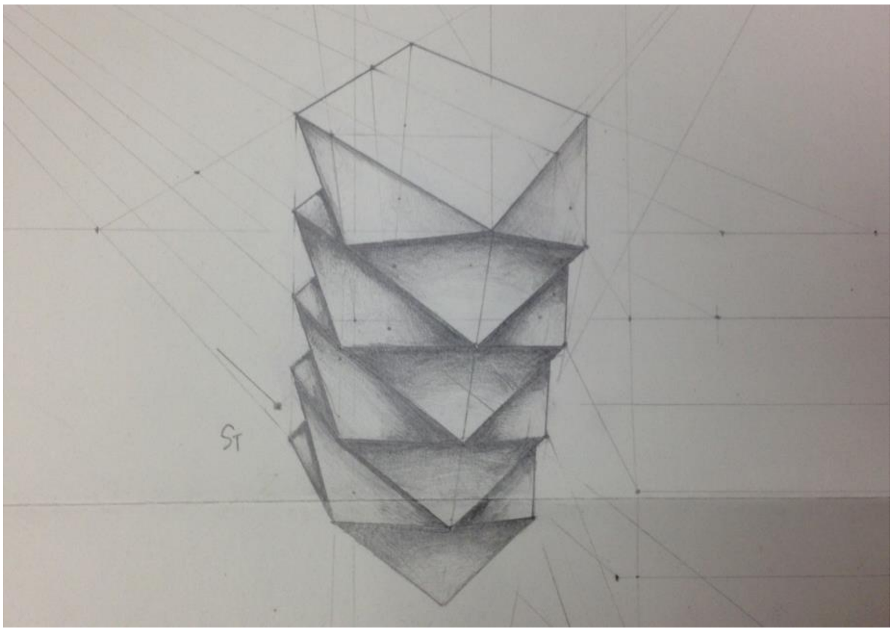

Fig. 12. An example of submitted works in the class of descriptive geometry exercise in Kobe University.

In the class, students manufactured their own model by cylindrical SQMF method first. Then they put their model around a light source and took a photo of the model to record luminance distribution on the model. Next, students were requested to draw a perspective drawing of the model by vanishing point method. Finally students expressed brightness on the drawing by pencil using the photo of the model as a reference.

Conclusions

In this paper, the author first defined the principle of the proposed paper folding method, second, explained the features of the shape made by the proposed method and the luminance distribution on the shape, third, indicated examples of applications of the proposed method. Finally, examples of application of the shape made by SQMF in the field of education are explained.

It seems that there are many possibilities for application of SQMF method. Left-right asymmetry SQMF method can be combined with non-parallel SQMF method. Outlines forms for cylindrical SQMF are not limited to a simple cylinder. The Edge of the shape made from SQMF method can be connected with the combined developable shapes which are proposed by Suzuki (Suzuki 2014a). The author would like to continue the research about SQMF method to develop further applications of the method.

Acknowledgements

The author found SQMF method during preparation for the workshop titled ‘Exploration of Light and Shape’ in June 2014. This workshop was one of the projects in the event ‘Riga days in Kobe’ which was held to celebrate 40th anniversary of sister city agreement between Riga city and Kobe city. The author would like to express the deepest appreciation to the person who attended to the event, including Dr. Modris Dobelis, professor of Riga Technical University, who devoted himself to realize the exhibition of academic exchange between Riga technical university and Kobe university in the event.

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TEXTURES ALPHA MAPPING TECHNOLODY REALIZATION WITH DIRECTX

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Abstract. Colours are described by three components RGB and alpha component. This component adds additional realism in the computer scene and means opacity. Alpha mapping is a process that regulates objects transparency. This is an often used and successful process. This effect is rather simple. The realization requires few and simple resources. Such modern graphics libraries as DirectX, OpenGL and WebGL have powerful opportunities to implement a light mapping. For the realization we can use powerful graphical library DirectX and OpenGL. There is also an opportunity to use the graphic library for the internet WebGL.

Keywords: alpha mapping, alpha map, blending effects, source pixel, destination pixel

Introduction

Alpha mapping can be used to add detail in a number of ways and this process is simply one part of the larger process that adds additional realism in the computer scene. Alpha mapping is a process that creates transparency. If an object is solid, it means full opacity. On the other hand, no opacity indicates a transparent object. The term opacity is often used in computer graphics. Alpha mapping is the creation of a texture map for an object that does not provide color or texture, but instead indicates varying levels of opacity for it. The map for this is typically created as a grayscale object, where white indicates full opacity, black is transparent, and varying shades of grey represent gradients between these two extremes.

Different types of images can be used during alpha mapping, though the image used is typically a simple grayscale graphic. This means that it does not contain any color, but instead consists only of black, white, and shades of grey. The image created in this way is referred to as an alpha map.

1. Alpha mapping application

Blending is a technique, that allows us to use two textures and to blend (combine) the pixels that we are currently rasterizing (so-called source pixels) with the pixels that were previously rasterized to the back buffer (so-called destination pixels). The main particularity is that we must use an alpha map texture. This technique enables us, among other things, to render transparent, semi-transparent and nontransparent (solid) objects for alpha mapping realization (An Introduction to Bump Mapping 2010; Foley 2000; Guinot 2006).

An alpha map contains information about a binary texture (Fig. 1). It is very important that binary texture allows all or nothing based choices. Alpha maps are usually used for tests at the pixel level (alpha-testing) in order to know if a pixel is either fully opaque or fully transparent. For saving a little of fillrate in memory, the pixel is not saved in the framebuffer.

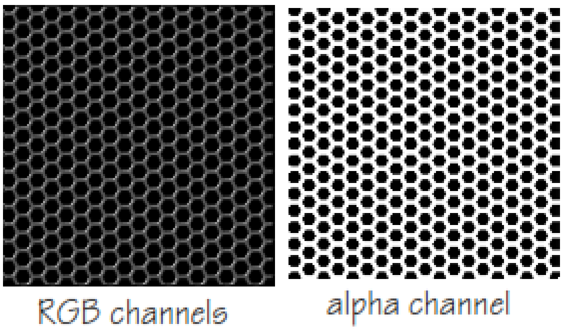

Fig. 1. RGB and Alpha textures

Alpha blending is a blending technique that uses the combination of two pixels colors (the source pixel and the destination pixel) allowing transparency effects. The alpha blending equation is as follows (1):

$$C_{final} = C_{src} \cdot A_{src} + C_{dst} \cdot (1 - A_{src}). \quad (1)$$

Where C_{final} – final color after alpha blending;

C_{src} – source pixel color;

A_{src} – source pixel alpha coefficient;

C_{dst} – destination pixel color.

We are shading in the pixel shader with the color C_{src} the *ij*th pixel (the source pixel). Currently the destination *ij*th pixel which is on the back buffer, has the color C_{dst}. If we don't use blending, $C_{src,}$ we should overwrite C_{dst} (assuming it passes the depth/stencil test) and a new color of the ijth back buffer pixel should appear (Luna 2012; Matsuda, Lea 2013; Sherrod, Jones 2011; Anyuru 2012; Cantor, Jones 2012; Danchilla 2012Danchilla 2012).

But if we use blending, the two C_{src} and C_{dst} are combined together in order to get the new color *C* that will overwrite C_{dst} (i.e., the blended color *C* will be written to the *ij*th pixel of the back buffer). Direct3D uses the rule in following blending equation to blend the two colors in the source and destination pixel (2):

$$C = C_{src} \otimes F_{src} \oplus C_{dst} \otimes F_{dst}. \qquad (2)$$

Where C – final color after alpha blending;

C_{src} – source pixel color;

F_{src} – source pixel blend factor;

C_{dst} – destination pixel color;

F_{dst} – destination pixel blend factor;

$\otimes$ – operator means componentwise multiplication for colour vectors;

$\oplus$ – operator may be any of the binary blending operators.

For blending effect calculation the source blend factor (colors F_{src}) coefficient and destination blend factor (F_{dst}) coefficient are used. These two coefficients may be any of the values depending on the desired effect. The original source and destination pixels may appear in a variety of ways, allowing for different effects to be achieved. The source and destination blend factors allow modifications to be made. . The $\otimes$ operator means componentwise multiplication for color vectors, and the $\oplus$ operator may be any of the binary operators. The blending equation has a similar use of the RGB and alpha components of the colors. For the alpha component we can apply the separate similar equation (3):

$$A = A_{src}F_{src} \oplus A_{dst}F_{dst}. \qquad (3)$$

Where A – final alpha coefficient;

A_{src} – source pixel alpha coefficient;

F_{src} – source pixel blend factor;

A_{dst} – destination pixel alpha coefficient;

F_{dst} – destination pixel blend factor;

$\otimes$ – operator means componentwise multiplication for colour vectors;

$\oplus$ – operator may be any of the binary blending operators.

The equation is essentially the same, but it is possible for the blend factors and binary operation to be different. The motivation for separating RGB from alpha is simply such that we can process them independently, and hence, differently.

The binary $\oplus$ operator used in the blending equation may be one of the following:

typedef enum D3D11_BLEND_OP

{

D3D11_BLEND_OP_ADD = 1, C = Csrc⊗Fsrc+Cdst⊗Fdst

D3D11_BLEND_OP_SUBTRACT = 2, C = Cdst⊗Fdst-Csrc⊗Fsrc

D3D11_BLEND_OP_REV_SUBTRACT = 3, C = Csrc⊗Fsrc-Cdst⊗Fdst

D3D11_BLEND_OP_MIN = 4, C = min(Csrc,Cdst)

D3D11_BLEND_OP_MAX = 5, C = max(Csrc,Cdst)

} D3D11_BLEND_OP;

These same operators also work for the alpha blending equation. Also, you can specify a different operator for RGB and alpha. For example, it is possible (4) to add the two RGB terms, but subtract the two alpha terms:

$$C = C_{src} \otimes F_{src} + C_{dst} \otimes F_{dst}.$$
$$A = A_{dst} \otimes F_{dst} - A_{src} \otimes F_{src}. \qquad (4)$$

By setting different combinations for the source and destination blend factors, dozens of different blending effects may be achieved. The basic blend factors are described in the following list, which apply to both F_{src} and F_{dst}. The D3D11_BLEND enumerated types are described in the SDK documentation. We can use advanced blend factors for blending effect realization.

