International
Association
BALTGRAF

ENGINEERING GRAPHICS BALTGRAF-14

Tallinn
University of Technology
2017

Engineering Graphics BALTGRAF-14
Proceedings of the Fourteenth International Conference
Tallinn, Estonia, June 1-2, 2017

The responsibility for language use rests upon the authors

Publisher: Tallinn University of Technology
Managing Editor: Tea Hunt

ORGANIZERS

BALTGRAF president - Assoc. Prof. Daiva Makuténiené *PhD*

Chairperson of BALTGRAF-14 - Tea Hunt *MSc*

Chairman of Organization Committee - Harri Annuka *PhD*

Chairman of Scientific Committee - Rein Mägi *PhD*

Secretary of Organization Committee - Külli Meister *MSc*

International Programme Committee

Harri Annuka	Tallinn University of Technology (Estonia)
Aleksandr Brailov	Odessa State Construction and Architecture Academy (Ukraine)
Modris Dobelis	Riga Technical University (Latvia)
Jolanta Dzwierzynska	Rzeszow University of Technology (Poland)
Tea Hunt	Tallinn University of Technology (Estonia)
Birute Juodagalviené	Vilnius Gediminas Technical University (Lithuania)
Urmas Jüriorg	CAD-süsteemide OÜ (Estonia)
Peeter Kukk	Estonian National Defense College (Estonia)
Harri Lille	Estonian University of Life Sciences (Estonia)
Daiva Makuténiené	Vilnius Gediminas Technical University (Lithuania)
Vidmantas Nenorta	Kaunas University of Technology (Lithuania)
Aurika Nõmm	Tallinn University of Technology (Estonia)
Raido Puust	Tallinn University of Technology (Estonia)
Claus Pütz	Aachen University (Germany)
Algirdas Sokas	Vilnius Gediminas Technical University (Lithuania)
Hellmuth Stachel	Vienna University of Technology (Austria)
Silvia Titotto	Federal University of ABC Sao Paulo (Brazil)
Ana Usovaitė	Vilnius Gediminas Technical University (Lithuania)
Sonata Vdovinskiené	Vilnius Gediminas Technical University (Lithuania)
Daniela Velichová	Slovak University of Technology in Bratislava (Slovakia)

CONTENTS

AUTHOR LISTING (18 authors)

COMPUTER AIDED DESIGN

RECONSTRUCTION OF 3D DATA FROM PHOTOGRAPHIC IMAGES

Daniela Velichová[1]

1. ABSTRACT

Process of analytic reconstruction of 3D real data of selected objects from photographic images is presented in the paper, using software application CamWitt. Algorithm for calculation of real dimensions is based on geometric principles of photogrammetry. Various solutions improving accuracy of the resulting real data are described, in addition to 3D visualisation GeoGebra applet for understanding proposed corrections to algorithm and their geometric interpretation. Methods of underlying principles of epipolar geometry are presented in brief.

KEYWORDS: photogrammetry, 3D reconstruction, epipolar geometry

2. INTRODUCTION

Results of the project of the Slovak Research and Development Agency APVV-1061-12 entitled „Determination of geometric characteristics of objects obtained from criminological relevant image recordings" are presented in the paper. Project is coordinated by the Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, with partners at the Faculty of Civil Engineering, STU and Criminological and Expertise Institute of Ministry of Defence of SR. Project aims to development of a correct and precise algorithms for processing of geometric characteristics and reconstruction of dimensions and position of selected objects in three dimensional scenes using principles of photogrammetry.

3. BASIC INFORMATION

Analysis was performed of criminological relevant image recordings obtained from on purpose installed stable camera systems with known calibration data. An interactive tool CamWitt was developed for filtration of data recordings, automatic detection of objects in these images and exact determination of dimensional and positional characteristics that enabled correct identification of recorded objects and their real dimensions. Used methods are extensively tested before they can be applied in the criminological practise, in detection of criminal acts, in collection and analysis of proofs of evidence recorded on images and during identification of suspected criminals. Several supportive digital tools were developed in order to analyze inaccuracy that might occur in the calculations of real dimensions from image data. One of them is the 3D visualisation GeoGebra applet for performing two different central projections of an object from different centres located in given distance. Basic principles of epipolar geometry are presented here in their geometric representation, which are underlying the classical photogrammetric methods applied in analytic form in the developed algorithm, see in Fig. 1.

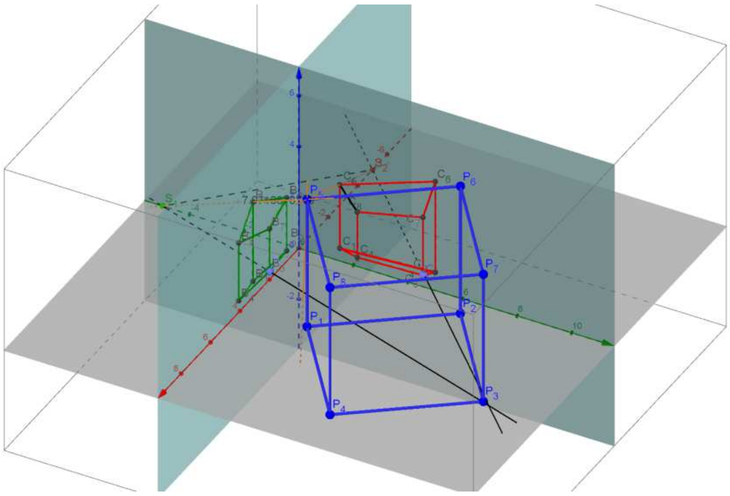


Fig. 1. Two central projections of a cube from two different centres.

Calculation of real 3D Cartesian coordinates of points detected from a photographic view is realized by means of algorithms based on properties of central or linear perspective, that are projective transformations represented in matrix form. Each central projection or photographic mapping defines a particular coordinate system in space, called the camera frame. Its origin is placed at the centre of projection, the principal ray of the camera is the *z* coordinate axis, and the principal directions in the photography image plane serve as *x* and *y* coordinate axes spanning the vanishing plane of

[1] *Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Námestie slobody 17, 812 31 Bratislava, Slovakia, e-mail: daniela.velichova@stuba.sk*

this central projection. Then the central projection in homogeneous coordinates denoted $(x_0\colon x_1\colon x_2\colon x_3) = (1\colon x\colon y\colon z)$ is expressed as a linear mapping determined by the focal distance d.

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & d & 0 & 0 \\ 0 & 0 & d & 0 \end{pmatrix} \cdot \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix}$$

Inverse problem, in which coordinates of points on the real object in space are calculated from plane coordinates detected in the central images of respective points, is the background of the analytic algorithm. Projection lines from the two given centres, so called epipolar lines of projection are lines intersecting in the mapped point located in the space, see Fig. 1. Image coordinates are detected always with certain errors, due to various reasons (manual data collection, size of analysed picture and its precision, contrast and resolution, etc.), which are reflected in different position of epipolar lines that might be intersecting in points not corresponding to real original points mapped in the central images, from which the views were detected. Lines can be either intersecting in points inside or outside the mapped object, as can be seen in Fig. 2. and Fig. 3., or in the worse case these two lines can be skew and not intersecting in a real point at all.

For obtained skew lines, when there is no solution of the inverse problem, additional algorithm had to be implemented. Corresponding point is calculated as the centre of the axis of respective skew lines. This means that line perpendicular to both skew lines and intersecting both of them is determined. Then, centre of symmetry of the two intersection points on skew epipolar lines, i.e. point in the minimal distance to both skew lines is determined as the corresponding point at the reconstructed real space object.

Several other attempts to improve precision of calculation of the real coordinates of points on selected reconstructed objects were analysed, dealing with information on photographic images, as e.g. position of the principal point (view of the centre of projection) in the two images, distance of the two centres of projection, and others. Impact on achieved accuracy of results was analysed, namely relation to inaccurate dimensions in direction of different coordinate axis. On the basis of this analysis some further improvements to algorithm will be introduced.

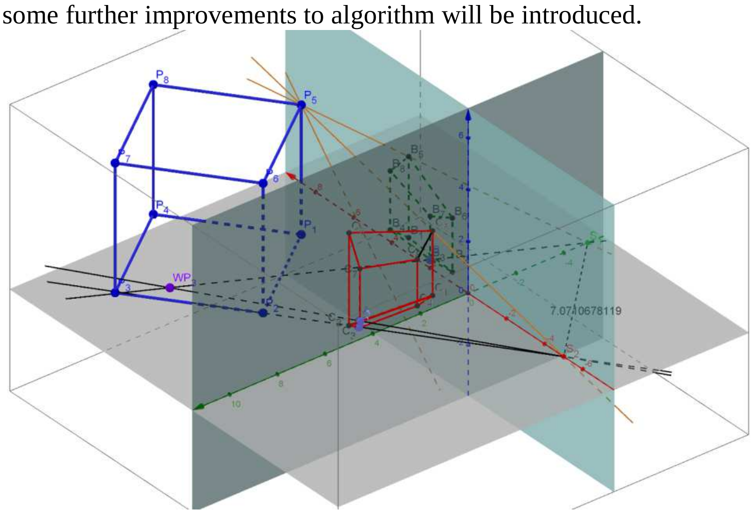


Fig. 2. Incorrectly meeting epipolar lines inside mapped cube.

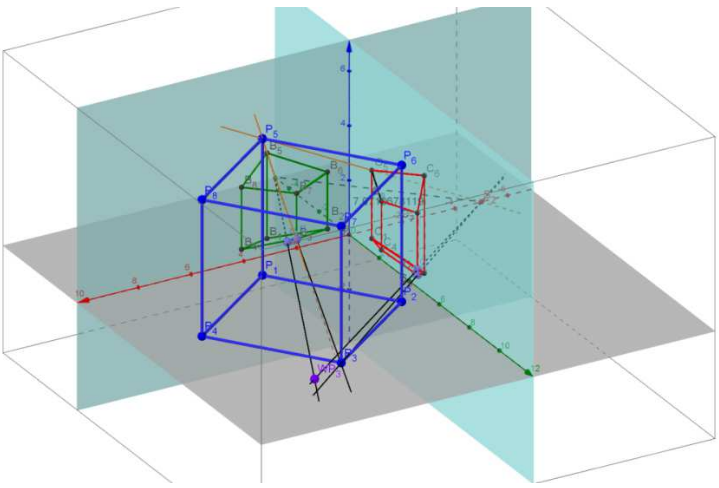


Fig. 3. Incorrectly meeting epipolar lines outside mapped cube.

CamWitt is a newly developed tool for 3D reconstruction. It is useful for automatic detection of objects in the recordings and precise determination of dimensional and positional characteristics. It enables reliable identification of depicted objects. In Fig. 4. the user interface of the CamWitt application is depicted, with two photographic images of a real 3D scene. User can manualy detect at least 9 corresponding points in the two windows with images. Then system automatically calculates the camera calibration and inner picture calibration and finds the inverse projection matrix. Coordinates of the real points in 3D are calculated from this matrix, while all results appear in the pop-up window.

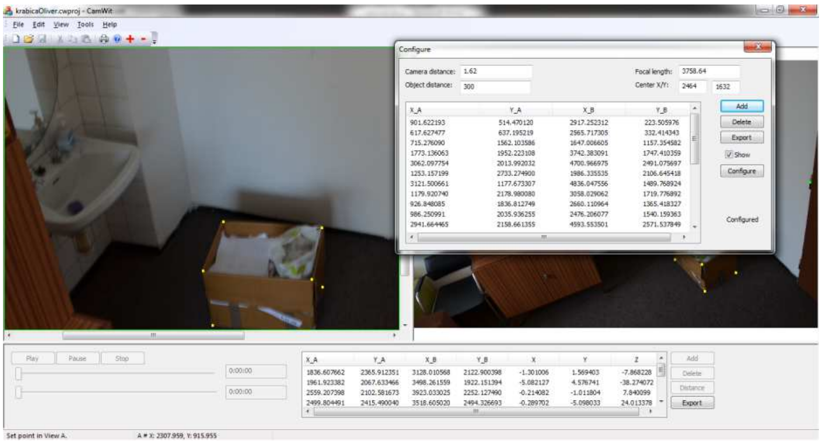


Fig. 4. CamWitt application interface

The presented methods are to be introduced in the criminological praxis, for investigation of acts of crimes. They will help in collecting and analysis of proofs of evidence recorded on video-cameras or on two stable cameras, or received from any other relevant recordings of 3D scene images, for the aims of identification of criminals and committed criminal acts.

Results of the presented project will be further generalised. Project team is now working on development of algorithms of videogrammetry, which is a new arising discipline aimed on reconstruction of objects detected on video-records that are taken from stable camera systems installed in surveyed areas. Such systems are used for emergency reasons in many public spaces, as e.g. shopping centres, airport, cultural premises, official buildings as government and parliament buildings, but also in banks and insurance companies.

4. CONCLUSIONS

Analysis and results of the project „Determination of geometric characteristics of objects obtained from criminological relevant image recordings“ were presented. Based on photogrammetric methods represented in analytic form, an algorithm for calculation of real three dimensional data of selected objects on two photographic images was developed, aiming to precise reconstruction of object dimensions and position in the space. Several methods for improving the accuracy of obtained calculation results were presented, together with GeoGebra applet visualising the geometric background of central mapping of 3D scene to two different planes from two different centres.

Acknowledgements

This paper was financially supported by grant from the Slovak Research and Development Agency awarded to the project APVV-1061-12 entitled "GEOCRIM - Determination of geometric characteristics of objects obtained from criminological relevant image recordings".

5. REFERENCES

1. Stachel, Hellmuth. Descriptive Geometry Meets Computer Vision. Journal for Geometry and Graphics, Vol. 10 (2006), No. 2, p. 137-153.
2. Velichová, Daniela. Basics of Videogrammetry. Proceedings of the 23[nd] International Symposium on Computer Geometry SCG´2014, SSGG, Bratislava 2014, SR, ISBN 978-80-227-4256-6, p. 84-88.
3. Velichová, Daniela. Videogrammetry and One of Its Applications. Scientific Proceedings of the 13[th] International Conference on Engineering Graphics BALTGRAF-13, Vilnius, Lithuania, 2015, eISBN 978-609-457-835-8, p. 23-28.
4. Velichová, Daniela. Reconstruction of 3D Object Dimensions from Videorecords. Proceedings of Aplimat, the 16[th] International Conference on Applied Mathematics, Bratislava 2017, ISBN 978-609-457-835-8, p.
5. Yi, Ma; Soatto, Stefano; Košecká, Jana; Sastri, Shankar. An Invitation to 3D Vision, Springer-Verlag, New York 2004.