D3D11_BLEND_ZERO: F = (0, 0, 0) and F = 0

D3D11_BLEND_ONE: F = (1, 1, 1) and F = 1

D3D11_BLEND_SRC_COLOR: F = (r_s,g_s,b_s)

D3D11_BLEND_INV_SRC_COLOR: F = $(1 - r_s, 1 - g_s, 1 - b_s)$

D3D11_BLEND_SRC_ALPHA: F = (a_s,a_s,a_s) and F=a_s

D3D11_BLEND_INV_SRC_ALPHA: F = $(1 - a_s, 1 - a_s, 1 - a_s)$ and F=$1 - a_s$

D3D11_BLEND_DEST_ALPHA: F = (a_d,a_d,a_d) and F=a_d

D3D11_BLEND_INV_DEST_ALPHA: F = $(1 – a_d, 1 – a_d, 1 – a_d)$ and F=$1 – a_d$ D3D11_BLEND_DEST_COLOR: F = $((r_d,g_d,b_d)$

D3D11_BLEND_INV_DEST_COLOR: F = $(1 – r_d, 1 – g_d, 1 – b_d)$

2. Alpha blending implementation

For alpha blending implementation we need three textures: first color texture, second color texture and third alpha texture. In the alpha map pixel shader we first take a sample of the pixel from the two color textures and alpha texture (Tutorial 19 2013; Tutorial 26 2013; Zink, Pettineo, Hoxley 2011).

```
float4 AlphaBlendingPixelShader(PixelInput input) : SV_TARGET
{
   //pixel shader variables
   float4 color1; // for first color texture
   float4 color2; // for second color texture
   float4 alphaValue; // for third alpha texture
   float4 blendColor;

   // There is a pixel color from the first texture.
   color1 = Textures[0].Sample(SampleType, input.tex);

   // There is a pixel color from the second texture.
   color2 = Textures[1].Sample(SampleType, input.tex);

   // Get the alpha value from the alpha map texture.
   alphaValue = Textures[2].Sample(SampleType, input.tex);
```

In the next step we must add the two pixel values together. There is a main part for alpha blending. We combine the two textures based on the alpha value. For alpha blending realization we need three textures: first color texture, second color texture and third alpha texture. In the alpha map pixel shader we first take a sample of the pixel from the two color textures and alpha texture.

```
   blendColor = (alphaValue * color1) + ((1.0 - alphaValue) * color2);
```

Then we need saturate blendColor value to produce the final blended pixel.

```
   // Saturate the final color value.
   blendColor = saturate(blendColor);

   return blendColor;
}
```


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```
//Pixel_Shader variables for two textures

uniform sampler2D Mapcolor;
uniform sampler2D Mapalpha;

void main (void)
{
	vec4 alpha_color = texture2D(alphaMap, gl_TexCoord[0].xy);