3D MODELLING OF EXISTING BUILDINGS FROM LASER SCANNER DATA

Modris Dobelis[1], Māris Kaļinka[2], Anatolijs Borodiņecs[3]

ABSTRACT

A growing attention to improve the building's thermal performance has initiated an increasing demand of innovative retrofitting solutions for existing houses [1]. Advancements in contemporary CAD and CNC manufacturing technologies allow the use of modular prefabricated insulated wood frame panels for this purpose as one of the possible solutions. More and more widely used Building Information Modelling (BIM) concept with its' parametric modelling capabilities allows to assess the outcomes of the results of preliminary building energy performance analysis and later coordinate these complex and complicate processes much easier and cheaper. As one of the key components in the solution of this problem is fast and precise acquisition of 3D geometry of the building. A digitally restored 3D model of existing building serves two purposes. One is a comparison of energy analysis before and after reconstruction by means of digital simulation methods when the selected type and/or variant of insulation solution are applied. The use of BIM concept in building industry allows fast and easy assessments of several possible solutions considered within the same parametric BIM model and finally choose the most advantageous. The second purpose is an elaboration of a subsequent detailed structural design of the selected optimal solution, which could be streamlined directly from CAD software to CNC fabrication.

This research was aimed towards reconstruction of BIM compatible 3D geometric model from laser scanned data that captures the building's external envelope with main openings. To capture the existing buildings' envelope a 3D laser scanner was used in this study. Laser scanning is getting increasingly wider application in many engineering solutions, like visual preservation of values of cultural heritage, geospatial and survey industries, architecture, mining industry, building infrastructure, archaeology capturing complicate plant systems as-build, etc. The present research focuses to the capture of building 3D geometric data in a BIM compatible format, which later may be used for energy analysis purposes during the renovation project and structural design of insulation systems.

A laser scan data at the building site was post-processed with software to comply with BIM concept. A tracing of 3D geometry of building was performed with a point cloud data as a reference. Manual, semi-automatic or automatic processes may be used to trace the external envelope of the building with required openings. Major developers of BIM software, applicable for these tasks are Autodesk, Bentley, and Nemetscheck. More widely used are the first two, therefore, in our study a Revit from Autodesk and an ArchiCAD from Graphisoft were tested for creating BIM compatible 3D from the scanned data of two-story building. A general workflow in both cases is very similar with minor variations depending on a performance of a software used for this purpose. The paper describes the approach used in the study, and the assessment of the results obtained.

Keywords: 3D Model, BIM, CAD, 3D Laser Scanning, Energy Analysis

1. INTRODUCTION

3D laser scanning techniques have been developed since the end of 1990s for 3D digital measurement, documentation and visualization in many fields of engineering [2-3]. Recent advances in hardware technology and increased BIM software performance are helping to overpass to a new level of scanning application for the building industry. The leading scanner manufacturers claim that scanning technology is becoming a critical function necessary to complete the integrated BIM cycle efficiently and provides a clear value-add for the integrated BIM workflow [4].

The captured 3D building model serves two purposes. One is for energy analysis before and after reconstruction when the selected type and/or variant of insulation solution are applied. The second goal is an elaboration of a detailed structural design for the selected solution, which can be later streamlined from CAD software directly to CNC fabrication site. Many project subcontractors are very sophisticated in their ability to create physical work assemblies in off-site locations and then bring them on-site in large clusters for rapid installation. Prefabrication offers many benefits, but can only be successful when used in conjunction with accurate information about the destination of the final installation, which laser scanning can provide much faster [4].

2. CREATING AS-BUILT MODELS

The forming of as-built model is a process of creation of objects that represent building elements, including both geometric and non-geometric attributes and relationships. If BIM is modelled on the basis of previously captured building information, the preceding data capture, processing and recognition methods influence data quality through the deployed technique and the provided level of detail [5].

Numerous plug-in or add-on software modules have been developed so advanced that it is possible to import and process large scanning data file directly into the end user software. In addition, many hardware producers now are

[1] *Dep. of Computer Aided Engineering Graphics, Riga Technical University, Ķīpsalas iela 6A, LV-1048, Riga, Latvia. e-mail: Modris.Dobelis@rtu.lv*
[2] *Dep. of Geomatics, Riga Technical University, Ķīpsalas iela 6B, LV-1048, Riga, Latvia. e-mail: Maris.Kalinka@rtu.lv*
[3] *Inst. Heat, Gas and Water Technology, Riga Technical University, Ķīpsalas iela 6A, LV-1048, Riga, Latvia. e-mail: Anatolijs.Borodinecs@rtu.lv*

trying to attract more customers, allowing their proprietary data formats convert into a neutral or not-protected file format, e.g. ASCII, in order to enable post-processing in many more various platform independent applications.

To choose an appropriate data export format one should consider which CAD software will be used in further workflow. Most of the popular CAD and BIM software packages, e.g. Autodesk AutoCAD, Autodesk Revit, Graphisoft ArchiCAD, and Bentley AECOsim Building Designer, allow direct import from scanners like Faro, Trimble or Leica using various data formats. They include xyz coordinates of the points, RGB colour, and point intensity. The only challenge is to follow the never ending version upgrades of CAD software, usually every year. When considering the application of special add-on or plug-in products from third party developers it is very important to analyse the compatibility issues. Sometimes the particular well documented module may not even work with a newer or older version of end user software for which it was originally developed.

Some registration software, such as Trimble RealWorks, has the capability to create content from within the point cloud by running special algorithms across the data points and recognizing surfaces directly from it [4]. Creating objects within the registration software offers the benefit of rapid creation but has some limitations surrounding the accuracy and metadata acceptance of modelled objects. Creation of object models using external authoring applications is slower with more manual work involved but has the benefit of detailed object representation and increased metadata acceptance.

In practice, as-built BIM modelling very often is done interactively in a time consuming and error-prone process [6-8], e.g. with the BIM compatible software from major vendors like Autodesk Revit, Bentley AECOsim, Graphisoft ArchiCAD, Trimble Tekla Structures or Nemetschek Allplan. The latest versions of this software provide powerful features for reverse engineering tasks and processing of captured point clouds. Although some allow the rapid generation of building floor plans or offer BIM integration, the depicted software solutions are far away from automated or semi-automated BIM modelling of existing buildings [5].

3. CASE STUDY – APARTMENT HOUSE

A typical two-story residential building was selected in a pilot study. There are several tools for building capture such as tachometry, 2D/3D geometrical drawings, and laser scanning. These tools require strong skilled personnel in order to model the existing buildings. First step is a recapture of building information with reverse engineering processes in terms of “points to BIM” or “scan to BIM” [5].

3.1 Laser scanning and data pre-processing

The building is located in a suburb territory of a small town Cēsis in Latvia and there were no concerns about how to eliminate pedestrian “noise” from the scan data. The building plot is single rectangle with rather simple facades having no tiny de-tails. Therefore the number of scan station lo-cations was basically determined only by the amount of adjacent greenery and interfering objects like cables, and etc. The laser scanning of the building was performed from nine positions (Figure 1) with phase shift technology scanner FARO 3D 120. The scanning work was carried out during on-site visit on a well-lit day without precipitations.

Figure 1. Nine scanner positions for two-story residential house.

Altogether 18 registration marks or spherical reference targets were used. The average distances between scan points on the walls were 5 mm. The scanning time in each scanner position took about 7 minutes. The actual time spent on-site for the equipment setup, calibration and data acquisition from the arrival until the departure in this study was about 6 hours. Information about geo-referencing (orientation, location and elevation) of the site along with the neighbourhood characteristic (soil type, trees, nearby buildings, etc.) required for further energy analyses was documented during the same day visit. All the procedures were performed by two persons.

Some of the metadata may be stored directly in the point cloud file format, or may be linked to the point cloud for later use in BIM models. The existing plan views and sections for the building were collected in an analogue format (blueprints) from the available inventory documentation and then digitalized.

The data sets with about 400 million points from all scanning positions were downloaded from the scanner. Pre-processed raw scan data as point clouds were positioned and oriented in their own coordinate systems. Merging or stitching together all the point clouds in a single coordinate system was performed by Faro Scene software on a network.

Not all the scan points in the data set may be used because of existing noise captured accidentally. For the cleaning noise points Faro Scene and Leica Cyclone software was used. The process took about 4 hours and included deleting outliers, unifying the scan points to delete double points, unifying the space between the points, and cleaning off the noise of neighbouring objects like trees, bushes, cables, etc. All the adjustments in the post processing stage resulted in 3 mm accuracy with respect to the station. It took another 4 hours to perform checking the convergence between the scan positions, checking the conformity of the reference dimensions for e.g. windows, doors or corners with different survey methods (total station, tape measure or laser distance measuring tool). In the present study the checked dimensions are between 5-10 mm.

Raw data obtained by laser scanning are referred as point cloud, which is a set of vertices in a 3D coordinate system. These vertices define or digitally represent xyz coordinates of the points of the external surface of the building. For most of the phase-based scanners, the raw scanning data are combined as both point and intensity, so the corresponding intensity image in both 2D and 3D can be obtained, which is useful for more detailed documentation and identification of objects. Data are stored in *.pts or *.e57 formats and examples of this representation are shown in Figure 2.

3.2 Data post-processing

The post-processing using software may be performed in two different ways – with specially developed software, or importing into specialized software. The first is dedicated for particular tasks and can process large amounts of scanning data, and create different results, including support for a CAD model, mesh-model, cross-section, etc. The results later can be exported into other systems, such as CAD, GIS, BIM or other user-familiar systems for different applications.

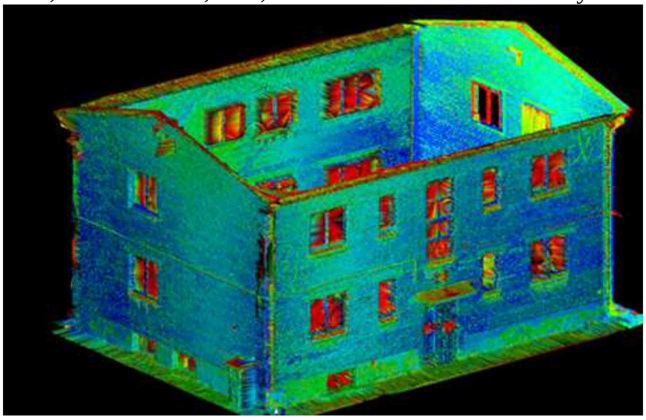


Figure 2. Surface model of a building visualized in Leica Cyclone software.

The most popular surface generation method is a triangulation. For this purpose different type of software may be used: post-processing (Farro Scene, Leica Cyclone, etc.), CAD soft-ware (Autodesk, Bentley, etc.) or specialized for surface generation (MeshLab, Geomagic Studio, 3DReshaper, etc.).

The triangulated surface mesh is quite complex and problematic for the use in most popular CAD formats because of model size (>100 MB). It was decided to use additional software and convert the mesh surface model into patch model (Geomagic Studio) or SmartSurface model (Bentley). The software uses other surface interpolation algorithms and after transformation the obtained surface models are much simpler and smaller, and easier for analysing the deviations from the exact geometry.

The existing information captured as point cloud data usually has a higher accuracy than the existing pre-construction drawings in blue-print format. Therefore the created 3D surface meshes can be used to create deliverables in the form of 2D drawings which may be imported into wide range of CAD or BIM applications. 3D model deliverables should be created using standard formats, such as *.ifc, or common ex-change formats like *.dxf to allow clients to retain as much data intelligence as possible. However, mesh models capture only the geometric properties of the building and are not suitable for direct use as BIM models.

Traditional 2D deliverables (plans, sections, elevations, details, etc.) can be generated directly from the point cloud data by taking virtual sections through the point cloud and generating drawings in conventional *.dwg or *.dxf format. The surface accuracy of point clouds is high, making this a superior method for reproducing existing conditions in comparison to manual measurements.

When the end deliverable of the visualization of the scanned environment is animated in fly-through mode, a HD quality movie files are easy available along with planned design features added. Using high definition point clouds the detailed 2D elevation drawings may be extracted that are delivered in *.dwg or *.dxf format or alternatively scaled ortho photograph elevations of the cleaned scan data. From the 3D laser scan data fully rendered visualizations can be pictured from any viewpoint to provide detailed graphics of existing structures or environments and optionally incorporated design elements. The results of thermographic measurement can be superimposed on the visualizations of the scanned building [9].

3.3 The capture of BIM model

The particular building elements in a BIM model are walls, slabs, foundation, roofs, windows, doors, and the soil of the terrain which is in contact with building foundation elements. None of the deliverables available in the 3D scan workflow described above provide a model in a BIM compatible format which is required for further studies.

Manual, semi-automatic or automatic pro-cesses for BIM model creation may be distinguished when capturing the external and/or internal elements of the building [9]. Some third party application designers have developed tools which are usable in Revit, ArchiCAD or AECOsim, and etc. software for automation of conversion process. However, according to [10] in practice a 3D model generation from point cloud data and setup for energy analysis so far is a time-consuming and labour intensive manual process subjected to numerous errors.

BIM models in this study were produced directly from the point cloud data. Autodesk Re-Cap freeware was used to cope with different scan data file formats (*.rcp, *.rcs, *.e57) to share the data with Revit or ArchiCAD software. The point cloud was adjusted to the zero level of the ground floor and the slab height was referenced with respect to the window sill and corresponding room height dimensions retrieved during the on-site visit.

An approach of manual BIM model production proved to be the most efficient and fastest workflow as compared to conventional on-site measurements. This method also minimizes efforts and time spent and cost of post-work when finding and fixing errors after automatic BIM model generation process [11].

Automatic process of BIM model creation has limited success due to some practical issues. One is related to the foundation settlement which in present study was almost 13 cm on the 10 m long base. The window openings are not strictly in vertical and horizontal directions anymore. Another factor preventing automatic recognition is that in practice the external walls very often are neither planar nor strictly vertical.