	if(alpha_color.r<0.1)
	{
		discard;
	}

	gl_FragColor  = texture2D(Mapcolor, gl_TexCoord[0].xy);
}
```

Conclusions

Alpha mapping method is successfully realized in DirectX or OpenGL platforms using pixel or fragment shader. Alpha mapping is based on blending effect. Alpha maps are usually used for tests at the pixel level (alpha-testing) in order to know if a pixel is either fully opaque or fully transparent. Alpha mapping is based on blending effect. This effect requires few computer resources.

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A NOVEL HYBRID TWO-STEP GROUP MULTI-ATTRIBUTE ASSESSMENT MODEL OF STAIRS SHAPE FOR TWO-STORY INDIVIDUAL DWELLING HOUSES

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Abstract. The article deals with a novel hybrid two-step group multi-attribute assessment model of stairs shape for two-story individual dwelling houses. There exist many available shapes of stairs for two-story dwelling houses. Selection among shapes and construction of stairs is a multi-attribute decision making problem in nature. It depends on a lot of different conflicting attributes, that have different optimisation direction, different measurement units. A determinated set of the main attributes to assess the alternatives includes the following: Stairwell Area, The Total Area of Climbing, "Climbing Lane" Area, The Cost of Stairs, and Ergonomics. The values of attributes and importance of attributes are determined by grey numbers. The paper presents a novel original hybrid model, which is based on two different multi-attribute decision making methods: ARAS-G (Additive Ratio Assessment) and AHP (Analytic Hierarchy Process).

Keywords: stairs, individual houses, Multi-Criteria Assessment, MADM, AHP, SAW, TOPSIS

Introduction

In modern world, more and more people are trying to separate working environment from the private one. That is incompatible with the concept of an apartment building. There is a growing number of residential dwelling houses.

A sustainable building is constructed of materials that could decrease environmental impacts, such as energy usage during the lifecycle of the building. Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Currently building technology and sustainable design are considered as fundamental to the growing field of contemporary architecture. High consumption of natural sources, high amount production of industrial wastes and environmental pollution are some of the factors which are responsible for obtaining new solutions for a sustainable development. In 1986, Graphisoft introduced its first "Virtual Building Solution" known as ArchiCAD (Kmethy 2008). This revolutionary new software allowed architects to create virtual, three-dimensional (3D) representations of their projects instead of the standard two-dimensional (2D) objects found in competing CAD programs of the time. This was important because architects and engineers then were able to store large amounts of datasets 'within' the building model. These datasets include the geometry of the building and spatial data, as well as the properties and quantities of the components used in the design. Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport, and install building materials and the operational energy, i. e., the energy consumed during the in-use phase of a building's life to provide necessary services, such as heating, cooling, and providing power for equipment. To reduce the thermal aspects of energy consumption in the operational stage, high-efficiency windows and insulation in walls, ceilings, and floors increase the efficiency of the building. The resource efficiency increment is possible by the reduction in use of energy and materials. Energy consumption in dwelling houses influences the climate change (Medineckienė and all 2015). As the house form is more like a sphere or a cube, as less energy is consumed in house. This means that a house will be equipped with a staircase, whose shape and size depends on a set of selection criteria. Different generations of people are choosing different criteria. Therefore significance of criteria is dependent on decision-makers preferences.

When designing low-energy architecture, minimizing of energy consumption requires thoughtful articulation of the shape and form of a building. The Architect's decision-making for a more energy efficient building form is often based on rules of thumb. Historically, the rule of thumb regarding passive solar building design suggests that the form and orientation matter to overall energy performance (Hemsath and Bandhosseini 2015).

The Passive house strategy employs super insulation to reduce the heat transfer through the building envelope. It has been argued that super insulated homes are vulnerable to summer overheating risks, even in the current climate. The Passive house approach can use much of the solar energy from its relatively large glazing in south facade but this large glazing may eventually lead to overheating in summer time. The study used parametric design modelling to generate differently inclined facade geometries for south elevations (Lavafpour and Sharples 2014). There exist some principles, on the basis of which the stairs and their form could be defined. .

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.018

The first principle - energy. To make energy consumption lower f within the time measurement unit, it is better to move inclined plane rather than the vertical. According to the Energy Conservation Law, the work done is the same, because it depends only on the difference in height between the levels and distribution in time here is more sustainable because of a longer road.

The second principle - anthropocentric. In this case, it could be formulated as follows: “stairs - for man, and not man – for stairs”. Vertical, according to contemporary designers in meeting the requirements of ergonomics, should be divided into discrete sections-modules corresponding to the main anthropocentric parameter - human step. Each of the multi-levels (tier planes) must have a small horizontal area to counter human foot during walking. The ratio between the height and width of these low levels can be different depending on the angle of inclination of the stairs and construction. Ergonomics is the formula for the above-mentioned values are selected (step height and width):

$S = a + 2h$

where a – width of a step,

h – height of the stage,

S – the average human step (600-640 mm).

However, this formula does not take into account the angle of inclination as well as stair-friendliness. Width of a step, which rests against the complete human foot, must be from 250 to 320 mm. It is argued that optimal geometric dimensions of stairs should be: 300 × 150 mm (angle about 27 °). Similar stairs are installed in residential and public buildings (. Limit values of the steps in single-family residential buildings are determined by STR (STR 2.02.09:2005as follows: width 250mm, height 200 mm. It is reasonable to not increase width of the step. The human’s step will be embarrassed, when stair step’s width is too big. The change of the stairs angle, when selecting the different sizes of steps, is shown in Figure 1.

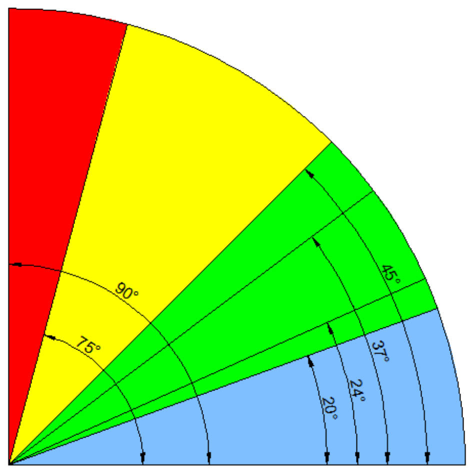


Fig. 1. The size dependence of steps from the stair inclination angle

Convenient staircase inclination angle is from 23 ° up to 37 °. The steeper the stairs, the less space of the building they occupy and vice versa, - as the shallower the stairs, the more space is needed for them. If the angle is less than 23 °, the stairs can be changed with the ramp, and if steeper than 45 ° - this is usually built stairs (ladder). If you do stair inclination of 40 ° -45 °, people will descend backwards. Selection problem of shape and criteria for internal staircase (when building has ground level and first floor) is being solved by all residential buildings’ homeowners (project architect). Furthermore, the problem is actual when designing a new or renovating an existing building. Traditionally Lithuanian residents in constructing own houses prefer a bearing wall construction system. It is known that the frame structural system of building could be installed up to 10 times faster, however such selection is still rare among Lithuanians, not only because of tradition, but also because of stability of the house (although in my opinion the most important is the vapour barrier film on the indoor side of the negative effect). A house of such wall structural system in most cases is planned to live with the family and when growing old maybe even to live with grandchildren. Therefore while designing the stairs, one needs to decide who and how often is going to use them: a child, an old man, or just young and energetic people. In other countries, with prevailing frame structural system of residential buildings, which are relatively easy to dismantle, stairs can be designed in different geometrical sizes, adapting them to specific individuals.

1. Graphics Stair-shapes

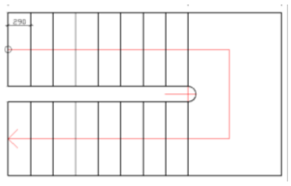
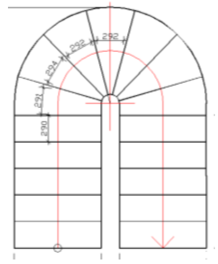
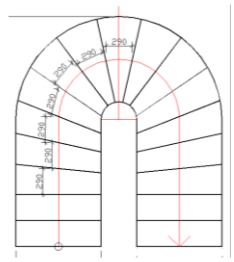
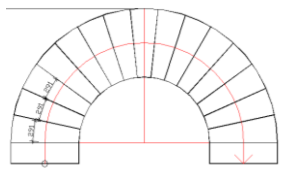
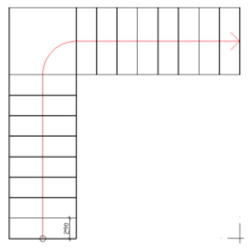
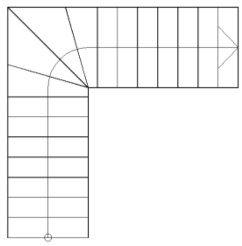
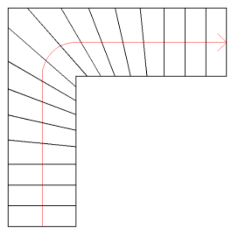
There exist eight main stair shapes for single flat dwelling houses (Table 1). It is a challenge for stakeholders and architects to select the best shape of stairs. There exists a set of criteria, which determines performance of stairs.

Quite often there are multiple conflicting criteria that need to be handled. The criteria have different optimization direction and are conflicting with each other. Satisfying one of these criteria comes at the expense of another. For a multi-criteria decision-

eISBN 978-609-457-835-9

making problem, there does not exist a single solution that simultaneously optimizes each criterion. In that case, the objective functions are said to be conflicting, and there exists a number of Pareto optimal solutions. A solution is Pareto optimal or Pareto efficient, if none of the objective functions can be improved in value without degrading some of the other objective values.

Table 1. Main stair shapes for single flat dwelling houses

L1 	L2 	L3 	L4 
L5 	L6 	L7 	L8 

Multi-attribute decision making methods deal with such problems solution.

Selecting a particular MADM method depends on the characteristics of a problem and is also partly based on the decision maker's preference. To solve MADM problems with homogenous data type, two approaches can be used. Firstly, data can be treated exclusively in order to form a set of uniform input parameters, and classical MADM methods can be used to solve the problem. Secondly, MADM methods should be modified in order to accept mixed input parameters.

2. Criteria set

The article presents the set of criteria for the selection among sixteen different shapes of steps, which vary in form (5 different shapes), stage height, and width of the variable-step staircase turns. There are selected is the most widely used steps in Lithuania - 170×290 mm and more comfortable steps153×300 mm. There are 18 and 20 steps respectively in order to ensure the same height of a floor, which is equal to 3060 mm.

Staircase area. This area includes stairs, landings (if any) and the space between the two flights of stairs, in the case of any other functional purpose this gap does not perform any function. The stairs shape and dimensions (if it is necessary to carry furniture) should to be of appropriate dimensions. The staircases area should have proper thermal insulation in cold season. year.