The identified cross sections in the point cloud at different story heights were used for existing external wall tracing. To create a medium fidelity BIM model the interior walls were also included in the model. The existing inventory plan drawings were digitally referenced to the BIM model and internal walls were manually traced over. Manually created as-is BIM model provides information at the required element level. They can be summarized by a small number of parameters therefore BIM model has the capability to supplement the 3D data with additional intelligent and semantic attributes before sharing it with other stakeholders. The prepared BIM model of the building (Figure 3) consists from parametric building elements with customizable semantic parameters for further analysis.

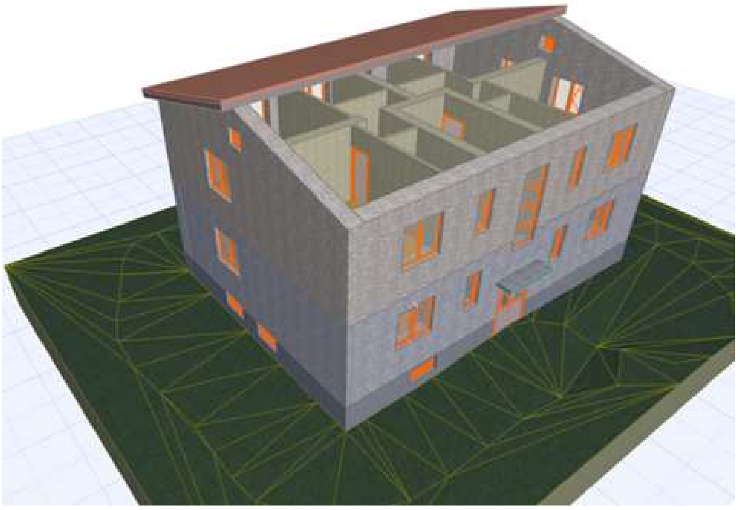


Figure 3. BIM model of building including terrain modelled in ArchiCAD.

Topographic surveys or geographic features surrounding a building are as important as BIM model itself. In the case of evident relief of the terrain it is possible to combine 3D scan data with existing LiDAR and GPS surveys to pro-vide topographical contours or other custom datasets. In this study the terrain was modelled with simple standard tools which are available either in ArchiCAD (Mesh) or Revit (Toposurface). The terrain interfering with the building foundation also carries physical properties.

4. CONCLUSIONS

A laser scanning is the fastest method of 3D data acquisition for the existing buildings. The selection of the scanner type and scanning setup depends on the architecture or geometric complexity of the building elements.

The accuracy of the points in the point cloud and average spacing between points in the pro-cessed point cloud is within 3 mm range. The accuracy of the surface model automatically generated from the point cloud with standard algorithms is within 5-10 mm.

The accuracy of a manually traced BIM model of the building highly depends on the accuracy of point cloud, the experience and skills of the modeller. The tested model was very simple therefore in the case of realistic and more complex buildings more precise scan data might be required.

ACKNOWLEDGMENTS

This work is part of the MORE-CONNECT project. This project has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement No 633477.

REFERENCES

[1] A. Lupisek, M. Volf, H. Pejtmanek, K. Sojkova, J. Tywoniak, and P. Op’t Veld, Introduction of a methodology for deep energy retrofitting of post-war residential buildings in central Europe to zero energy level. Komunikacie, 2016, 18 (4): 30-36.

[2] W. Böhler, G. Heinz and A. Marbs. The Potential of Non-Contact Close Range Laser Scanners for Cultural Heritage Recording. In: Proc. of XVIII Int. Symp. of CIPA 2001. Surveying and Documentation of Historic Buildings – Monuments – Sites. Traditional and Modern Methods. Potsdam, Germany, September 18-21, 2001. -p. 430-436.

[3] F. Remondino and S. Campana. 3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices. Archaeopress: Oxford. 2014. -171

[4] D. Gleason. Laser Scanning for an Integrated BIM. In: Lake Constance 5D Con-ference, Constance, Germany, October 28-29, 2013. -8 p.

[5] K.P. Kim and K. Park. BIM feasibility study for housing refurbishment projects in the UK. Organiz., Technol. & Managem. in Constr., 2013, 5(Special):756-774.

[6] C. Eastman, P. Teicholz, R.Sacks and K. Liston. BIM Handbook. A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. John Wiley & Sons, Inc. 2nd ed., 2011. -648 p.

[7] Y. Arayici. Towards Building Information Modelling For Existing Structures. Structural Survey, 2008, 26 (3): 210-222.

[8] P. Tang, D. Huber, B. Akinci, R. Lipman and A. Lytle. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. Automation in Constr., 2010, 19: 829-843.

[9] C. Wang, Y.K. Cho. Performance Evaluation of Automatically Generated BIM from Laser Scanner Data for Sustainability Analyses. Procedia Engineering, 2015, 118: 918-925.

[10] P. Tang, D. Huber, B. Akinci, R. Lipman, A. Lytle. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. Automation in Construction, 2010, 19:929-843.

[11] X. Xiong, A. Adan, B. Akinci, D. Huber. Automatic creation of semantically rich 3D building models from laser scanner data. Automation in Construction, 2013, 31:325-337

FUZZY NAVIGATION SYSTEM FOR VIRTUAL ROBOT

Algirdas Sokas[1]

1. ABSTRACT

This is an idealize task that a virtual robot has to solve seeking to find its way in the drawing with graphical objects obstacles. The virtual robot uses the five graphical sensors system. The fuzzy navigation system control three states target, obstacle and workaround. All states present robot's steering angle. Graphical AutoCAD environment with Visual Basic Application programming language enlarges possibilities in modelling fuzzy navigation systems. Fuzzy system, example of virtual robot presented and conclusions made.

KEYWORDS: Fuzzy system, navigation, virtual robotics, CAD.

2. INTRODUCTION

The basic idea of underlying fuzzy logic control suggested by Lotfi A. Zadeh [1]. A fuzzy linguistic label represented by a fuzzy number. They is expressed by a fuzzy set. Fuzzy sets capture the ability to handle uncertainty by approximate methods. A triangular fuzzy number applied mostly in the fuzzy theories and applications. The first implementation presented by Mamdani and Assilian [2] in connection with the regulation of a steam engine. Mobile robot local path planning in an unknown environment with uncertainties is one of the most challenging problems in robotics. For autonomous navigation, the robot should be capable of sensing its environment, interpreting the sensed information to obtain the knowledge of its position and the environment, planning a route from an initial position to a target with obstacle avoidance, and controlling the robot direction to reach the target [3]. In mobile robot computer program the navigation procedure is applied iteratively until the robot reaches its final destination [4]. The fuzzy logic control applied to mobile robot navigation and obstacle avoidance has investigated by several researchers. The control based on this theory with virtual robots [5] provides satisfying results. AutoCAD is a program used as operating environment, and Visual Basic for Application (VBA) is a language used for programming. Author presented virtual robot working in the drawing environment.

3. NAVIGATION SYSTEM

In the drawing we draw a rectangle 1234 which we call the robot as it, using its fuzzy navigation system, will bypass obstacles and move to the target object (Fig. 1). Robot step is from point *a* to point *b*. It is simply copied from point *a* and moved to point *b* with the angle α turn presented by the system. Robot-to-target distance *D* is known as the program states points and target coordinates. The robot has graphical sensors. One is the front sensor that mimics a line drawn through the robot points *a*, *b* and extending 30 mm; if the intersection point c with obstacles is found, we have the front sensor value $F = bc$ (Fig. 1).

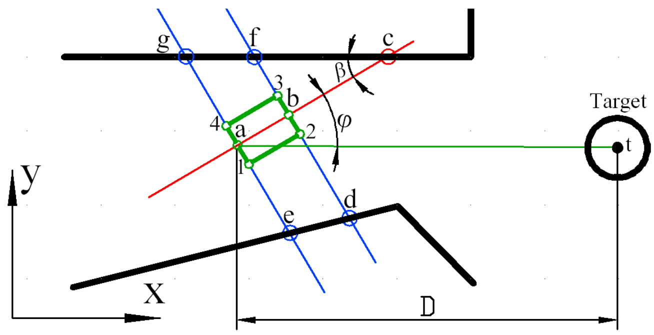


Fig. 1. The virtual robot with sensors system and coordinates.

On its right are two sensors, one of which is produced by a line from point *b* to point *2* and extending 30 mm; if the intersection point *d* with obstacles is found, we have right side sensor value *2d*. The other right sensor is equal to *1e* distance. Analogously the left sensors distances are found *3f* and *4g*. This can be done programmatically. A line extension performed with *SendCommand "lengthen"* operation, and an intersection with an obstacle captured with *object.IntersectWith* operation. We draw a lines between intersection points *e*, *d* and *g*, *f* to the robot axis passing through *a*, *b* and find angles β_r, β_l of the tangents, which show the object's approach angles to the obstacles. Hence, we have a whole range of parameters and must decide what angle to rotate the robot in the next step. We will use the fuzzy navigation system, which has three states: target, obstacle, and workarounds. We are dealing with the problem of obtaining fuzzy navigation system. We will analyze fuzzy rules in the next chapter.

4. FUZZY RULES

[1] *Department of Engineering Graphics, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania, e-mail: algirdas.sokas@vgtu.lt*

Fuzzy set fully characterized by the dependence functions. We will use symmetrical triangular dependence function, which presents two points on axis X (Fig. 2). In the first state the robot moves towards the target. Distance (*D*) to the target captured and presented in four membership fuzzy parameters pairs. Robot's orientation (φ) with respect to target presented in seven membership fuzzy parameters pairs (Fig. 2). The numerical values in the tables are determined from programing experiments in the drawing. In the second state the robot detect the obstacle. Side distance (*S*) to the obstacle captured and presented in fifth membership fuzzy parameters pairs (Tab. 1). Robot's front distance (*F*) with respect to obstacle presented in third membership fuzzy parameters pairs (Tab. 2).

Table 1. Robot side distance (*S*).

Left Large	-10	-5
Left Small	-5	0
Zero	-5	5
Right Small	0	5
Right Large	5	10

Table 2. Robot front distance (*F*).

Left Small	15.0	17.5
Left Medium	15.0	20.0
Left Large	17.5	20.0

In the third state the robot workarounds near obstacle. Robot's tangent angle (β) with respect to obstacle and presented in fifth membership fuzzy parameters pairs (Tab. 3). Robot's side distance (*S*) with respect to obstacle presented in fifth membership fuzzy parameters pairs (Tab. 4). All this membership fuzzy parameters are named input fuzzy sets.

Table. 3. Robot tangent angle (β).

Negative Big	-60	-30
Negative Small	-40	0
Zero	-5	5
Positive Small	0	40
Positive Big	30	60

Table. 4. Robot side distance (*S*).

Left Large	-8	-2
Left Small	-4	0
Zero	-2	2
Right Small	0	4
Right Large	2	8

We have one output fuzzy set of robot steering angle (α) (Fig. 3) with linguistic values of big left (BL), medium left (ML), small left (SL), zero (ZE), small right (SR), medium right (MR), big right (BR).

Fuzzy logic control based on the knowledge base of linguistic variables and logic control rules. Fuzzy rules base is a simple set of rules that describes the relationship between input and output sets fuzzy sets. Robot's steering angle (α), which is presented in seven membership fuzzy parameters, is determined based on its distance (*D*) and orientation angle (φ). The fuzzy rule matrix for steering angle (Tab. 5) made according to these three sets, whose columns named after distance memberships and rows named after orientation angle memberships, and the matrix filled with the appropriate robot steering angle values. This matrix allows to programmatically automat the entire fuzzification process.

α		*D*			
		ZE	**DS**	**DM**	**DL**
φ	**NL**	-30	-15	-15	-7.5
	NM	-30	-30	-15	-15
	NS	-30	-15	-15	-7.5
	ZE	0	0	0	0
	PS	7.5	15	15	30
	PM	15	15	30	30
	PL	7.5	15	15	30

Table 5. Robot steering angle α dependent from *D* and φ.

Analogically robot's steering angle (α) is determined based on the front distance (*F*) and side distance (*S*). Analogically robot's steering angle (α) is determined based on the tangent angle (β) and side distance (*S*).

5. PROGRAM

At the beginning, the virtual robot is at the start point and turned by the original angle. The program emulates robot and cyclically rotates by the specified angle. If the road is clear, the robot moves the shortest distance to its destination. Algorithm is presented by a program consisting of four classes which manage the robot and its three situations. Software sensors controlled by five module procedures (front distance, left and right side distances, left and right side tangents). In our case, we have the following two initial sequences of fuzzy graphs: distance (*D*) and orientation angle (φ) (Tab. 5). 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 linguistic values range of variation is fixed in the row. Program function *Miu* takes variables from dependency function matrix of distance and specific parameter (*D*). The result of the function is a result matrix. Results of the function presented in (Fig. 2), where the values and the linguistic values are serial number (triangular number).

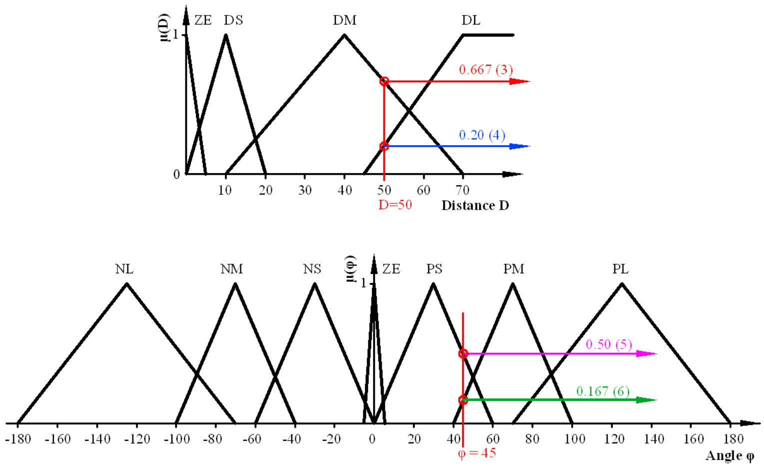


Fig. 2. Input fuzzy sets of robot distance D and orientation angle φ.

Mamdani method uses minimum operator as a fuzzy implication operator. 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).