Total climbing area. In four cases out of sixteen (L1a, L1b, L5a, L5B) the present total climbing area of stairs equals to the stairwell area. This value differs only in case when width of steps is varying.

Despite estimates of material resources and work force demand the ergonomic and aesthetic requirements should be taken into account.

"Climbing lane" area. This lane area determines area which is convenient for climbing stairs with human foot. When all the steps are the same width, this area does not differ from the total climbing area. This value is searchable only on variable-width steps.
Usually a man climbs the stairs perpendicular to the tier of the working edge. A big enough, but a reasonable range interval of human-step length is established: $570 \geq S \geq 750\ (mm)$. The research deals with two height and width sizes stairs. The first stairs (1): line of climbing from a = 290 mm, h = 170 mm, the second stairs (2) - a = 300 mm, h = 153 mm. According to Blondel formula we calculate the relative width of the stairs (handy foot) for the minimum (570 mm) and maximum (750 mm) length of human-step:

$$b_{min} = 570 - 2 \times 170 = 230, \text{ and}$$
$$b_{max} = 750 - 2 \times 170 = 410 \text{ (mm)} \quad (1)$$

$$b_{min} = 570 - 2 \times 153 = 264, \text{ and} \quad (2)$$

$$b_{max} = 750 - 2 \times 153 = 444 \text{ (mm)}$$

The lines are drawn parallel to the working edge step of stairs by calculated values, indicating the points of intersection with the next step. This operation is repeated for all steps of varying width. The set points are connected by a broken line, and the resulting polygon is hatched. The resulting figure is named a "climbing lane" (Fig. 5). The wider the band and the more comfortable the distance from the railing, the more comfortable is to climb the stairs.

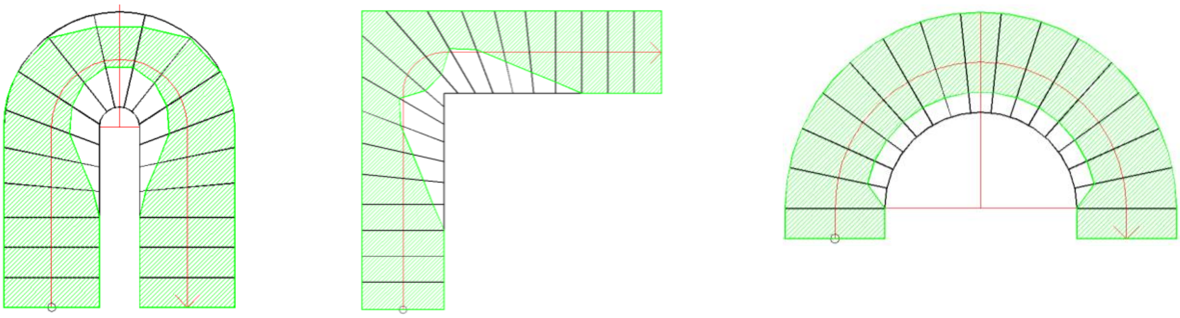


Fig. 5. Climbing lane width of a different forms of stairs

Costs. This case study includes only the installation price of the stairs (operation costs are ignored). In all considered cases the same load-bearing elements are selected to all forms of stairs: metal tube beams 100 × 150 × 5, the same cross-section beams and ash steps finishing. In each case the following installing works are taken into account: : stairs beams preparation, welding, priming, painting, staining and lacquering steps and steps installation on the stairs (metal beams angles are used).

Ergonomics. In short, ergonomics is the science of the comfortable environment. In most cases ergonomics deals with objects and equipment, but ergonomically optimized processes are object of this science. This is done by examination of how to change the process to match the user's requirements. It must be comfortable to use and most importantly - safe.

According to statistics, disaster on the stairs occurs two times more than on a slippery bath or sauna floor. This happens because of the steep stairs, lack of railings, lack of intermediate courts, or defective steps.

Generally, the standards are drawn up taking into account the ergonomic requirements of the stairs (STR 2.02.09:2005, Neufert 2012.The comfort of stairs depends on the width and height of steps. As judged by climbing the stairs down, the most important ergonomic criteria are depth and width of steps. Therefore, designers offer to evaluate the following criteria for the stairs: how often the stairs will be used and will thedirt to the floor be carried by them. Handrails with retracted rails should be chosen in case there live or will live children in the house and instead of balusters stringers should be used. It is important to ensure enough height of space above the stairs so that the head of a climbing man should not strike the ceiling.).

Basically lighting of stairs depends on the general assumptions and ideas of the house project. A special project designed for specific lighting of stairs will make them more beautiful and safer. Illuminated stair marches, steps, railings serve both as interior design and means of security.

The traditional L2b type stairs are of the safest form (from cases considered in this study) both for climbing of young as well as old people. . However, this type of stairs requires the largest area of the floor.

Aesthetics. Often stairs are one of the most important interior accents of the house. A customer has to decide what type of stairs (price of stairs) he wants. An architect must perfectly adapt the stairs to the available space, taking into account their functionality, safety and importance to the interior. Today one can choose from a wide variety of available types and constructions of beautiful and stylish stairs. In any case, if an adult man or children climb the stairs, they must be safe. For example, despite the fact that the spiral stairs (which are not considered in the case study) are one of the most attractive, they are most inconvenient and dangerous stairs. The aesthetic view of stairs is influenced by a design of the stairs (wooden, metal or reinforced concrete strings), steps attachment to the strings, installation of risers or their absence , selected material, railing construction, lighting and form of stairs (investigated in this case study). Of course, the form of stairs is determined not only by the desire to have one or another form of stairs. It is influenced by building's bearing constructions, walls and building plans. For example, if the contour line of walls is not only strict beeline, other types of stairs shape could be used. The arc-shaped wall space is perfect for L3, L4 and L5 stairs shape, but the usual rectangular shape of house-type walls hardly fits the shape of the interior stairs.

Technological properties of construction. In principle, all the stairs in single dwelling houses are non-standard products. It's great when there is not too little space left for installing stairs. Stair hole must meet the stair configuration (shape). The surface must be specially prepared and plated to make the stairs look attractive and serve longer. There is a simple rule: the more attractive the design of stairs, the more difficult is to install them. Of course, to install steps with arched shape and variable-width will take more time, but after all, this leads out-off costs.

Based on the research it could be stated that selection of stairs shape is multi-criteria decision making problem. Each performance criterion of stairs has its own significance for a decision-maker.

Authors propose to use Analytic Hierarchy Process (AHP) method to determine relative significance (weights) of criteria. The AHP was developed by Saaty (Saaty 1980). The essence of the process is the decomposition of a complex problem into a hierarchy with the goal (objective) at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy. In the standard AHP model the decision maker judgments are organized into pair wise comparison matrices at each level of the hierarchy. Five high-skilled experts (civil engineers and architects having PhD degree) made pair-wise comparisons of criteria importance and determined criteria weights as is shown in table 2.

Table 2. The comparison of weights of criteria

	Attributes						
Alternatives	Staircase area., m^2	Total climbing area, m^2	**Total climbing area,** m^2	Cost, Eur.	Ergonomics	Aesthetic view	Technologic
	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Weights-*w*	0.144	0.060	0.104	0.154	0.254	0.167	0.118
Optimum	min	max	max	min	max	max	max
L1a	4.680	4.680	4.680	1596.68	0.120	0.130	0.345
L1b	5.420	5.420	5.420	1775.66	0.120	0.130	0.345
L2a	7.390	4.410	4.410	2623.09	0.180	0.035	0.160
L2b	8.190	5.130	5.130	2788.75	0.240	0.035	0.160
L3a	5.040	4.640	3.750	3073.16	0.090	0.074	0.100
L3b	5.850	5.520	4.470	3161.49	0.040	0.074	0.100
L4a	5.330	4.700	3.880	3073.16	0.060	0.074	0.033
L4b	6.210	5.430	4.370	3161.49	0.040	0.074	0.033
L5a	4.700	4.700	4.100	2561.11	0.090	0.497	0.053
L5b	5.450	5.450	4.420	2634.67	0.060	0.497	0.053
L6a	5.310	4.410	5.310	2224.28	0.040	0.265	0.160
L6b	6.020	5.120	6.020	2389.37	0.170	0.265	0.160
L7a	4.890	4.890	4.210	2335.50	0.060	0.265	0.093
L7b	5.650	5.650	4.960	2508.98	0.040	0.265	0.093
L8a	4.890	4.890	4.510	2446.71	0.060	0.265	0.055
L8b	5.650	5.650	4.810	2628.30	0.040	0.265	0.055

At the next step performance of each alternative was determined by using SAW (MacCrimon 1968, Zavadskas *et al.* 2010), TOPSIS (Hwang and Yoon 1981, Zavadskas et al. 2014), and Full multiplicative (MEW) methods (. Final decision-making results are shown in Table 3.

Table 3. Integrated table of results

	SAW		Full multiplicative form		MEW		TOPSIS			Sum of ranks	Final rank
	K	Rank	K	Rank	K	Rank	K	Rank			
L1a	0.7168	1	0.003277	2	0.9395	1	0.478	4		8	1=2
L1b	0.7021	2	0.003412	1	0.9377	3	0.471	5		11	3
L2a	0.5643	7	0.000208	12	0.8924	10	0.376	7		36	9
L2b	0.6332	5	0.000319	10	0.9018	7	0.452	6		28	6
L3a	0.4818	13	0.000155	13	0.8813	12	0.202	13		51	13
L3b	0.4299	14	0.000082	14	0.8561	14	0.130	14		56	14
L4a	0.4229	15	0.000034	15	0.8519	15	0.126	15		60	15
L4b	0.3977	16	0.000025	16	0.8389	16	0.089	16		64	16
L5a	0.6402	4	0.000787	4	0.9187	4	0.532	2		14	4
L5b	0.5995	6	0.000550	7	0.9042	5	0.498	3		21	5
L6a	0.5617	8	0.000697	5	0.8988	8	0.366	8		29	7
L6b	0.6962	3	0.003201	3	0.9462	1	0.535	1		8	1=2
L7a	0.5518	9	0.000552	6	0.9021	6	0.351	9		30	8
L7b	0.5258	11	0.000404	8	0.8881	11	0.325	11		41	11
L8a	0.5392	10	0.000334	9	0.8941	9	0.335	10		38	10
L8b	0.5058	12	0.000221	11	0.8790	13	0.309	12		48	12

Preference order of investigated alternatives is determined as follows:

L1a≈L6b≻L1b≻L5a≻L5b≻L2b≻L6a≻L7a≻L2a≻L8a≻L7b≻L8b≻L3a≻L3b≻L4a≻L4b

It means, that the best selection is alternative L1a or L6b, and the worst alternative is L4b.

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GEOMETRY AND DECISION SUPPORT SYSTEM FOR ROOF INSTALLATION

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Abstract: The authors of the article carried out analysis of the complex decision support system application for roof installation methodology. This analysis was based on a created database of roof design variants. Applied methods – there were analysis of scientific literature and other information sources, study of decision support systems, analysis of its application cases, and the modelling of complex decision support system for the roofing. The authors of this work established the goal - to make feasibility study of the complex decision support system for the roofing. After the assessment of such systems creation methodology, parameters used in the system used, indicators and the practical aspects of the application, it was planned to create the prototype of the system. For this purpose decision support systems of a variety of application fields and their development processes were researched. Based on the analysis, the authors proposed the complex decision support system model.

Keywords: Decision support system, decision making, roof installation, case study

Introduction

Application of the complex decision support system for roofing activities creates new opportunities to make more effective decision and to choose the most suitable option, which would align the interests of the customer, architect, and builder.

After the analysis of the expertise documents about poor quality of construction work was carried out by the authors of the article, it was found. that an ordinary person, without a civil engineer's qualification, might face a lot of problems related with the failure during the installation of a new, or renovation of an old roof construction, if problem evaluation and adequate solutions are not made before the work begins.