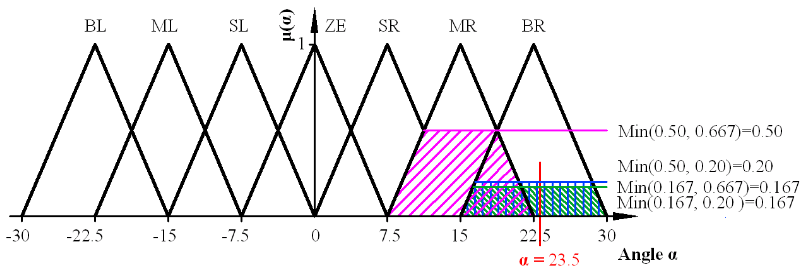


Fig. 3. Output fuzzy set of robot steering angle α.

Defuzzification is the last phase of this methodology. Defuzzification a reverse action, when the answer comes from fuzzy set to traditional mathematics numerical value. Defuzzification procedure operates with existing rules vague conclusions sets to find the perfect expression of the output value. Simply put fuzzy forced expressive values. Centre of area (COA) defuzzification method calculates the significance of the expression as follows:

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

Here x_i is the centre of dependence functions and A_i - space is limited function dependency (hatch areas in the Figure 3).

6. EXAMPLE

Here is example of conduct of the virtual robot in the graphical environment. The robot moves from the start (point S) towards the target (point T) and is bumps into a circle, point A (Fig. 4).

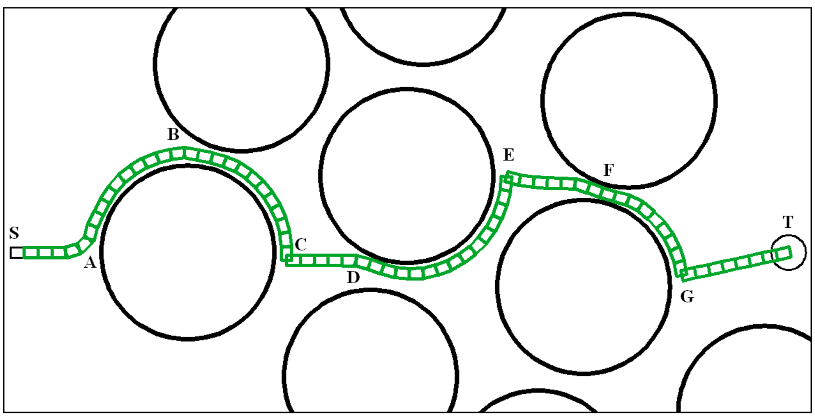


Fig. 4. An example of the virtual robot motion in the drawing with circles

In the fifth step distance $D < 30$ mm runs the Obstacle procedure, the robot turns left (based on the algorithm), and in the next step it turns to the left even more. The lateral sensors show the values and when they become $S < 30$ mm it starts the third procedure Workarounds. The robot starts to move near the obstacle. When the shortest distance to the target object is exposed, the robot turns towards it. How virtual robot acts between several circles on the way towards the target object. At first the robot avoids the first circle until the left lateral sensor shows lower values than the right and the robot starts to bypass the second circle (point B), but the way is free and a few steps straightens towards the target (point C). The robot encountered a third circle (point D) and it changes direction. The virtual robot intersecting lines and circles points are noted, distances are calculated and tangents are determined. When the shortest distance to the target object is exposed (points C, E, G), the robot turns towards it. In this example, the graph exhibits high sensitivity. The robot behaves as if intellectual.

7. CONCLUSIONS

- A utility is designed that allows to go deeper into the decision made by a computer program how a robot can find a free route in an unknown environment having 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 are bound by matrices and functions provide a definitive answer.
- The virtual robot's behavior depends largely on all the charts parameters. The smallest change in the chart settings makes major changes in the virtual robot's behavior.

8. REFERENCES

1. Zadeh, L. A. Outline of a new approach to the analysis of complex systems and decision processes. IEEE Trans. Systems, Man and Cybernetics, USA, 1973, vol. 1(1), p. 28-44.
2. Mamdani, E. H.; Assilian, S. An experiment in linguistic synthesis with a fuzzy logic controller. International Journal Man-Machine Studies, 1975, vol. 7, p. 1-13.
3. Motlagh, O. R. E.; Hong, T. S.; Ismail, N. Development of a new minimum avoidance system for a behaviour-based mobile robot. Fuzzy Sets and Systems, Netherlands, 2009, vol. 160, p. 1929-1946.
4. Abiyev, A.; Ibrahim, D.; Erin, B. Navigation of mobile robots in the presence of obstacles. Advances in Engineering Software, United Kingdom, 2010, vol. 41, p. 1179-1186.
5. Lee, S.; Adams, T.M.; Ryoo, B. A fuzzy navigation system for mobile construction robots. Automation in construction, Netherlands, 1997, vol. 6, p. 97-107.

TEACHING CAD/CAM: EXCHANGING EXPERIENCES FROM BRAZILIAN AND LATVIAN COURSES

Silvia Titotto[1] and Modris Dobelis[2]

1. ABSTRACT

The paper briefly discusses pedagogical methods for incorporating computer aided design and manufacture into higher education engineering based on surveying two universities: Federal University of ABC, Brazil and Riga Technical University, Latvia. It seeks to identify strengths and weaknesses in contemporary teaching practices; highlighting innovative methods that nurture design problem solving, technical competence, exploration of new materials and dynamic form generation. The researches concern possible teaching strategies for instructing students in the use of Computer Aided Design (CAD), through software such as Dassault Systemes Solidworks, Autodesk Inventor, Autodesk Autocad and Open source Freecad. Alongside modes of teaching Computer Aided Manufacture (CAM) including additive technologies such as 3D Printing, alongside digital photo-etching and movie-making. It is relevant to mention that the selected students had no previous experience in technical drawing neither with computer aided design.

KEYWORDS: CAD/CAM Education, Teaching experiences, Undergrads

2. INTRODUCTION

This paper is the result of a collaborative effort of its two authors, Assistant Professor Silvia Titotto (Federal University of ABC, Brazil) and Full Professor Modris Dobelis (Riga Technical University, Latvia).

In December 2016, the authors began the project in a flurry of optimism and excitement. And now six months later, they reflect on the path from initial conversation to completed work.

It aims to investigate pedagogical methods for incorporating computer aided design and manufacture (CAD/CAM) into higher education interdisciplinary engineering.

In so doing, it seeks to identify strengths and weaknesses in contemporary teaching practices; highlighting innovative methods that nurture design problem-solving skills, engender technical competence, and encourage the exploration of new materials and dynamic form generation.

The authors started by attending each other's classes and discussing about their daily strategies and their collection of articles about CAD/CAM that had been published in design journals worldwide.

3. BASIC INFORMATION

The first analysis CAD/CAM technologies were created by Ivan Sutherland and they first emerged at the Massachusetts Institute of Technology (MIT) in 1969 in the USA.

Months later Computer Aided Design (CAD) started to be seen as the use of computer systems to assist in the creation, modification, analysis or optimization of a design so that there could be productivity gains for the designers, improvement of the quality of design, shorten of the designing process, improvement of the communication of the design idea and the creation of information for manufacturing.

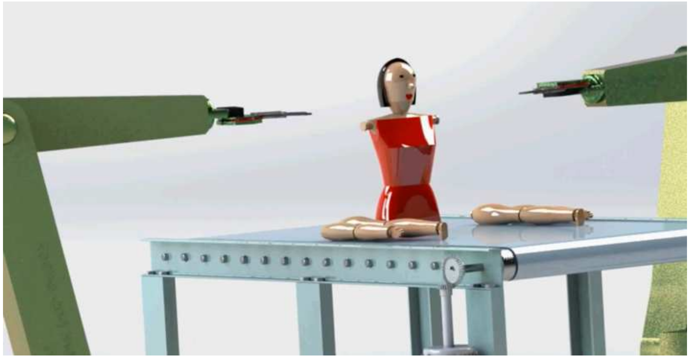
The 1980s witnessed the introduction of NURBS to define virtual 3D forms by effectively skinning a linear skeleton, which could itself be manipulated via control points, but only in 1982 Autodesk released CAD programs for IBM personal computers, with early adopters centred on design and engineering.
The development of programmes such as ACIS, Parasolids, SolidWorks and Solid Edge helped to spread 3D modelling software in the 1990s.

In the last 25 years the use of CAD has been playing an important role in engineering. While it may increase the quality of design idea representation, it can also provide feedback on the feasibility of production through geometric analyses that reveal surface errors. CAD software can also expand possibilities for form generation and therefore make acquisition of its skills an imperative for many students.

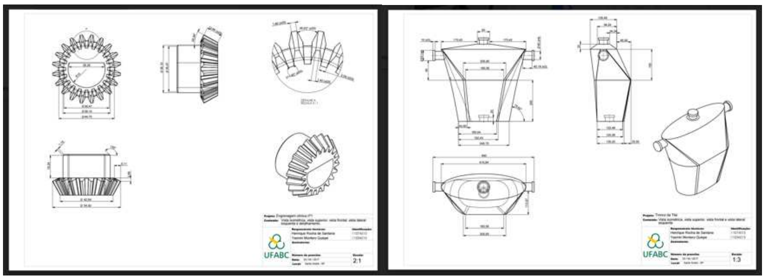
With the emergence and increased use of digital technologies the desire to incorporate CAD/CAM into teaching curricula has inevitably accelerated. In some developed countries, for example, CAD /CAM was introduced in the National Curriculum for Secondary schools in the beginning of the year 2000 (Fullwood, 2002).

[1] *CECS - Center of Engineering, Modelling and Applied Social Sciences, Federal University of ABC (UFABC).*
[2] *Faculty of Civil Engineering, Riga Technical University (RTU).*

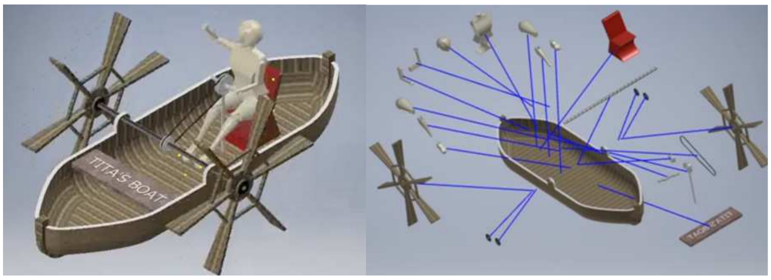
4. EXAMPLES OF STUDENTS'ACOMPLISHEMENT



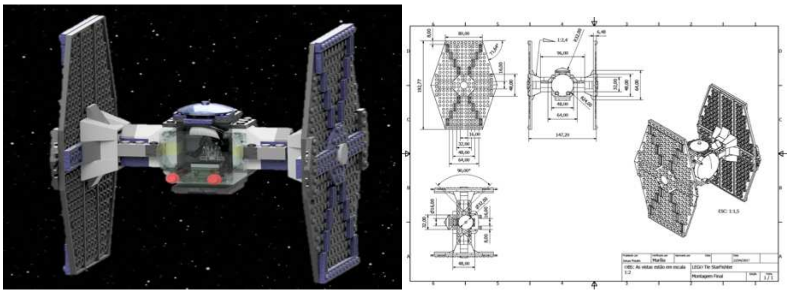
1



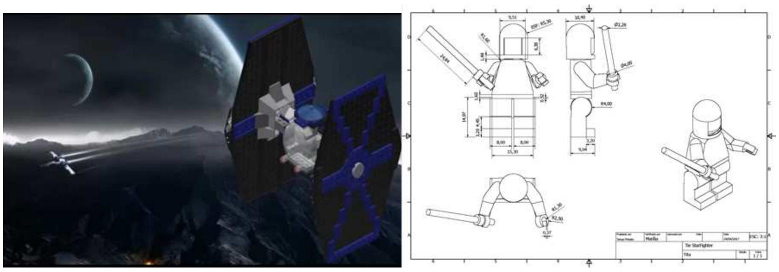
2, 3



4, 5



6, 7



8, 9

1. Video: Manufacturing of a doll. Henrique e Yasmin Montero, UFABC, 2017.
2. Technical drawings: Manufacturing of a doll. Henrique e Yasmin Montero, UFABC, 2017.
3. Technical drawings: Manufacturing of a doll. Henrique e Yasmin Montero, UFABC, 2017.
4. Video: Doll's boat. Renato Maffei, UFABC, 2017.
5. Assembly: Doll's boat. Renato Maffei, UFABC, 2017.
6. Video: Lego at Star Wars'Aerospace environment. Jonas Poiato e Marilia, UFABC, 2017.
7. Technical drawings: Lego at Star Wars'Aerospace environment. Jonas Poiato e Marilia, UFABC, 2017.
8. Video: Lego at Star Wars'Aerospace environment. Jonas Poiato e Marilia, UFABC, 2017.

9. Technical drawings: Lego at Star Wars'Aerospace environment. Jonas Poiato e Marilia, UFABC, 2017.

5. MATERIALS AND METHODS

The authors' experience related to the 24-60 hour courses they had been teaching recently. The experiences were focused on:

- Junior undergraduate course in engineering graphics: to use a CAD system as an electronic drafting tool to practice engineering graphics knowledge; and
- Senior undergraduate course and junior graduate course in CAD/CAM/CAE: to use a CAD system as a tool for engineering design, manufacturing, and analysis.

Certain strategies have been identified to encourage student uptake of CAD/CAM, by setting projects where they can exploit pre-existing skills in Adobe Photoshop and Adobe Illustrator to produce better visualization of their ideas. The use of two dimensional vectors in Adobe Illustrator can offer a pathway to the acquisition of 3D modelling skills in other softwares using NURBS; thereby expanding planar designs into voluminous pieces.

The main learning outcome of the CAD/CAM courses included:

- Understanding the role of CAD/CAM in product development;
- Relating CAD/CAM to various industrial applications;
- Relating CAD/CAM to traditional rapid prototyping methods;
- Creating 3-dimensional CAD models; and
- Managing team-based projects.

6. CONCLUSIONS

This work introduced our experience of teaching a CAD course in interdisciplinary engineering programs.

Three aspects of the CAD knowledge, including computer graphics theory, practice of CAD systems, and applications of CAD/CAM in engineering design and manufacturing, including additive manufacturing, were discussed based on the requirements for the engineering programs of the faculties.

The various components of a CAD course at both universities including laboratories, lectures, accurate assignments, textbooks, and course modelling projects, were important so that students could learn faster.

In order to try to neutralize some of the disadvantages students use to mention in their usage of CAD/ CAM, namely a reduction in hand skills, the loss of tactile making and the reduced appreciation of physical dimensions, the teaching of CAD/CAM is best synthesized with traditional modes of design and production.

It means, CAD/CAM should ideally become an addition to the process of form generation, design development and production through drawing and hand produced models, rather than a substitute for them.

When discussing examples of best practice a commonly opinion spoken by most students was that a successful combination relies on traditional modelling and drafting skills taught alongside of CAD/CAM skills in order to successfully translate tacit knowledge into more updated technological outcomes.

Acknowledgements

Students of Fundamentals of Drawing and Design courses at Federal University of ABC and Technical Drawing and CAD/CAM courses at Riga Technical University.

7. REFERENCES

1. Bordegoni, M. and Rizzi, C. (2011) *Innovation in Product Design – from CAD to Virtual Prototyping.* London, Springer.
2. Brown, P. (2009). CAD: Do Computers Aid the Design Process After All? *Intersect: The Stanford Journal Of Science, Technology And Society*. Vol. 2(1), p52-66.
3. Lyons, N.; Wilker, M. (2012). Interactive Project Management: Pixels, People, and Process. Berkeley, California: New Riders. ISBN 978-0-321-81515-6.
4. Nadeau, J-P; Fischer, X. (2011). Research in Interactive Design: Virtual, interactive and integrated product design and manufacturing for industrial innovation. ISBN 978-2-8178-0169-8
5. Wigdor, D.; Wixon, D.. (2011). Brave NUI world: designing natural user interfaces for touch and gesture. Elsevier. 978-0123822314
6. Lantada et al. (2013) Comparative Study of CAD-CAE Programs taking Account of the Opinions of Students and Teachers. *Computer Applications in Engineering Education*. Vol. 21, No. 4, p641–656.
7. Jefferson, M. (2015). There's nothing much new under the sun:The challenges of exploiting and using energy and other resources through history. *Energy Policy* 86:804– 811. doi:10.1016/j.enpol.2015.01.022
8. Bernabei, R. et al (2015). CAD/CAM and jewellery design education. *Making Futures* 2015, 24th-25th September 2015, Plymouth.

DESCRIPTIVE GEOMETRY

MODEL AND PAPER SPACE

Rein Mägi[1]

1. ABSTRACT

There are two distinct working environments, called "Model space" and "Paper space," in which a designer can work with objects in a drawing. By default, we start working in a limitless 3D drawing area called Model space.

Another environment “Paper space” enables to operate with 2D-objects, we can use Viewports to watch model space objects.

Although in AutoCAD basically is used Model space, the Paper space offers also interesting possibilities. Successful operating with Model and Paper spaces requires both special knowledges and skills from designers and users of drawing files.

KEYWORDS: AutoCAD, Model Space, Paper Space

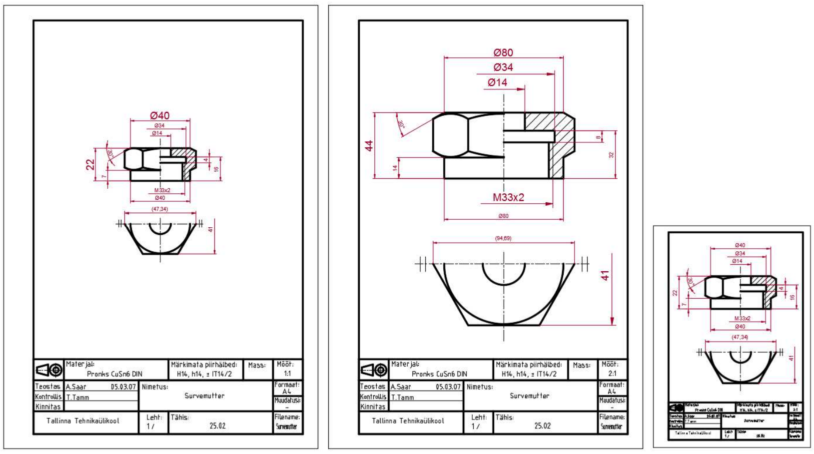
2. INTRODUCTION

Our research [1] found that the most widespread program in Estonian Companies is AutoCAD (75%). There are two distinct working environments, called "Model space" and "Paper space," in which a designer can work with objects in a drawing. Model space contains 2D- and 3D-objects but Paper space can include only 2D-objects. Although it is possible to use only Model space, the Paper space can add some useful opportunities.

To prepare the drawing for printing, it is recommendable switch to Paper space. Here we can set up different Layouts with title blocks, dimensions and notes; and on each Layout, we can create Layout Viewports that display different views of Model space.

3. USING MODEL SPACE

By default, we start working in a limitless 3D drawing area called Model space. We begin by deciding whether one unit represents one millimeter, one centimeter, one inch, one foot, or whatever unit is most convenient. We then draw at 1:1 scale. After creating the content of drawing - representations (views, sections etc.), dimensions - we need to surround this content with format frame line and the title block [2].
It is OK, if we can print this drawing in scale 1:1 (Fig. 1a). But using other printing scales, we need to increase or decrease the drawing objects (Fig. 1b) or frame and title block (Fig. 1c).



a) b) c)

Fig. 1. a) Drawing of the compression nut in scale 1:1 on format A4.
b) After increase twice the drawing content by command *Scale*.
c) After decrease twice the frame and title block by command *Scale*.

Which is better variant – b) or c)? In variant b) all dimension values have become twice bigger - it is not recommended. The general rule is “the real object is sacred, do not touch it!”.

Using recommended variant c) we have to apply printing scale 2:1 on format A4 (Fig. 2).

[1] *Centre of Engineering Graphics, Tallinn University of Technology , Ehitajate tee 5, Tallinn 19086, Estonia, e-mail: rmagi@hot.ee*

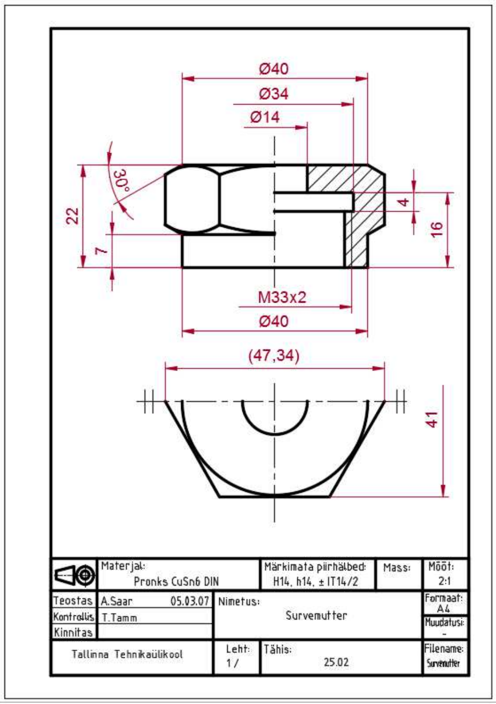


Fig. 2. The final drawing on format A4 in scale 2:1.

Only in Model space we can create 3-dimensional object defined by x-y-z coordinates (Fig. 3).

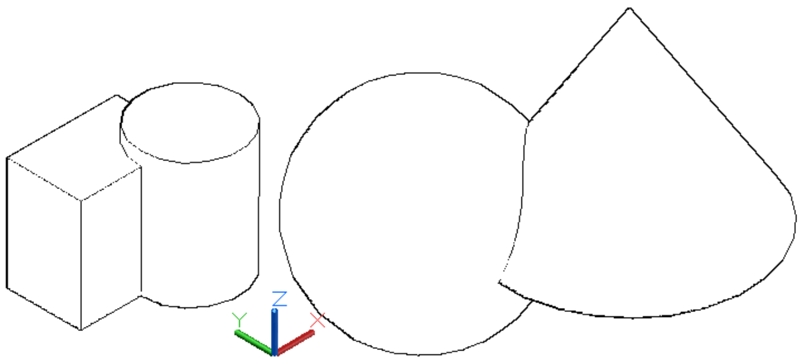


Fig. 3. 3D-objects (x, y, z) in Model space

But next we can examine specific features of Paper space.

4. PAPER SPACE OPPORTUNITIES

The another environment Paper space is only two-dimensional (x,y). But Paper space can contain Viewports with views to Model space objects.

It is possible to create only representations (views, sections etc.) in Model space (Fig. 4a) and additions (dimensions, title block, format frame, notes etc.) place in Paper space (Fig. 4b). We can change the contours of the Viewports invisible turning off the Layer according to them (Fig. 4c).

On technical drawings we can use only parallel projections, because it is only way to show true dimensions.

But human vision and photography are based on central projection (perspective) where the center of projection rays is located in the focus of the eye or the camera. Therefore the perspective view is more realistic and expressive than parallel projection [3].

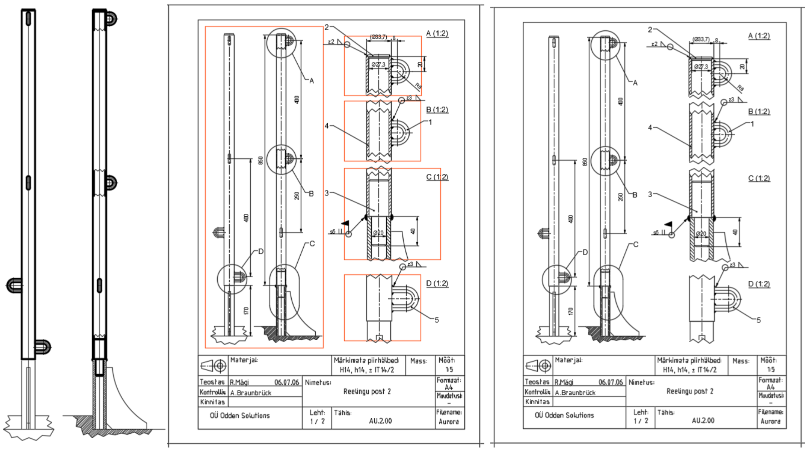


Fig. 4. a) Representations of the gunwale post in Model space (scale 1:1) without dimensions.
b) Technical drawing in Paper space with Viewports to Model space objects (in different scales).
Additions (dimensions, title block, format frame, notes etc.) are located in Paper space.
c) The final drawing after turn off visibility of Layer with Viewports contours.
From Paper space we can print this drawing in Plot scale 1:1.

Several methods of constructing perspective views exist, but graphically 2D-constructing is quite uncomfortable and capacious process. More rational is to create central projection using 3D-modelling in Model space. AutoCAD enables even to demonstrate various visual styles in different viewports (Fig. 5). Rendered view allows to show even the shadows and texture of materials.

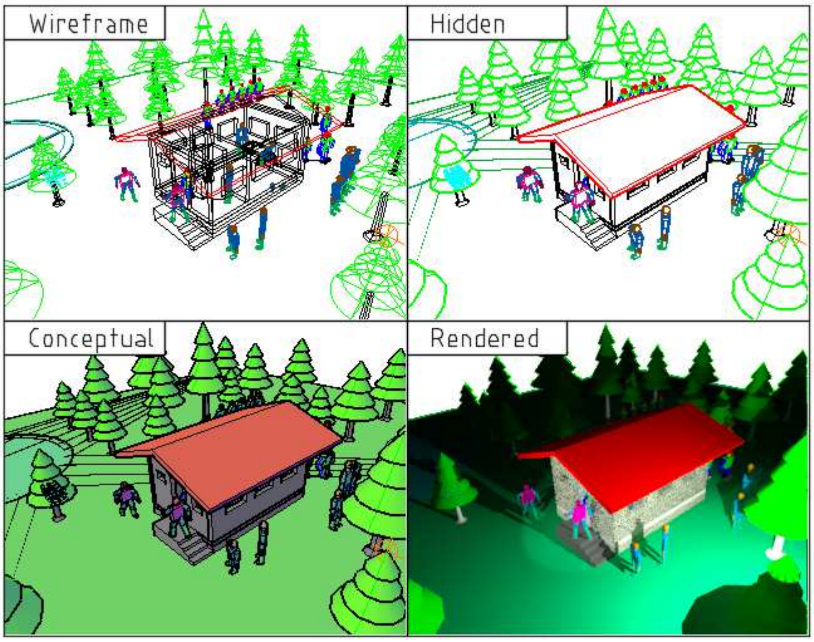


Fig. 5. Using various Visual styles in different Viewports for the same objects shown in perspective view.

It is quite comfortable to get perspective view by 3D-modelling. In AutoCAD it suits using command *Dview>Points>Distance* (Fig. 6).

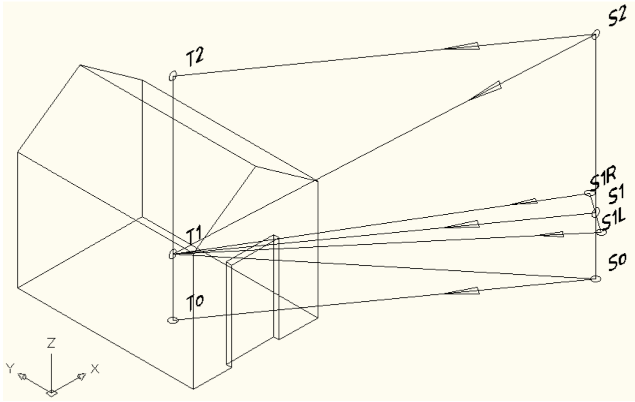


Figure 6. 3D-object (house) with target-points (To, T1, T2) and camera-points (So, S1, S2; S1L, S1R).Even more showy is to create stereogram of 3D-objects. Stereo-effect is based on two- eye seeing. Images for left (S1L>T1) and right (S1R>T1) eye are different (Fig. 7).