Installing or replacing roof elements often raises the question of how to design the roof structure (rafters must withstand the load on them, the wood must be properly covered with antiseptic, etc.), or how to fix, modernize the entire roof structure (as it is well insulated, the new roof is durable, efficient in use, etc.), to use money for construction or repair in a meaningful and rational way. This requires special knowledge. It is understandable that for the decision to build or renovate an existing roof, it is necessary to consult with an experienced roofer, so that he would examine and assess the roof structure as well as estimate potential costs of various roofing installation. Key indicators influencing the choice of roofing are balance between quality and cost, design requirements, and roof construction techniques (eg., incidence angle). The most common mistake, in selecting roofing, is decisions after evaluation only of the roofing price per square meter. Indeed, first of all it is worth to count all the construction or renovation costs if one or another roof covering was chosen, only then to compare. Here you need to evaluate everything from the price, which includes the specific elements of the roof structure, roofing with all the necessary accessories and ending with a price of the roofing. Assessing the quality of the roof, eg., tightness, durability, and good looks, also it is worth to look into the manufacturer's experience guarantee.

Best if you start from the consultation with the roofer, after which it is necessary to make evaluation of roof construction and selection of the pavement. Thus we avoid major mistakes or unexpected expenses. After taking apart old roof coating and after preparation of wooden structures, workflow will be the same as the roof covering for the new house.

As shown by the bitter experience, is not always possible to rely on promises from the companies offering their services in the field of roofing installation. Often it is the case, when the customer is faced with unskilled labour, and without the suspension of activities in time it is likely permanent damage to the entire roof structure or surface. Customer expects to have high quality product for the paid money, but without having adequate competence, may need to invite experts to identify the effects of the low-skilled work results, to seek solutions to correct the existing violations, which leads to time, moral, and financial losses.

According to the authors, after assessment of the conflicts resolution complexity, number of participants, the abundance of information and data, to the have success of the roofing work, an advanced decision support system is needed. The system's objective and purpose is to collect, analyse, and visualize data and processes, after that to submit them to an expert and building customer assessment. Importance of the information visualization was defined in many scientists' scientific publications and there are potential benefits from using visual representations of project interdependence (C.P. Killen (2013)). The system

baltgraf.vgtu.lt
eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.019

collected various types of data - numerical and textual, graphical and logical. Their search and management can be optimized by means of imaging techniques.

Information visualization goal is to provide information to the user graphically, to help analyse the data, when the abundance and multidimensional approach prevent proper evaluation and all these factors increases the possibility of errors. Information subsystem of decision support system must provide information about the acquired expertise regulations, laws and regulations, companies and manufacturers, as well as structured information about roof structures, pavement types, work rates, that would make it possible to more effectively analyse the data, if it is constantly updated, assessing the changing environmental conditions. Visualization techniques can help to make correct interpretation of the search results, without the primal error. This requires a knowledge base, evaluation criteria, and solutions.

The authors believe that the customer, not being the expert in the researched field, but using a decision support system, has an access to information source for better quality decision or for checking of the rationality of the proposed project (construction of the roof, pavement, etc.).

The authors of this work established the goal - to make feasibility study of the complex decision support system for roofing modelling. For this purpose, were researched decision support systems of a variety of application fields and their development tendencies. Based on the analysis, the authors proposed the prototype model of the complex decision support system.

The methods applied are as follows: analysis of scientific literature and other information sources, study of decision support systems, analysis of its application cases, and the modelling of the complex decision support system for the roofing.

1. Methodology

X. Luo, G.Q. Shen, S. Fan, X. Xue (2011) concluded that the group decision support system can effectively facilitate the implementation of value management in construction briefing. The system allows a client to define and represent his or her requirements with functions and functional performance, to bring forward ideas to achieve the functions, and finally to evaluate and highlight the ideas against the functional performance for further development in design.

D.C. Novak, C.T. Ragsdale (2003) proposed methodology for solving stochastic, multi-criteria linear programming problems. The first step in methodology is to formulate a valid model for the problem at hand. Once the model is formulated, it is then used to generate and solve a series of problem scenarios. As each problem scenario is generated, methodology solves a weighted Tchebycheff programme to identify a non-dominated (or efficient) solution for the current problem. The criterion weights are randomly generated. The process of generating scenarios and solving weighted Tchebycheff programmes continues until a sample of m candidate solutions exists, each representing a non-dominated solution to a problem scenario. The next step is referred to re-evaluation. The re -evaluation process provides an indication of how robust a particular candidate solution is to uncertainty. The next step is to determine the Pareto ranking for each candidate solution. This process continues until all candidate solutions have been assigned a Pareto ranking. The next step is to present the statistical and Pareto ranking information about the solutions to the business decision makers.

J. Gottschlich, O. Hinz (2014) proposed decision support system that can support the investor in three different aspects. First, by creating a ranked list, the investor gets advice about the most preferable securities on a specific date. In addition, the system supports the implementation and simulation of strategies based on the computed ranking so that investors can test and explore different approaches to identify promising investment strategies. Once a suitable strategy has been identified, the system can be used to automatically follow a specified strategy day by day and create orders to modify a portfolio. The system's task is to transform crowd votes into actionable share ratings for a given day.

In K. Fagerholt, M. Christiansen, L.M. Hvattum, T.A.V. Johnsen, T.J. Vabø (2010) methodology Microsoft Excel is used for input of case and scenario information to Turbo Router and for output of results from the analysis. The scenario building is carried out by entering some static data such a port locations and distances directly in Turbo Router. The dynamic data that can differ between scenarios are stored in Excel sheets. This is typically fleet and demand information. Macros made in Visual Basic perform the scenario generation process by transforming these data in to detailed demand instances of desired length, and store them in text files suited for Turbo Router. The original version of Turbo Router has been configured to implement the rolling scheduling horizon. For each instance, Turbo Router gives output ton sailing schedules and economical figures, which are used to analyze and evaluate the scenario results.

A. Kengpol, P. Neungrit (2014) proposed methodology consists of the prediction modelling and risk assessment analysis.

G. Kyriakarakos, K. Patlitzianas, M. Damasiotis, D. Papastefanakis (2014) methodology approach followed for the implementation of decision support toolkit consists of four discrete stages: parameters (legal/regulative/administrative, financial, technical, social and environmental) investigation, indicators choice, fuzzy cognitive maps implementation, and implementation of the decision support toolkit in a web-platform.

According to L. Yu, K.K. Lai (2011) multi-person multi-criteria group decision making model is composed of six main procedures: to construct the group decision making environment, to select different decision criteria for decision alternative evaluation, to formulate various decision alternatives, to used criteria weight determination methods to determine criteria weights, to give different decision results for every alternative, to aggregate different decision results into a group consensus in

eISBN 978-609-457-835-9

terms of the maximum agreement principle. The aggregated group consensus value can be used as a final measurement for the final decision-making purpose.

According to the T. Wanderer, S. Herle (2015) decision making is influenced by a multitude of different physical, economic or social criteria with many of them being of spatial nature.

C. Bolchini, F.A. Schreiber, L. Tanca (2007) proposes a design methodology for very small databases. According methodology the main mobility issues are considered along with data distribution, context awareness is included in the data design issues to allow full exploitation of context-sensitive application functionalities, and the peculiarities of the storage device are taken into account by introducing a logistic phase.

In D. Tang, J. Yang, K. Chin, Z.S.Y. Wong, X. Liu (2011) paper, a novel method is proposed to generate a belief rule base, which is the basis of the Belief Rule-Base Inference Methodology using the Evidential Reasoning. Due to its capability in dealing with complex reasoning problems under uncertainty, Rule-Base Inference Methodology using the Evidential Reasoning is then applied to assess customer perception risk in an new product development process.

E. Dupuit, M.F. Pouet, O. Thomas, J. Bourgois (2007) proposed methodology for decision support approach to manage a refinery wastewater treatment plant by using model of the network.

After evaluation of above examined literature, the authors of the article proposed to applied methods for complex decision support system modelling:

1. Alternatives of roofs selection: analysis of all roofs types and the elements of the roofs.
2. Work organization.
3. Customers objects analysis: objects preserved by State; VIP roofs, the average customer orders, and cheap options.
4. Databases formation.
5. Decision making.

2. Identification of the parameters

2.1. Alternatives of roofs selection: analysis of all roofs types and the elements of the roofs

The main parameters of roof are described by geometry and topology. Common roof parameters are shown in figure below:

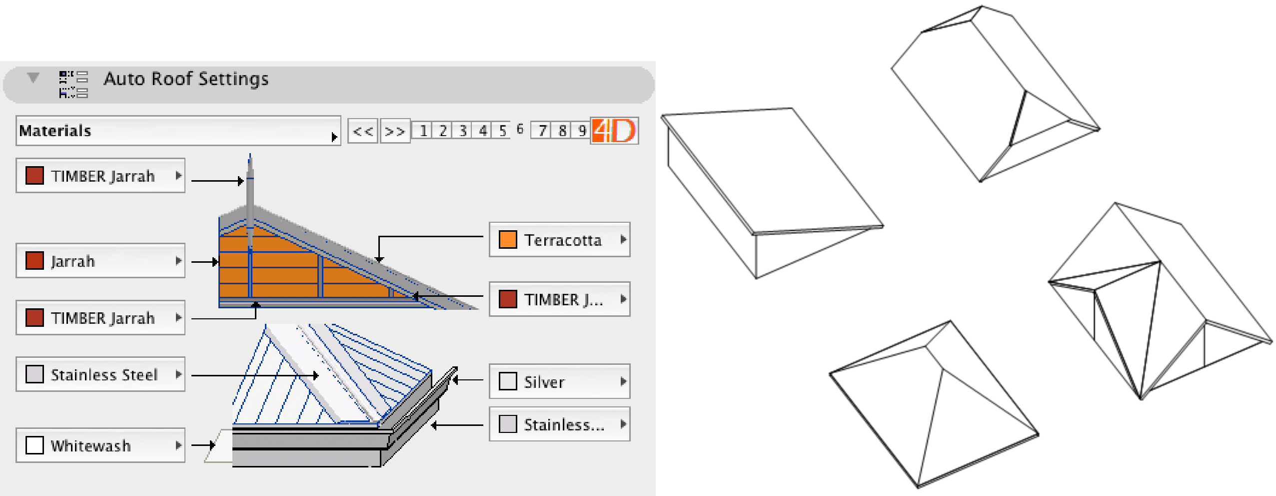

Fig. 1 Auto Roof Settings in ArchiCAD (source http://4dlibrary.com.au/library/wp-content/gallery/auto-roofing-gallery/*) and few common roof types