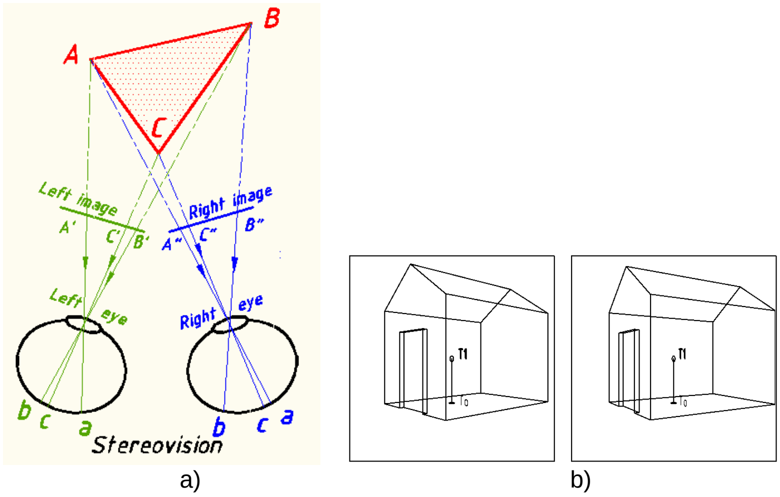


Figure 7. a) The principle of stereovision; b) Stereogram made by 3D-modelling – Viewports with different Left and Right images.

Using 3D-modelling some problems may occur occasionally [4]. For example, Bottom view is rotated 180° (Fig. 8). The right solution is to rotate Camera (*Twist*), not object.

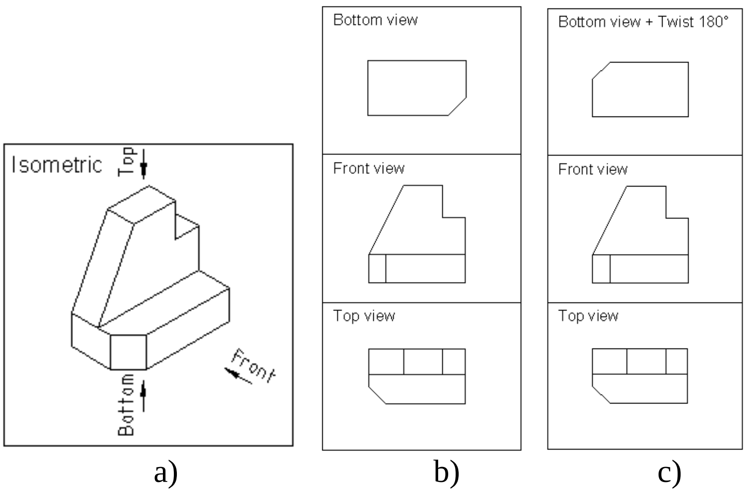


Figure 8. a) source 3D-object; b) 3 views with incorrect Bottom view; c) corrected Bottom view (*Dview* >*Twist*>180°). A long-time AutoCAD problem in 3D-modelling is that the Bottom view is rotated 180° (all other views are correct).
The right solution is: *Dview* >*Twist*>180°. Do not *Rotate* the object 180°!

Quite effective is to create 3D-object in Model space and then to form suitable views in different Viewports to show true sizes and dimensions of this object. In figure 9 we can see the original shape of triangle ABC (view L) and the angle α between faces ABC and ABDE (view M). Commands *SOLVIEW* and *SOLDRAW* allow create auxiliary views quite comfortably [5].

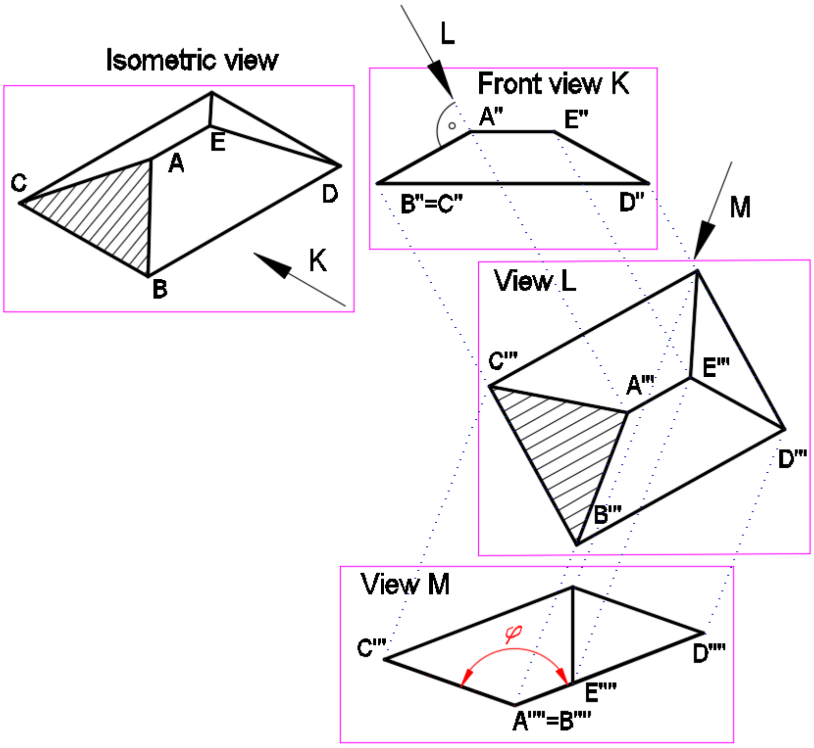


Figure 9. 3D-solid object in Model space and some auxiliary views in different Viewports enable to show true sizes and dimensions of the same object.

Viewports are like „security cameras“ watching the same object from different directions (Fig.10). Every change in Model space is observable through Paperspace Viewports (Fig.11).

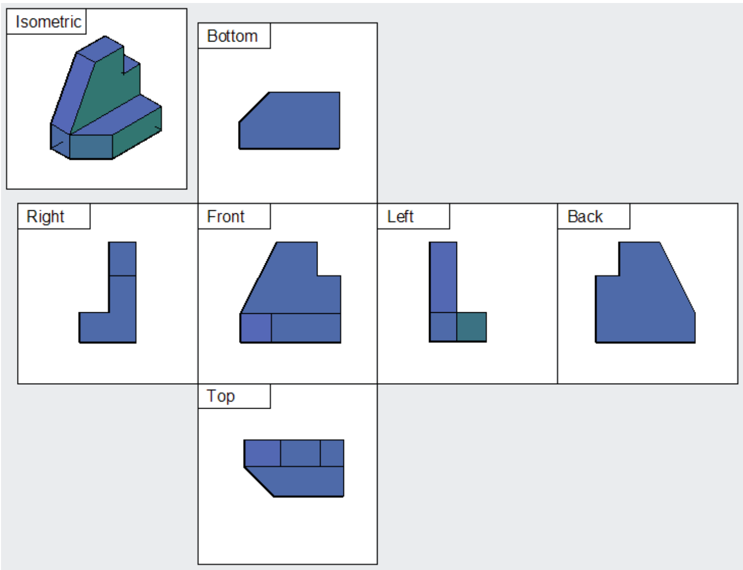


Figure 10. Isometric view and 6 general views of the same object in different Viewports.

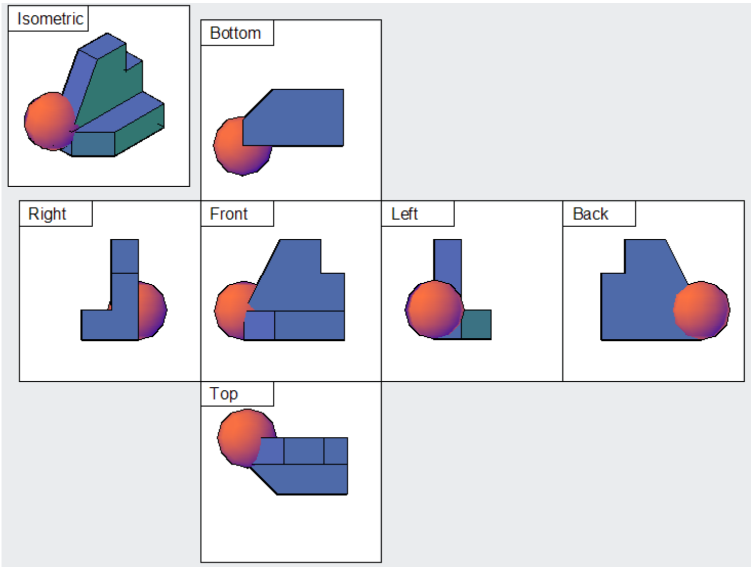


Figure 11. Scene on display after addition the new object (sphere).

5. CONCLUSIONS

Although in AutoCAD basically is used Model space, the Paper space offers also interesting possibilities. Successful operating with all spaces requires both special knowledges and skills from designers and users of drawing files.

6. REFERENCES

1. Mägi, R., Sepsivart, M. Drawing Management in Estonian Companies // In: Engineering Graphics BALTGRAF-7. Proceedings of the Seventh International Conference, Vilnius, Lithuania, May 27-28, 2004, p.111-115. (http://deepthought.ttu.ee/graafika/BaltGr-7_Draw-Manag.pdf)
2. Creating drawing of the compression nut (learning video): https://www.youtube.com/watch?v=eGnQRIVAR2Y&feature=youtu.be
3. Mägi, R. Perspective View Possibilities // In: Scientific Proceedings of the 12th International Conference on Engineering Graphics BALTGRAF 2013/ Riga Technical University, 2013, p 149- 156. https://www.etis.ee/File/DownloadPublic/bcadf680-caf6-4167-b794-a90b505d9107?name=Fail_BaGr12-Perspective%2B%2B%2B%2B.doc&type=application%2Fmsword
4. Mägi, R., Möldre H. CAD Problems and Solutions // 10th International Conference on Engineering Graphics BALTGRAF-10; Conference Proceedings. June 4-5, Vilnius Gediminas Technical University, Lithuania. Vilnius, 2009. p. 104-109. http://deepthought.ttu.ee/graafika/magirein_BaGr10-CADproblem.pdf
5. AutoCAD 2017 and AutoCAD LT 2017 essentials / Scott Onstott. Indianapolis, Ind. : Sybex, aWiley Brand : Autodesk Official Press, 2016. 412 p.

SLOPING ROOF MODELING FEATURES AND ASPECTS OF SUSTAINABILITY

Birutė Juodagalvienė[1]

ABSTRACT

Sustainability is a very broad, all encompassing concept that has implications for every aspect of society, including people of all ages and abilities. Houses and their roofs that incorporate sustainable design features will derive numerous ongoing benefits, including enhanced values. Slope of the roof planes is formed while installing rafters, trusses or beams, having a specific oblique angle. The paper analyzes the modeling features of roof surfaces and their influence on the shape of the building sustainability.

KEYWORDS: roofs modeling, shaped roofs, sustainability of the building.

1. INTRODUCTION

Today more and more people (including ones from economy class) are thinking about the A class energy performance when building their own houses. Such buildings are attractive in several aspects: improved microclimate and energy saving intended for thermal insulation. Improper selection of structures and forms of the main house partitions (walls and roof) can ruin the plans to design the A class house, i.e. sustainable house.

The concept of sustainability is becoming increasingly important in different spheres, including the construction industry: design of buildings, new materials, structures, technology development and production. The construction industry is one of the areas covering all the three main stages of sustainability: environment [1, 2], economic [3] and social [3, 4].

Typically, the external shape and orientation of the building are determined by the architectural solutions, functional and space constraints [5]. Qi and Wang [6] have evaluated the shapes of roof slopes and positions according to the building orientation in respect to the cardinal directions and have based their impact on the energy efficiency of buildings.

While comparing buildings with simple forms and the unique design, one can see that costs of the energy consumption of the latter ones are much higher [7, 8].

The factors that make the physical structure of a home sustainable or not are: type, size, shape, position, orientation and location, materials, construction. House shape is predicated on a number of factors. However the basic rule is that a simple shape is much more sustainable than a complex shape. Complex shapes use more materials and they are not as energy efficient because they have more surface area.

2. ROOFING FORM OF THE SINGLE-FAMILY HOUSES

Selection of architectural-design solutions, detail shape and size of residential houses is influenced by the climate characteristics, nation's historical development peculiarities and national culture [9]. There is a try to preserve the aesthetics of architectural forms of the buildings [10] and to deal with contemporary design issues [11] with the help of information tools by simulating different roofing options. The scientific literature mainly focuses on the unique shape of heritage or building groups and their roofs. On the one hand, the roof shape simplicity reduces its area, construction installation and consumable materials. On the other hand, overhang of the roof and its shape parts reduces the thermodynamic effects in the entire house, in addition being an important aesthetic aspect. Therefore, there are separate function groups for the roof modeling in the building simulation programs (Revit Architecture, ArchiCAD and others). Influence of elements to the sustainability of the typical single-family houses is not even under consideration in practice, because the demand of them is growing rapidly in all EU countries [12], according to the scientific literature.

The roof shape is selected only in part according to the walls contour in the plan. Roof of even the same contour of walls' house can have a different shape (Fig. 1). In this case not only number of the slopes may vary, but also the slope of the planes and position of insulation material and the thermal insulation material.

Fig. 1. Roof shapes: mono-pitched, gable and hip roof

Certain geometric shapes houses are usually designed and built in Lithuania: rectangular, square, L and cross-shaped (Fig. 2). It was noted after the evaluation of many years of experience in building design that pitched roofs are the most suitable ones in Lithuanian conditions, which are designed according to the principal-type schemes (Fig. 3).

[1] *Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania, e-mail: birutej@vgtu.lt*

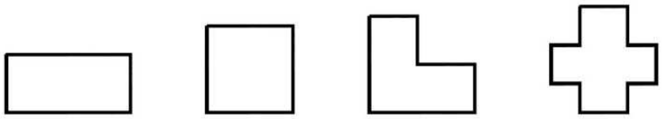


Fig. 2. Shapes of single-family houses

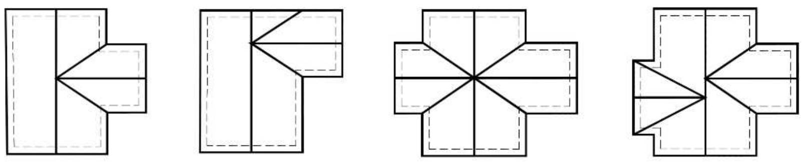


Fig. 3. Principal-type schemes of pitched roof plans

Roof shapes used to be essentially the same for decades, but their structure was constantly changing. This change took place and is taking place now due to the increased thermodynamic requirements. With changes of the normative value of heat transfer coefficient not only the thickness of the insulation layer is increasing, but also the build. In Soviet times, houses had not been insulated, so roofs of the single-family houses were cold. Today, in most cases, the attics (warm lofts) are being installed. This choice is used as one of the ways while achieving the building sustainability or A-class energy efficiency.

Like any other element of the building, the roof can be represented in orthogonal (roof plan, facades) and axonometric projections. Not all customers are able to imagine the real picture of the future roof according to the roof plan. Therefore, the system should present three orthogonal images near the house model, also (Fig. 4).

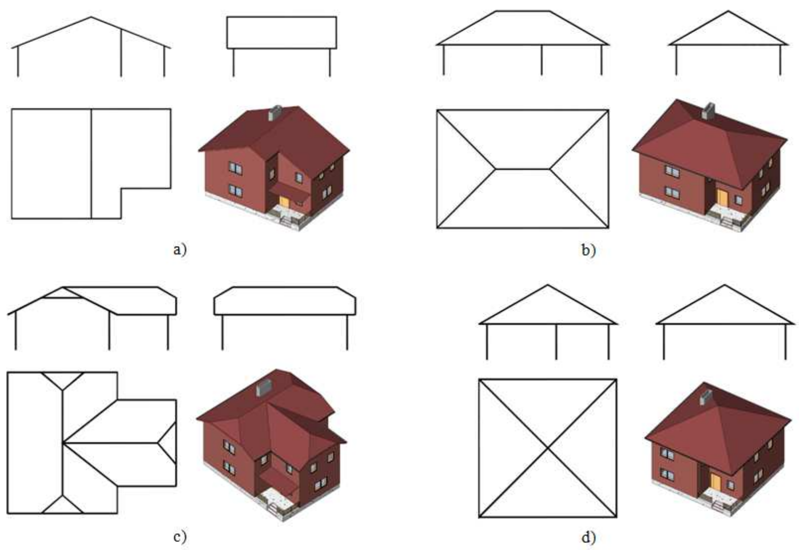


Fig. 4. Three projections of the pitched roof contour: a) - the gable b) - gable with hip c) - gable with half-hip, d) - the four-slope

3. ROOFING MODELING SYSTEM

The customer, thinking about the construction of single-family house, may find on the internet many different spreadsheets associated with price of the house elements. There is no selection of spreadsheets intended for geometric parameters of the elements related to the sustainability of the house. True, there are some spreadsheets, thanks to which stairs can be simulated in the defined space [13], but the ergonomic aspects here are not indicated. Roofing spreadsheets have not yet been designed, because there was no need for it. The first test of roofing spreadsheet system [14] appeared on the internet in Lithuania after the change in the energy efficiency requirements, which essentially is advertising products of the company. This article provides system's principal scheme of shape selection of the pitched roof and its impact on the sustainability of the house (Fig. 5). After creating the system, there are plans for its management and selection:

- shape of the house,
- roof shape,
- size of pitch,
- position of thermal insulation layer,

- roofing materials,
- cornice component structures (continuous rafters or sub-rafters),
- others (other aspects of choice could appear while testing the system).

Most people have already realized that selection of the cheapest house materials is not the best option, so it should be proposed the influence of sustainability index on the whole house in addition to the estimates of roof elements.

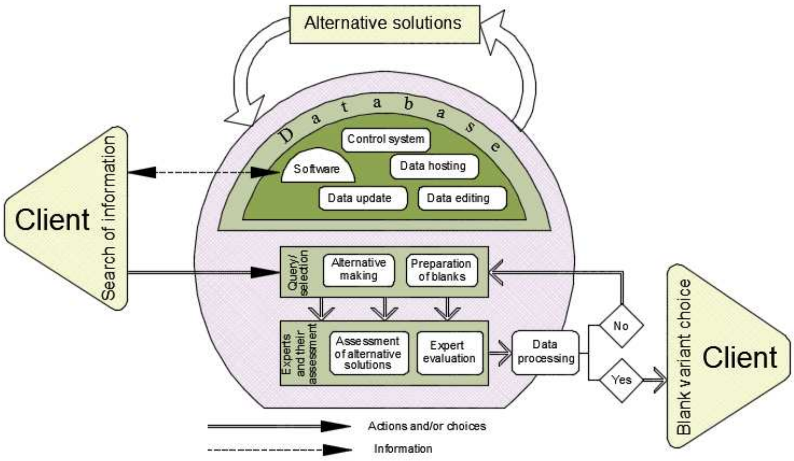


Fig. 5. Principal scheme of selection system of the pitched roof shape

In order to implement the scheme in Figure 5 shows the idea, the project and a working group should finance it with the manager, developer and construction experts. So far, the project is only deals with ae theory.

4. CONCLUSIONS

With the growing demand for the typical single-family houses, aspects of their sustainability become more and more important. Shape of the elements (as one of the constituent parts of sustainability) affects sustainability of the whole house. The article proposes theoretical model of selection of the pitched roof, which is timely and informative. Selection of roof shape and materials and their mutual harmony have a major impact not only to the urban context of the house, but also to the customer's psychological comfort. After development of the system, the customer will be able to assess the influence of roof shape not only on the sustainability of future house, but on the aesthetic image, too.

REFERENCES

[1] Holmstedt, L., Brandt, N., Robert, K.H. 2017. Can Stockholm Royal Seaport be part of the puzzle towards global sustainability? – From local to global sustainability using the same set of criteria. Journal of Cleaner Production. 140(1), 72–80. http://dx.doi.org/10.1016/j.jclepro.2016.07.019.

[2] Kosanovic, S., Fikfak, A. 2016. Development of criteria for ecological evaluation of private residential lots in urban areas. Energy and Buildings. 115, 69–77. http://dx.doi.org/10.1016/j.enbuild.2015.02.037.

[3] Mulliner, E., Smallbone, K., Maliene, V. 2013. An assessment of sustainable housing affordability using a multiple criteria decision making method. Omega, 41(2), 270–279. http://dx.doi.org/10.1016/j.omega.2012.05.002.

[4] Kamali, M., Hewage, K. 2017. Development of performance criteria for sustainability evaluation of modular versus conventional construction methods. Journal of Cleaner Production. 142(4), 3592–3606. http://dx.doi.org/10.1016/j.jclepro.2016.10.108.

[5] Mooneghi M. A., Kargarmoakhar R. 2016. Aerodynamic Mitigation and Shape Optimization of Buildings: Review, *Journal of Building Engineering* 6: 225–235. http://dx.doi:10.1016/j.jobe.2016.01.009.

[6] Qi F., Wang Y. 2014. A new calculation method for shape coefficient of residential building using Google Earth. Energy and Buildings 76: 72–80. http://dx.doi:10.1016/j.enbuild.2014.02.058.

[7] Bobrova D. 2015. Building-Integrated Wind Turbines in the Aspect of Architectural Shaping. Procedia Engineering, 117: 404 – 410. http://dx.doi:10.1016/j.proeng.2015.08.185.

[8] Mottahedi M., Mohammadpour A., Amiri S. S., Riley D., Asadi S. 2015. Multi-linear Regression Models to Predict the Annual Energy Consumption of an Office Building with Different Shapes, *Procedia Engineering* 118: 622 – 629. http://dx.doi:10.1016/j.proeng.2015.08.495.

[9] Kociecki, M., Adeli, H. 2015. Shape optimization of free-form steel space-frame roof structures with complex geometries using evolutionary computing, Engineering Applications of Artificial Intelligence 38: 168–182. http://dx.doi.org/10.1016/j.engappai.2014.10.012.

[10] Guillen-Lambea S., Rodriguez-Soria B., Marín J. M. 2016. Evaluation of the potential energy recovery for ventilation air indwellings in the South of Europe, *Energy and Buildings* 128: 384–393. http://dx.doi.org/10.1016/j.enbuild.2016.07.011.

[11] Helenowska – Peschke, M. 2016. Experimental Designs of Mass Customized Passive Single-family Houses - Prospects and Limitations, Procedia Engineering 161: 1620–1624. http://dx.doi.org/10.1016/j.proeng.2016.08.636.

[12] Eurostat, 2014. Statistics Explained. http://ec.europa.eu/eurostat/statistics-explained/index.php/Housing_statistics/lt (accessed 17.01.16).

[13] Step master. Laiptų skaičiuoklė (in Lithuanian). http://www.stepmaster.lt/laiptu-skaiciuokle.html (accessed 17.01.16).

[14] Eternit Baltic. 3D skaičiuoklė (in Lithuanian). http://www.eternit.lt/c/skaiciuokle.97/ (accessed 17.01.16).

DELPHI METHOD APPLICATION FOR THE ROOFING PROJECTS

Daiva Makutėnienė[1], Olga Regina Šostak[2], Augustinas Maceika[3]

1. ABSTRACT

The authors of the article carried out feasibility study of the Delphi method application to improve the decision-making in assessing of the roofs installation projects. Applied methods – there were analysis of scientific literature and other information sources, analysis of decision support systems, and study of Delphi method application for decision support system for the roofing. The authors and during Delphi method process interviewed experts had to select the essential parameters to be assessed in order to help for the customers to choose the desired project. These parameters were of properties: geometric, aesthetic, physical, ecological, economic, durability, efficiency, ecological, safety, and warranty for the roof. Selected parameters and their weights were used in the decision support system database development. In the data base, an individual roofs graphic representation and the projects costs were added to. Roof installation projects evaluation by points and these projects evaluation results presentation to the customers is helpful in choosing the right roof design.

KEYWORDS: *Delphi method, decision support system, roof geometry*.

2. INTRODUCTION

Roofing projects customers have demand for greater visualization of the proposed option. They need a graphical part of the project, as well as expert evaluation of the project. Customers wants a number of options which are diferent in designe, price, and fulfillment to be offered. In response to these needs, it is appropriate to create a roofing projects database containing the details of the proposed roof options. For decision making, based on database data, the Decision Support System (DSS) is useful. DSS provides opportunities for more effective decisions, but decisions must be based on clear estimation of the necessary parameters and sub parameters, also supported with evaluation criteria. For selection and estimation of the parameters, it is necessary to have a vision that can be created by using the Delphi method.

The goal of the work: to provide a research of the Delphi method application possibilities for the roof installation projects evaluation when for roofing modelling the complex (DSS) can be used.

3. PROBLEM STATEMENTS

I. Andreescu, A. Keller and M. Mosoarca (2016) [1] argued that until mid XIX-th century the roofs were produced by craft guilds, influenced not only by their practical knowledge but also by symbolic and traditional knowledge manifested in the choice of peculiar geometric traces, but starting with the end of the XIX-th century, the guild system vanished along with the symbolic and traditional meanings, leaving the practical knowledge completely independent – ready to be used for spectacular and aesthetic purposes.

According to S. Rahman et al. (2012) [2] and A. Spanaki et al. (2011) [3] it can be said, that the work to improve information systems in the field of construction can have a great outcome.

According to S. J. Barnes and J. Mattsson (2016) [4] the first phase of a future study would be to build on the current factors to develop an event set that can be used to construct dynamic scenarios. Such dynamic scenarios can be used via a Delphi study to determine the strongest “if then” relationships between events that might foster either good or bad outcomes, identifying the events that have the strongest negative and positive interactions in bringing about a degree of collaborative consumption (ranging from nothing to everything). By focusing upon very specific subsets, such as cars, we may be able to create a series of specific models that lead to the best understanding for reaching a more comprehensive approach to collaborative consumption.

According to J. Cho and J. Lee (2013) [5] the results of the FAHP method indicated that marketability is predominant criterion for the commercialization of technology products. In particular, market potential, customer needs, profitability, and market competition factors seem to have distinctively higher importance, indicating that they are the key factors for commercializing technology for new products.

According to C. Okoli and S. D. Pawlowski (2004) [6] a Delphi study does not depend on a statistical sample that attempts to be representative of any population. It is a group decision mechanism requiring qualified experts who have deep understanding of the issues. Therefore, one of the most critical requirements is the selection of qualified experts.

J. V. Meijering, and H. Tobi, (2016) [7] study showed that agreement among experts in Delphi studies does not necessarily increase across rounds. In most cases there was no significant change in level of agreement among experts. According to S. Kermanshachi, B. Dao, J. Shane and S. Anderson (2016) [8] The hierarchical list of complexity

[1] *Department of Engineering Graphics, Vilnius Gediminas technical university, Saulėtekio al. 11 Vilnius, 10028 Lithuania, e-mail: delta@vgtu.lt*

[2] *Department of Engineering Graphics, Vilnius Gediminas technical university, Saulėtekio al. 11 Vilnius, 10028 Lithuania, e-mail: delta@vgtu.lt*

[3] *Department of Mechanical Engineering, Vilnius Gediminas technical university, J. Basanavičiaus str. 28, Vilnius, 03224, Lithuania, e-mail: augustinas.maceika@vgtu.lt*

indicators and their weights enables owners and contractors to approach their project planning and execution more precisely and wisely.

4. APPLICATION AREA

The main application area for the research results is roof design projects preparation and evaluation activities. The research involved Lithuanian experts of various field to participate in the Delphi method for DSS system elements development and roof installation projects evaluation. After Delphi method results implementation in the DSS, the customer of the roof installation project can view a variety of appropriate options, which have been already evaluated by the 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.

5. RESEARCH COURSE AND METHOD USED

The authors had the idea to try to use the Delphi method for generating and evaluating projects of roofing. For this purpose, questionnaires were prepared and three rounds of investigation were carried out, in which participated 30 experts as the respondents for roof installation projects evaluation. The process of Delphi method application is presented in the Figure 1.