For example, the roof selection depends on many parameters and variables - textual, logical, esthetical, economical etc. Footpath of the roof depends on main constructions of a house. When setting out a roof, there are certain essential factors that must be considered. These are:

– roof span – This is the distance across the roof and measured to the outer edges of the wall plates.
– roof height or rise – This is the vertical height of the roof at its highest point and is measured from the top of the wall plates to the intersection of the rafters at the top of the roof. When measuring rafters, the length is taken as a straight line running through the centre of the rafter.
– roof pitch – This is the angle or slope of the roof and can be expressed in degrees or as a fraction or ratio found by dividing the rise by the span.

PARAMETERS	SELECTION	appraisal tariff	Quantity	Selection
I COVERING SELECTION				
	COVERING MATERIAL			
1) Roof baseline + lathing	**1.Clay pantiles on simple roof** (with lathing)	N12-19	100 m²	Slope Area S
	Clay pantiles on semi-complex roof	N12-20	100 m²	Slope Area S
	Clay pantiles on complex roof	N12-21	100 m²	Slope Area S
2) Roof baseline + lathing	**2.Plain clay pantiles** on simple roof (with lathing)	N12-22	100 m²	Slope Area S
	Plain clay pantiles on semi complex roof	N12-23	100 m²	Slope Area S
	Plain clay pantiles on complex roof	N12-24	100 m²	Slope Area S
3)Roof baseline + lathing	**3.Concrete tiles** on simple roof (with lathing)	N12-14-3	100 m²	Slope Area S
	Concrete tiles on semi complex roof	N12-14-4	100 m²	Slope Area S
	Concrete tiles on complex roof	N12-14-5	100 m²	Slope Area S
II INSULATION SELECTION				
	Material of insulation			
4) No additional materials	**1.No insulation**			
5) Instalation method	**2. Mineral fiber**	N12-149	m³	Slope Area
	mineral fiber 140 mm installed by staples	N12-60-1	100 m²	Slope Area
	mineral fiber 160 mm installed by staples (140+20)	N12-60-2	100 m²	Slope Area

Fig. 2 Variability in data set of roof coverings. Part of Data base (author O. R. Šostak)

All the roofs have lot of types of covering - tiles, plates, shingles etc. This variability of roofs is big challenge for house owners how to make aesthetical, ecological and cheep roof.

2.2. Estimation of the separate parameters

Estimation of the separate parameters for each possible alternative of the roof installation projects can be accomplished by the formula turning them into 0 – 100 points system from the 1 – 5 points system:

$$F_{hj} = 100\left(\frac{V_{hj} - \min_F}{\max_F - \min_F}\right); \qquad (1)$$

where V_{hj} – evaluation of j parameter for the h project (points assigned by the expert from 1 to 5), $\max_F$ –maximum points for V_{hj} parameter evaluation (in our case 5 points), $\min_F$ –minimum points for V_{hj} parameter evaluation (in our case 1 points).

The total evaluation for the each possible roof installation projects can be done as a weighed average of the separate parameters evaluated by the expert (the 0 – 100 points system):

$$A_h = \frac{\sum_j W_{hj} F_{hj}}{\sum_j W_{hj}}; \qquad (2)$$

where W_{hj} – is the weight of j parameter for the h project (weight of the parameter is positive and common for all valued projects if there are no specific conditions and is assigned by the expert from 1 to 5 points).

3. Indicators establishment

After the analysis of implemented roof installation projects, indicators for decision making were established. Since during the implemented project study a lot of parameters were found, but for visualization it was necessary to decrease the amount of information, the parameters of similar nature were joined into the groups and presented in the 1 Table.

eISBN 978-609-457-835-9

Table 1. Indicators for decision making

Parameter	The explanations of the parameter
Parameter of geometric properties (j=1)	Roofs geometric properties depending on the design of the roof. For parameter evaluation, it is necessary to take into account roof relations to the base of the roof, angles and elevation of the roof, and the workability of the roof structure and elements
Parameter of aesthetic properties (j=2)	This evaluation must include a comparison of the roof parameters according to the best examples of this area (benchmarking), taking into account the environmental conditions, design of the other neighbouring buildings and the overall picture of the building design. Here it is especially important to take into account the roofing material aesthetic qualities (colour, profiles and forms)
Parameter physical properties (j=3)	Dimensional tolerances and the strength of the roof elements, water-resistancy and noise insulation qualities of roofing elements must be assessed in required properties .
Parameter of ecological properties (j=4)	For this parameter evaluation it is necessary to make benchmarking for roof elements if they are recyclable, made from renewable resources, and not having negative impact on the nature and humans
Parameter of economic properties (j=5)	For this parameter evaluation it is necessary to make benchmarking for roof installation cost and benefits for the customer
Parameter of longevity properties (j=6)	For this parameter evaluation it is necessary to make benchmarking for roof elements durability, taking into account the weather, roof operating, and maintenance condition of the region
Parameter of efficiency properties (j=7)	Evaluation of the roof energy performance class
Parameter of safety properties (j=8)	Evaluation of roof elements for the fire resistance class, lightning protection, installation of human safety measures, electrical safety, and resistance to high-wind and earthquakes effect
The weight of j parameter for the h project	The weight of parameter must be determined by an expert to assess its importance to the project's success and longevity of results
Total evaluation for the project (h) in points	The total evaluation can be done as a weighed average of the separate parameters evaluated by the expert
Estimate project price (Ph) in €	Project budgeting
Compliance with norms and standards	The project must be in accordance with necessary norms and standards

The parameters were entered into Excel programme for many variants of the roof design generation.

4. System Design

The authors of the article established that the efficient use of information requires developed information network, which is connected via architects, experts and new roof construction or reconstruction customers. This network is a basis of the complex decision support system thanks to the appropriate dissemination of knowledge through visualization tools.

The conception of the complex decision support system design is presented in the Fig. 3.

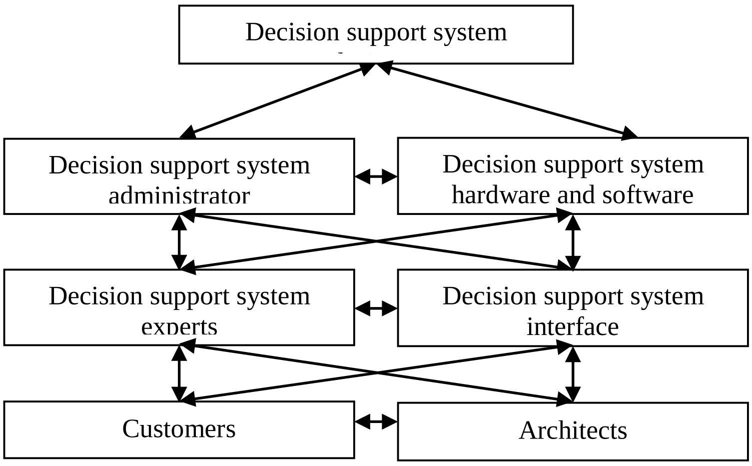

Fig. 3. Complex decision support system design

The final decision about the choice to implement appropriated variant of the roof installation project must be done by the customer.

5. Development of the system

For decision-making support the comprehensive database consisting of the various roofing types and configurations on the basis of Microsoft Excel programme was developed. Each option has been connected to the costing subsystems and final expert evaluation subsystem. Simplified principle classification scheme for roof project variants generation is presented in the Fig. 4.

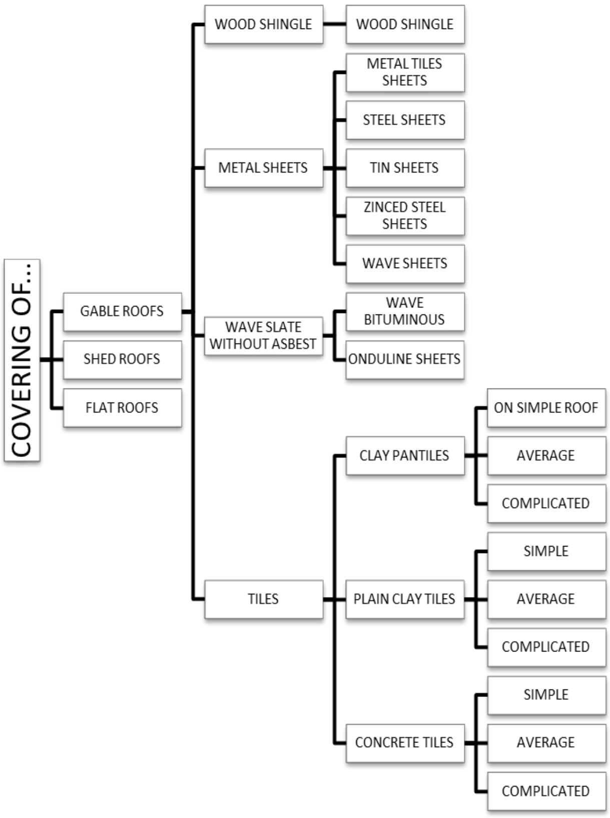

Fig. 4. Roof types and coatings at various levels of detail for possible projects variants generation

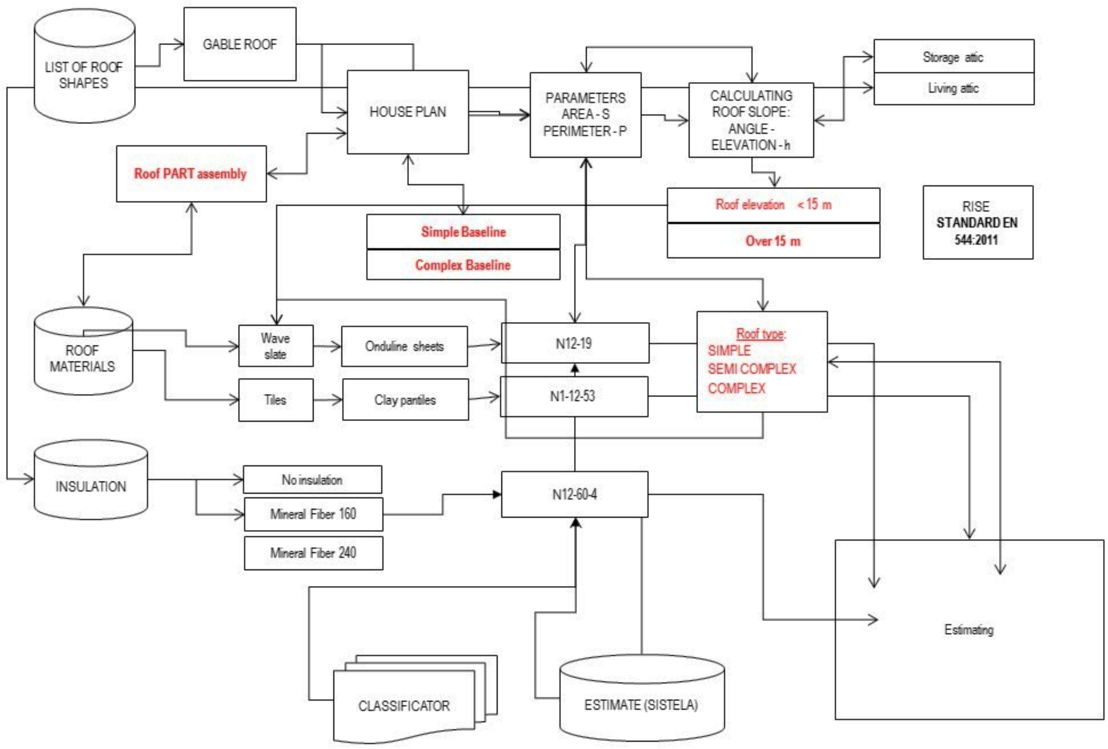

Fig. 5 Part of Decision making process

Roofing options generated from the variants of roof profile, the current typical pavement elements in sale, their design features, colours. It is possible to generate specific options, when completely new materials and additionally on a roof installed solar panels or solar thermal collectors will be used. The diagram in Fig. 2 shows only part of the available options. The cost of the project also can be taken into account, whether it is the cheapest, but not the best option, or mean, or exclusive, or for the state protected object, but an expensive project.

Options of chimney decoration, rainwater system, skylights, ventilation equipment, insulation, safety means, protection from lightning and other items can also be included. They consist of a number of additional options. In order to minimize the flow of information of roof installation project variants, the particular cases under the original user preferences can be generated.

An example of experts using data from the Table 1 and making evaluation for each variant of the roof installation project, is presented in the Fig. 5.

1	Decision support system application for roof installation				
2					
3					
4					
5					
6			Project No. GTCA0101 evaluation		
7					
8			Weight	Evaluation of parameter	
9		Parameter	W_{1j}	V_{1j}	F_{1j}
10		Parameter of geometric properties (j=1)	5	5	100
11		Parameter of aesthetic properties (j=2)	3	4	75
12		Parameter physical properties (j=3)	4	3	50
13		Parameter of ecological properties (j=4)	3	3	50
14		Parameter of economic properties (j=5)	5	4	75
15		Parameter of longlivity properties (j=6)	3	4	75
16		Parameter of efficiency properties (j=7)	4	3	50
17		Parameter of safety properties (j=8)	5	5	100
18		Total evaluation for the project (h) in points		A_1	74.21875
19		Estimate project price (Ph) in €		P_1	15910
20		Compliance with norms and standards			Yes
21					

Fig. 6. Example of the roof installation project parameters evaluation by the experts of the decision support system

The customer of the roof installation project can view a variety of appropriate options, which have been already evaluated by experts, and to decide which one to choose. If none of the proposed options satisfies the customer, then the new stage for potential new options generating and evaluation can be implemented.

Fig. 6 presents an example of evaluation of the small apartment house with an option of a gable roof and clay tiles. These options can be generated as much as possible and necessary. The expert must be familiar with the user's requirements. Parameter scoring is based on the subjective thinking of the expert and the quantitative estimation of the project budget. Some of the rateable parameters are composed of several smaller subparameters, which must be evaluated and worked out from the average and then entered into the table. If any of subparameters are assessed as 1 point from 5, it can have a greater impact on the final parameter evaluation. After the implementation of the selected project option, the assessment of its success must be carried out and a further review must be done on exactly how close to the project's final results the expert's assessment was. Then, the data is stored in a database for results analysis and for the feedback assurance.

6. System application peculiarities

The results of the roof installation project implementation will depend on the conditions existing in the system environment. During the implementation of the project, the construction organization team must be in contact with the architects from the designing organization and the customer (Fig. 7). Decision support database provides a list of well proven construction companies, as well as contentious and problematic situations analysis.

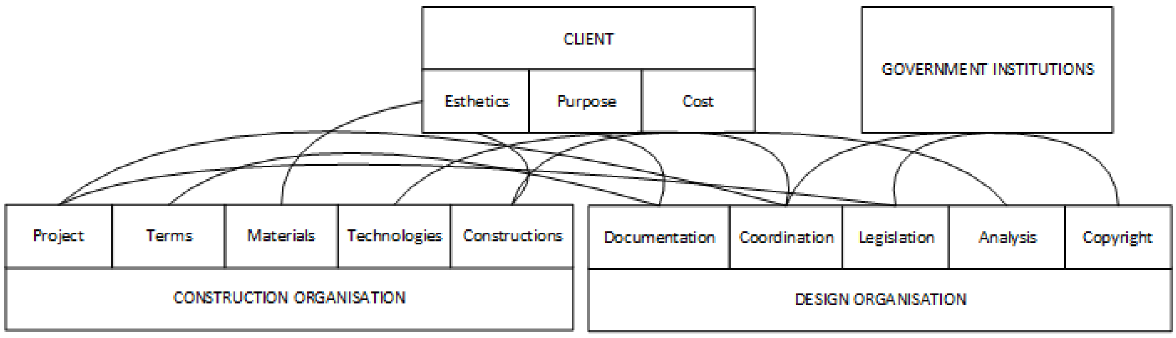

Fig. 7. Participants of the roof designing process

After case studies of the small houses roofs project implementation, it was found that the larger problems do not arise when using bitumen tiles. Such roofs are quite easily and quickly installed by builders, however, after some time, in rare cases, roofing tiles slightly lift up from the base in a few places due to incorrect mounting, caused by stress and temperature effects. Sometimes significant problems relating to the recklessly equipped rainwater drainage system, or corroded fasteners, which had to be made of stainless steel, were noticed. However much worse results were observed in the analysis of clay tiled roofs. In this case, the problems were seen in the installation of a round-shaped skylights, ensuring good ventilation of wooden structures. In one case, the client even had to change the construction company to correct the defects and to ensure the desired quality of the work.

From the above presented case study it is possible to envisage that the choice of building organizations for project implementation is a sensitive issue. Experts should gather a list of potential candidates and to offer for the customer only a well proven foreman. The database should be compiled of the disputable problematic cases and solutions made. That can be very useful for solving such structural defects problems, as well as prevention, which saves a lot of money.

Only full involvement of the roof installation project participants and their efforts to ensure good quality of the work, which meets the customer's requirements, can lead to success.

After the review of publications about the application of the similar systems (S. Rahman, H, Odeyinka, S. Perera, Y. Bi (2012) and A. Spanaki, T. Tsoutsos, D. Kolokotsa (2011)), it can be said,that the work to improve information systems in the field of construction can have a great outcome.

Conclusions and suggestions

The analysis of the literature sources and cases study results showed that there are a lot of engineering and management activities in decisions making process, and that these activities must be provided with the relevant information and judgment.

Recent roofing operations are related with the product and process innovations, when the results of the product development can be in many cases achieved through systems design and new materials introduction to improve the product.

Obviously, the application of innovative knowledge in the construction processes is closely related to the updates of products used in building and their production technology, also with new products and services design and its implementation in the production, and even with markets development. Finally, without innovative knowledge it is difficult and sometimes impossible to detect and nurture innovation, especially in the field of engineering.

Information visualization goal is to provide information to the user graphically, to help analyse the data, when the abundance and multidimensional approach prevents proper evaluation and all these factors increase a possibility of errors.

Information subsystem of decision support system must provide information about the acquired expertise regulations, laws and regulations, companies and manufacturers, and also structured information about roof structures, pavement types, work rates, that would make it possible to more effectively analyse the data if it is constantly updated, assessing the changing environmental conditions. Visualization techniques can help to make correct interpretation of the search results, without the primal error. This requires a knowledge base, evaluation criteria, and solutions.

The complex decision support system for specific activities like roofing can be a start line for innovation in doing improvements and in making good decisions for sustainable upgrade with green design technologies.

The authors believe that the customer, not being an expert in the researched field, but using a decision support system, has access to information source for better quality decisions or for checking of the rationality of the proposed project (construction of the roof, pavement, etc.).

For the complex decision support system for roof installation development it is very important to apply new communication channels and case study in forming the base to increase the effectiveness of this phenomenon.

Summary

The authors of the article have carried out analysis of the complex decision support system application for roof installation methodology. This analysis was based on a created database of roof design variants. The methods applied are as follows:analysis of geomtery of roof, scientific literature and other information sources, study of decision support systems, analysis of its application cases, and the modelling of decision support system for the roofing. The authors of this work established the goal - to make a feasibility study of the complex decision support system for roofing. The assessment of such system's creation methodology, parameters used in the system, indicators and the analysis of practical aspects of the application of the the system were made. Based on the analysis, the authors proposed the complex decision support system model.

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ACADEMIC EXCHANGE BETWEEN BALTIC UNIVERSITIES AND KOBE UNIVERSITY

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Abstract. For long years, Baltic cities and Kobe city had strong relationship at administrative aspect and academic aspect. Recent several years, the relationship has been recognized again and started cooperative activities again. And there are some cooperative plans in future. In this paper, authors would like to explain history and starting/restarting chance of relationship between Baltic university and Kobe University, cooperative activities in recent years, and cooperative activities at now and in future.

Keywords: Academic Exchange, Vilnius Gediminas Technical University, Riga Technical University, Kobe University, Graphic Science, Cooperative Activities

1. History and starting/restarting chance of relationship between Baltic Universities and Kobe University

In 1991, faculty level agreement of academic exchange was established between Riga Technical University (hereafter, RTU) and Kobe University (hereafter, KU). For KU side, dean of faculty of Engineering signed on the document, and for RTU side, deans of following five faculties were signed on the document as shown in Fig. 1.

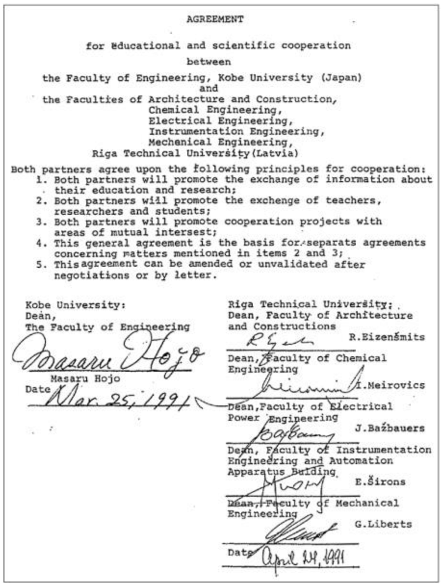
- Faculty of Architecture and Constructions
- Faculty of Chemical Engineering
- Faculty of Electrical Power Engineering
- Faculty of Instrumentation Engineering and Automation Apparatus Building
- Faculty of Mechanical Engineering

Promotion of cooperative activities in the field of education and research was described in the document.

Earlier than establishment of academic exchange agreement, Riga city and Kobe city established sister city agreement in 1974. Kobe city sent clock tower in 1993 to celebrate independence of the Republic of Latvia and the tower is still located in Riga city now as shown in Fig. 2. Riga city and Kobe city has been keeping friendly relationship and had ceremonies celebrating anniversary of the agreement.

Comparing to sister city agreement, academic exchange agreement was not successful. After long time, the persons concerned with the agreement disappeared in both universities. If Dr. DOBELIS of RTU did not recognize existence of the agreement, it might be abolished as invalid agreement.

In March 2010, Dr. MAKUTĖNIENĖ of Vilnius Gediminas Technical University (hereafter, VGTU) came to Osaka Japan and visited Osaka City University and discuss about future cooperative activities between VGTU and Osaka City University in the field of graphic science when SUZUKI was a staff of graphic science education in the university. As shown in Fig. 3, Dr. MAKUTĖNIENĖ also visited Osaka University to experience virtual reality system.



AGREEMENT

for Educational and scientific cooperation
between
the Faculty of Engineering, Kobe University (Japan)
and
the Faculties of Architecture and Construction,
Chemical Engineering,
Electrical Engineering,
Instrumentation Engineering,
Mechenical Engineering,
Riga Technical University (Latvia)

Both partners agree upon the following principles for cooperation:
1. Both partners will promote the exchange of information about their education and research;
2. Both partners will promote the exchenge of teachers, researchers and students;
3. Both partners will promote cooperation projects with areas of mutual intersest;
4. This general agreement is the basis for separats agreements concerning matters mentioned in items 2 and 3;
5. This agreement can be amended or unvalidated after negotiations or by letter.

Kobe University:
Dean,
The Faculty of Engineering
Masaru Hojo
Masaru Hojo
Date Mar. 25, 1991

Riga Technical University:
Dean, Faculty of Architecture and Constructions
R.Eizenšmits
Dean, Faculty of Chemical Engineering
I.Meirovics
Dean, Faculty of Electrical Power Engineering
J.Bažbauers
Dean, Faculty of Instrumentation Engineering and Automation Apparatus Bulding
E.Širons
Dean, Faculty of Mechanical Engineering
G.Liberts
Date April 24, 1991

Fig. 1. Document of academic exchange agreement between RTU and KU (1991)

Fig. 2. Memorial clock tower sent from Kobe city (1993)

eISBN 978-609-457-835-9
http://doi.org/10.3846/baltgraf.2015.020

Fig. 3. Dr. MAKUTĖNIENĖ trying to experience virtual reality system in Osaka University (2010)

Fig. 4. A group photo taken at the 14th International Conference on Geometry and Graphics (2010)

Fig. 5. SUZUKI visiting VGTU to proceed the process of academic exchange agreement (2013)

Fig. 6. A shape of traditional Puzurs

In August 2010, Dr. DOBELIS visited Kyoto Japan to participate the 14th International Conference on Geometry and Graphics held in Kyoto University as shown in Fig. 4. Dr. DOBELIS and SUZUKI got to know each other at the conference and discuss about future cooperative activities.

These visits from Baltic countries to Japan were starting and restarting chance of relationship between Baltic Universities and KU.

2. Cooperative activities between Baltic Universities and KU in recent years

2.1. Establishment of academic exchange agreement between VGTU and KU

After SUZUKI moved from Osaka City University to KU in October 2010, SUZUKI realized significance of cooperative activities beyond a university because worldwide topics in liberal arts education were highly required in KU. Therefore, Dr. MAKUTĖNIENĖ and SUZUKI started discussion to establish academic exchange agreement. After long discussion, SUZUKI visited VGTU to received official document with signature of Dr. Rimantas BELEVIČIUS, dean of the Faculty of Fundamental Sciences as shown in Fig. 5. After process of KU side, the exchange agreement was officially established on 26th March 2014.

2.2. Exhibition titled ‘Riga Days in Kobe’

Dr. DOBELIS and SUZUKI also agreed with strengthening a relationship between RTU and KU in the field of graphic science. As the year 2014 was the 40th anniversary of sister city agreement between Riga city and Kobe city, Kobe city government had decided to have several events in Kobe city. One of the event was exhibition titled ‘Riga Days in Kobe’ held from 12th to 17th June. Dr. DOBELIS and SUZUKI decided to have a corner titled ‘Adventure of Light and Shape –Exhibition of Academic Exchange between Riga Technical University and Kobe University-’ in the exhibition and exhibit academic exchange panel in the event.

Considering theme of exhibition ‘Adventure of Light and Shape’, each university made panels explaining relationship between culture and light/shape. RTU selected Puzurs (see Fig. 6.), regular octahedron ornament, as a subject of the panel. Puzurs is constructed at solstice and equinox day or at ceremonial occasions. Following text is summary of explanation of Puzurs on the panel made by RTU.

For centuries culture and traditions has been inalienable part of Latvian identity. Through songs, dances, festivals and celebrations in national costumes people still keep alive the spirit of our ancient philosophy.

The changes of seasons – solstices is the most important events of the year. Changes in nature are closely bound with lifecycles and there is on key for all of them. ”Puzurs” is a symbol of beginning and ending, ancient knowledge compares it with a model of universe. It is a part of all solstice rituals and most important moments of people lives such as the time of birth and wedding.

In Baltic region Puzurs was known long before first arrival of Christian missionary. Ancient historical research indicates the period of early agriculture as the origin moment of Puzurs. More than four thousand years ago Latvian peasants made "Puzurs" of the cereal stem at the end of the summer season. At the beginning it was symbol of welfare but in the same time it contained the philosophy of the space and time. Three dimensional structures of "Puzurs" consist of vertical axis which signifies the time line - past, present and future. The horizontal axis defines four angles. Each of them symbolizes one solstice ritual in summer, autumn, winter and spring time. One complete module of "Puzurs" is made of 12 elements. According to earliest Latvian calendars one year consisted of twelve months.

Order of the solstice rituals were closely bound with lifecycle of the people. Worldview and sense of the Nature in ancient Latvian civilization describes the expression: "Universe has the order but it is not static. It is moving all the time."

Basic module of ”Puzurs” is made of dry straw, cereal stem or reed which is cut in pieces of correct size – structural elements. Then all the pieces are joined by wool yarn. One ”Puzurs” can be made from 12 up to 600 elements. The crystalline structure of the "Puzurs" basic module is the same as the atomic structure of carbon.

The structural complexity of the "Puzurs" depends of the creativity. Range of different shapes and elemnts is wide. Starting from simple and ascetic "Puzurs" which is made only from 12 reed elements, and ending with composition of diverse structures which combined with adornment of feather, dry bent-grass or yarn tassels.

In spite of that traditional "Puzurs" itself have never been used as a daily lighting source, in some regions it is called - lantern. To be correct, "Puzurs" lights up only for one time in its lifetime.

Lifetime of this delicate and complex structure is not long. Usually for three evenings ”Puzurs” is swinging over the room guarding from darkness and malice. Lighted by open fire it is making incredible shadow images on the wall. After the mission is completed ”Puzurs” is burnt in the fire. This moment is the end and the beginning of one period of life.

On the other side, KU selected Andon, Japanese traditional lampstand, as a subject of the panel. History of light source, history of Andon and shapes of traditional Andons were described on the panel. In addition to traditional Andon, some of geometric

Andons made by 3DCAD, 3D printer and paper folding were introduced also as shown in Fig. 7. And many geometric Andons constructed by KU graduate school students were exhibited at the corner as shown in Fig. 8.

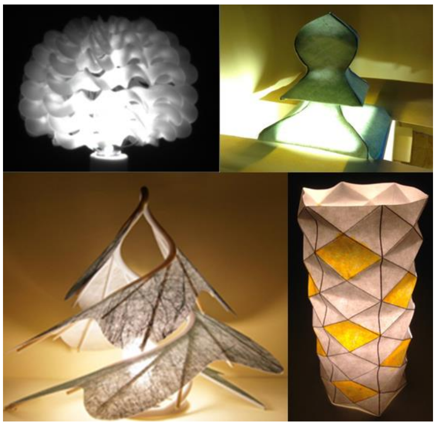


Fig. 7. Geometric Andons explained on panel

Fig. 8. Exhibited geometric Andons constructed by KU graduate students

At the corner, KU held Andon craft workshop. The shape of Andon derived from Kobe port tower, one of famous symbol architectures in Kobe city. The shape of Kobe port tower is perfect hyperboloid of revolution of one sheet. As shown in Fig. 9, plastic bottles, papers and drinking straws were selected as material of craft Andon for primary school students, junior high school students and high school students. Fig. 10 shows Andons crafted by participants of the workshop.

Fig. 9. Flyer of Andon craft workshop

Fig. 10. Andons crafted by participants of Andon craft workshop

2.3. BALTIC - KOBE University Engineering Graphics Education Seminar 2014

A seminar titled ‘BALTIC - KOBE University Engineering Graphics Education Seminar 2014’ was held on the 3rd November 2014. The purpose of the seminar was promotion of mutual cooperation between Baltic universities and KU in the field of graphic science. Dr. MAKUTĖNIENĖ, Dr. DOBELIS, Dr. ODAKA of KU and SUZUKI participated the seminar to report and discuss graphic science education in each country and future works as shown in Fig. 11. And a class with exercise titled ‘Graphic science education for manufacturing making good use of paper folding’ was performed as shown in Fig. 12.

Fig. 11. Engineering Graphics Education Seminar 2014

Fig. 12. Class with exercise of graphic science Education for manufacturing

2.4. Lectures in RTU and VGTU

Dr. ODAKA and SUZUKI visited RTU on the 5th November 2014 to present lectures. After courtesy visit on Dr. Uldis SUKOVSKIS, vice rector of RTU, and Dr. Igors TIPANS, deputy rector of RTU (see Fig. 13), SUZUKI made presentation with exercise making use of paper folding to teach basis of differential geometry and laws of illuminance, and Dr. ODAKA explained content of graphic science education in KU as shown in Fig. 14.

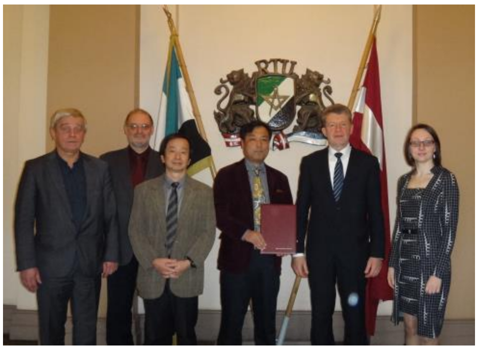


Fig. 13. Courtesy visit at RTU

Fig. 14. Lectures at RTU

Dr. ODAKA and SUZUKI also visited VGTU on the 7th November 2014. After courtesy visit on Dr. Antanas ČENYS, vice rector of VGTU and Dr. Rimantas BELEVIČIUS, dean of the faculty of fundamental sciences of VGTU (see Fig. 15), SUZUKI and Dr. ODAKA made same presentation as those in RTU as shown in Fig. 16.

Fig. 15. Courtesy visit at VGTU

Fig. 16. Lectures at VGTU

2.5. Acceptance of a researcher of RTU in KU

KU accepted Dr. VEIDE from 10th to 22nd Mar. to promote cooperative activities between RTU and KU. Within 13 days stay, Dr. VEIDE participated following activities.

- Courtesy visit on Dr. Matsuto OGAWA, dean of graduate school of engineering.
- Courtesy visit on Dr. Ryuji KURODA, chairman of department of architecture.
- Lecture meeting at headquarters of Japan society for graphic science in the University of Tokyo Komaba campus (See Fig. 17).
- Gathering of information about relationship between geometry and Japanese culture at Tokyo National Museum.
- Study tour to Osaka University to learn high resolution huge display (See Fig. 18).
- International seminar on algorithm design held at Kyoto University.
- Exercise of paper folding to craft Andon in KU (See Fig. 19).
- Lecture meeting at KU (See Fig. 20).

Fig. 17. Lecture meeting at headquarters of Japan

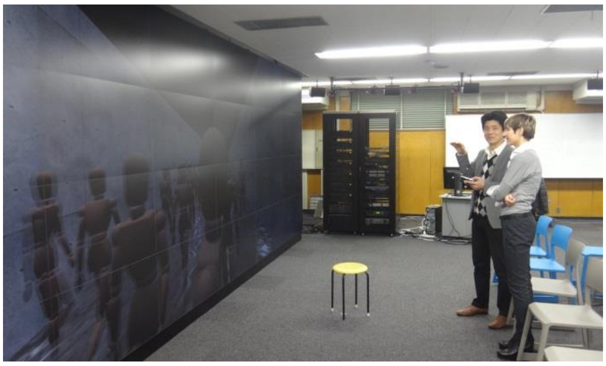


Fig. 18. Study tour to Osaka University society for graphic science

Fig. 19. Exercise of paper folding to craft Andon

Fig. 20. Lecture meeting at KU

As a series of cooperative activities between RTU and KU were evaluated by each University, agreement of academic exchange was decided to be promoted from faculty level to University level on 25th Feb. 2015, Dr. VEIDE received the document of academic exchange agreement at courtesy visit on Dr. OGAWA as shown in Fig. 21.

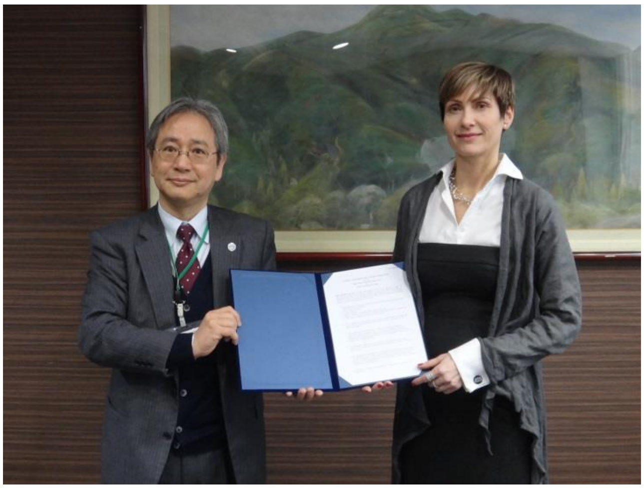


Fig. 21. Courtesy visit on Dr. Matsuto OGAWA to receive document of academic exchange agreement between RTU and KU.

In the lecture meeting at the University of Tokyo and KU, Dr. VEIDE made two lectures titled ‘Engineering Graphics Education in Riga Technical University’ and ‘Latvian Culture and Geometry’ In the first lecture, transition of engineering graphics education including hand writing education was explained as shown in Fig. 22 and Fig. 23. And in the second lecture, geometric pattern in traditional belts design in Latvia (see Fig. 24), project about new design method making use of binary system and description of Puzurs (see Fig. 25) were explained.

Milestones of EG Change in Curricula – Contact hours

Faculties or	1977-1979	1993	1997/98	From 2002
Study Programs	Pure PAD	PAD & CAD	PAD, CAD and BIM	PAD, CAD and BIM
Mechanical Engineering	**177 h= 34 L + 143 P**	**32 h 16 L + 16 P**	**32 h= 2 CP**	**32 h= 2 CP**
Civil Engineering	**170 h= 34 L + 136 P**	**32 h= 16 L + 16 P**	**32 h= 2 CP**	**64 h= 4 CP**
Architecture and Urban Planing	**180 h**	**80 h**	**64 h= 4 CP**	**64 h= 4 CP**
Chemical Engineering	**85 h = 17 L+ 68 P**	**32 h**	**32 h= 2 CP**	**32 h= 2 CP**
Telecommunication Engineering	**85 h = 17 L+ 68 P**	**32 h**	**32 h= 2 CP**	-
Electrical Engineering	**85 h = 17 L+ 68 P**	**32 h**	**32 h= 2 CP**	-
Engineering Economics	**85 h = 17 L+ 68 P**	**32 h**	**32 h= 2 CP**	-
Computer Science	**85 h= 17 L+ 68 P**	**32 h**	**32 h= 2 CP**	-

L – Lecture, P – Practical Session
Plus the same amount hours for homework

CP - Credit Point, 1 CP=1 contact hour/week
1 CP = 40 hours total

Fig. 22. Transition of engineering graphics education in RTU

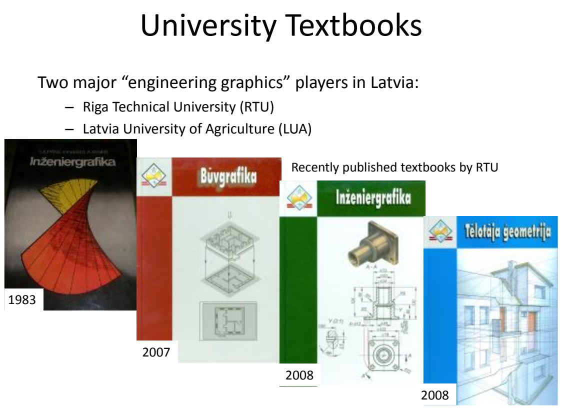
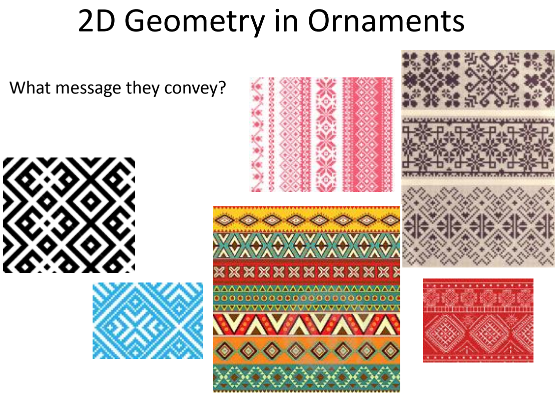


Fig. 23. Course textbook of engineering graphics education in RTU



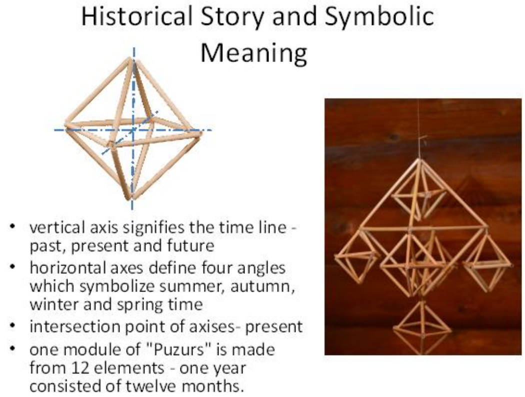


Fig. 24. Geometric pattern in traditional belts design in Latvia

Fig. 25. Description of Puzurs

3. Cooperative activities between Baltic universities and KU at now and in future

From 25th to 26th June 2015, SUZUKI will visit VGTU to join BALTGRAF. In the conference, SUZUKI will make two presentations titled ‘SKEW QUADRILATERAL MEMBRANE FOLDING FOR LAMPSHADE DESIGN’ and ‘ACADEMIC EXCHANGE BETWEEN BALTIC UNIVERSITIES AND KOBE UNIVERSITY’. In the second presentation, history and detailed content of cooperative activities between Baltic Universities and KU will be explained.

And Dr. MAKUTĖNIENĖ and SUZUKI will discuss practical method of lecture exchange at the time. Lecture exchange was one of future cooperative activities which were discussed when SUZUKI visited VGTU in 2013. As liberal arts education, lecture of relationship between culture and shape by native lecturers should be attractive and useful for University students. At first, online class was considered as method of lecture exchange. However, exchange of movie lecture was adopted later considering unexpected troubles of network and information devices. As shown in Fig. 26, movie recorded at KU is already completed with the help of KU School of Languages and Communication (SOLAC). The educational material is composed by two movies. The first movie is about 10 minutes long including history of cooperative activities between VGTU and KU, history

eISBN 978-609-457-835-9

of light source and Andon, and basis of illuminance calculation method. The second movie is about 15 minutes long including explanation of basic differential geometry and exercise of Andon crafting. Bilateral network of graphic science education between VGTU and KU must be expanded multilateral network in the world in future.

Fig. 26. Movie for lecture exchange

Conclusions

In this paper, authors explained history and starting/restarting chance of relationship between Baltic universities and KU, cooperative activities in recent years, and cooperative activities at now and in future. Authors would like to keep current strong relationship in future and transfer it to younger generation.

Acknowledgements

Authors would like to thank the persons concerned with establishment of academic exchange agreement, the persons concerned with the event ‘Riga Days in Kobe’, the persons concerned with the seminar titled ‘BALTIC - KOBE University Engineering Graphics Education Seminar 2014’, the persons concerned with the events for Dr. VEIDE and the persons concerned with movie recording for lecture exchange.