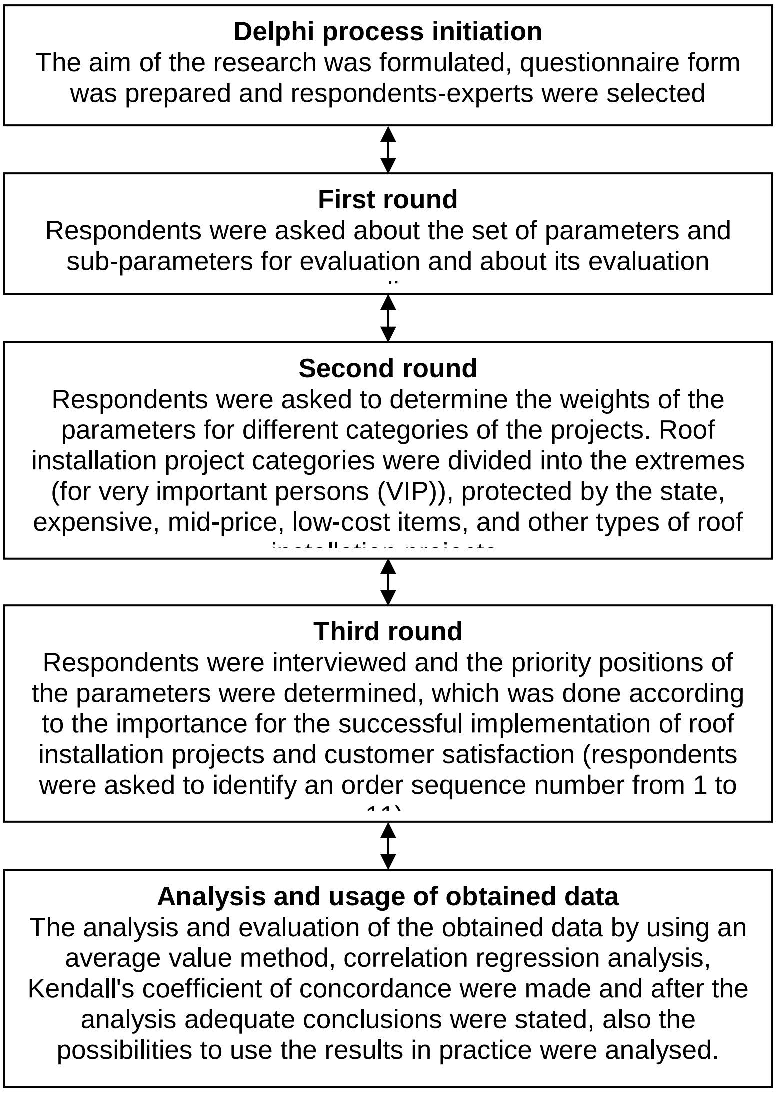


Fig. 1. The Delphi method application process

Kendall's coefficient of concordance KW was calculated as:

$$\mathrm{KW} = \frac{12\left(\sum_{\mathrm{i}=1}^{n}\left(\sum_{\mathrm{k}=1}^{m} r_{i,k} - \frac{1}{n}\sum_{\mathrm{i}=1}^{n}\left(\sum_{\mathrm{k}=1}^{m} r_{i,k}\right)\right)^2\right)}{m^2(n^3-n)}; \quad (1)$$

where $r_{i,k}$ is given the rank for the object i by the judge number k, n – the total number of the objects, and m – the total number of the judges. If the KW is 1, all the survey respondents have assigned the same rank sequence to the list of concerns. If KW is 0, then there is no overall trend of agreement among the respondents.

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

$$F_{hj} = 100\left(\frac{V_{hj} - \min_F}{\max_F - \min_F}\right); \qquad (2)$$

where V_{hj} – evaluation of j parameter for the h project (average points assigned by the experts 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 point).

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

$$A_h = \frac{\sum_j W_{hj} F_{hj}}{\sum_j W_{hj}}; \qquad (3)$$

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 of the selected type of the roof and was assigned as average of 30 respondents answers presented from 1 to 5 points).

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

6. RESULTS

The field study showed that for solving roof engineering problems the respondents offered only a few additions to the authors proposed parameters and sub-parameters set.

Nevertheless, it was found that in general the average evaluation points of the individual parameters of individual types of projects, evaluated by the experts in various stages of investigation, were correlated. In this regard, in order to evaluate objectively and to select the best roof design, the options have to rely on few experts' opinion and then it is good to use their average evaluation as a basis for possible options selection.

After the analysis of received data and application of the Kendall concordance coefficient calculation methodology it was found that there is a large difference of the experts' opinion what the parameters should be a priority. The concordance rate of 0.14 was obtained when the maximum value is 1.

During Delphi method investigation, roof installation project categories were divided into the extremes, protected by the state, expensive, mid-price, low-cost items, and other types of roof installation projects. The weights (W_{hj}) of the parameters were obtained very different for all of the selected type of the roof installation project categories.

For the individual projects assessment, it is necessary to evaluate parameters of geometric, aesthetic, physical, ecological, economic, durability, efficiency and safety properties, also warranty for the roof, plus estimated project price (Ph) in €, and the compliance with the norms and standards.

7. CONCLUSIONS

1. The DSS can be efficiently used to collect, analyse, and visualize the data and processes, after they are submitted for the experts and building customer assessment.
2. The analysis of roof designing projects must be supported by the evaluation criteria system. To create this evaluation criteria system it is necessary to make study of the evaluation subject, to found options that are important for the customers, engineers designers, builders, and other interested groups of influence.
3. After the analysis of received data and application of the Kendall concordance coefficient calculation methodology it was found that there is a large difference of the experts' opinion what the parameters should be a priority. The concordance rate of 0.14 was obtained when the maximum value is 1 (the minimum value is 0).
4. The average evaluation points of the individual parameters of individual types of the projects, evaluated by the experts in various stages of investigation, were correlated. In this regard, in order to evaluate objectively and to select the best roof design, the options have to rely on few experts' opinion and then it is good to use their average evaluation as a basis for possible options selection.
5. Delphi method opens up new possibilities for the development and evaluation of the roof designing solutions, but this method requires special knowledge and survey data processing takes quite a long time, in our case it took two months.

8. REFERENCES

1. Andreescu, I.; Keller, A.; Mosoarca, M. Complex Assessment of Roof Structures. Procedia Engineering, Vol. 161, 2016. p. 1204-1210.

Kermanshachi, S.; Dao, B.; Shane, J.; Anderson, S. Project Complexity Indicators and Management Strategies- A Delphi Study. Procedia Engineering, Vol. 145, 2016. p. 587-594.

2. Rahman, S.; Odeyinka, H.; Perera, S.; Bi, Y. Product-Cost Modelling Approach for the Development of a Decision Support System for Optimal Roofing Material Selection. Journal of Expert Systems with Applications. Vol. 39, No. 8, 2012. p. 6857-6871.

3. Spanaki, A.; Tsoutsos, T.; Kolokotsa, D. On the Selection and Design of the Proper Roof Pond Variant for Passive Cooling Purposes. Journal of Renewable and Sustainable Energy Reviews, Vol. 15, No. 8, 2011. p. 3523-3533.

4. Barnes, S. J.; Mattsson, J. Understanding Current and Future Issues in Collaborative Consumption: A Four-Stage Delphi Study. Technological Forecasting and Social Change, Vol. 104, 2016. p. 200–211.

5. Cho, J.; Lee, J. Development of a New Technology Product Evaluation Model for Assessing Commercialization Opportunities Using Delphi Method and Fuzzy AHP Approach. Expert Systems with Applications, Vol. 40(13), 2013. p. 5314–5330.

6. Okoli, C.; Pawlowski, S. D. The Delphi Method as a Research Tool: an Example, Design Considerations and Applications. Information & Management, Vol. 42(1), 2004. p. 15-29.

7. Meijering, J. V.; Tobi, H. The Effect of Controlled Opinion Feedback on Delphi Features: Mixed Messages from a Real-World Delphi Experiment. Technological Forecasting and Social Change, Vol. 103, 2016, p. 166-173.

8. Kermanshachi, S.; Dao, B.; Shane, J.; Anderson, S. Project Complexity Indicators and Management Strategies- A Delphi Study. Procedia Engineering, Vol. 145, 2016. p. 587-594.

GRAPHICS EDUCATION

TEACHING CAD WITH A PEDAGOGICAL SYSTEM SPANNING FROM VIDEOS TO INDIVIDUAL TUTORING

Claus Pütz[1]

ABSTRACT

This CAD course aims at lifting as many students as possible to a preferably high and well-defined level of competence. At the same time, the teacher's workload should be kept within limits that allow him or her to spend the majority of his or her capacity on supporting the individual student. In order to reach this aim in spite of common unfavourable teaching conditions a complex pedagogical concept of individual learning in large groups is developed. This course has already been carried out several times with great success and has been further optimized. Key elements of this concept are the following: the motivation of students, a knowledge transfer taking into account the memory system of the human brain, 150 short videos relating to a hands-on project, the graded exercises, the comprehensive system of support and the teamwork in all learning phases.

KEYWORDS: advanced instructions, blended learning, CAD education, didactic conception, individual learning, learning processes, soft skills

1. INTRODUCTION

Many teachers suffer from time constraints and often inattentive students who are either bored or overcharged. If students acquire basic knowledge on their own, it is often fragmentary and left to chance in spite of the high expenditure of time. Consequently, lecturers repeatedly have to deal with basics instead of more advanced subjects. Moreover, achievement of the teaching goals appears at stake.

This course offers a solution for the transfer of basic CAD knowledge [4]. It enables students to obtain well-defined fundamentals within a minimal amount of time. At the end of the course, the lecturer can be sure students will master the basics smoothly and reliably. Many of the methods used may seem unorthodox at first and require some adaption time. Nevertheless, due to the positive outcome, four other colleagues have adopted this course into their curriculum. The software used is Autodesk Inventor2017 professional.

We shall describe a pedagogical concept that enables students and teachers to focus successfully on the essentials for a high standard of teaching and learning.

2. BUILDING UP AND MAINTAINING THE STUDENTS´ MOTIVATION

Participants will only take full advantage of the teacher's input when able to pay undivided attention. This depends on various aspects. The more convinced the student is of the importance of the subject matter for him- or herself personally the more focused he or she will be. Statements made by other lecturers, experienced practitioners and graduates often appear more convincing than those of the lecturer in charge. Arguments, however, can only ever ensure motivation on a cognitive level. Not until students experience their individual competence, will positive feelings and evaluations be produced that are subsequently increasing intrinsic motivation. During the course, the quality of learning increases in proportion to the students' sense of achievement and lack of unnecessary frustrations. It is therefore essential for the teacher to remove all obstacles, which are of no value concerning the teaching aim.

3. FAVOURABLE CONDITIONS FOR A SUCCESSFUL TEACHING PERFORMANCE

Teaching is successful only if it enhances the participants' competence [6]. This requires new powerful neural networks to be built up in the human brain. Research in brain science shows that the effective construction of neural networks is proportionally influenced by the degree to which the following criteria are met:

The student

- feels safe
- feels part of a social environment
- considers subject significant for his or her own life
- has to apply the new input promptly
- has a realistic self-assessment
- can adapt the degree of difficulty of the task to his or her abilities
- realizes that he or she him- or herself can influence his or her learning results
- is not distracted by disturbances.

4. KNOWLEDGE TRANSFER ORIENTED AT THE STORAGE SYSTEM OF THE HUMAN BRAIN

The human brain is very effective in connecting apparently useful new information to already stored data using multitudinous references [1]. However, it is less suited to processing new data without prior experiences. Thus, one should not aim to establish a broad basis from the very beginning. Instead, we will start only with what is needed for

[1] *Institute for Geometry and Applied Mathematics, RWTH Aachen University, 52056 Aachen, Germany, e-mail: puetz@igpm.rwth-aachen.de*

a quick practical implementation (Figure 1a). Experiences gained through application facilitate the subsequent reception of further information during the next lesson (Figure 1b-e). Contents will be introduced at the time when needed for the project so that their relevance is obvious to students at any time, making time-consuming explanations superfluous. Only very few topics will require a lecturer's summary on top of the students' overview gained by their own experiences and reflections.

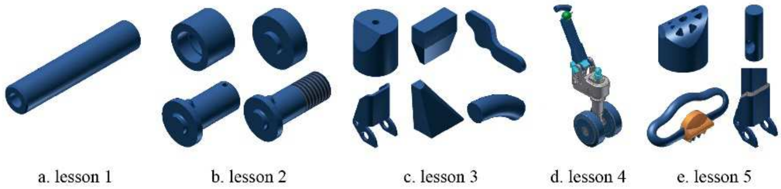


Fig. 1. Content structured in five lessons.

5. HANDS-ON PROJECT FOR THE PRESENTATION OF CONTENTS AND METHODS

The use of a single demanding project from professional practice (Figure 2) throughout the course ensures that at no time the relevance of the teaching material is questioned. High complexity is reached due to the fact that four partners each prepare and compile the single elements of the project. Thus, these really intricate topics can be practiced and reflected. Hence, this is an attractive task for both participants and teacher.

Fig. 2. Project pallet truck.

6. USING 150 SHORT VIDEOS TO CONVEY CONTENTS AND METHODS

Contents and methods are being imparted via a series of 150 short videos divided into 5 units. Each unit is followed by exercise periods for the application and consolidation of the skills learnt. Our students use the videos and do the exercises in class (Figure 3). Each video has its own topic. It starts with performing construction steps within the software accompanied by superordinate explanations. Emphasis is put on enabling students to manage follow-up exercises independently and without further support. To minimize the dependency on supervision each video concludes with pointing out frequently observed mistakes. The shortness of the videos is tailored to the students´ attention span (2-10 minutes) while at the same time enabling optimal usage of the storage system of the brain via speedy application. The students get access to the videos of the next unit after finishing the previous one.

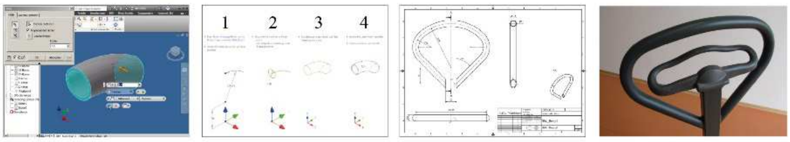
Fig. 3. Tutoring via videos in classroom.

7. GRADED TASKS FOR DIFFERENT DEMANDS

The solution process of engineering tasks can be divided into different steps. For this CAD course, we have derived the following types of tasks with corresponding requirements and a supplementary video module.
For a structural component the following items are given:

- a photograph or sketch: The student defines suitable measures for the structural component in a sketch or a technical drawing (Figure 4d).
- a technical drawing: The student develops the structuring of the necessary construction steps for the component (Figure 4c).
- a structuring of constructions: The student shows that he or she can implement the constructions independently with CAD software step by step (Figure 4b).
- a video presentation with software inputs: The student acquires knowledge through independent repetition of the software inputs (Figure 4a) .

During the course students have to be led to this practice-oriented process step by step. The respective superior aspects are given in the video as supplements to the software inputs. They are then applied in reverse order.



a. Video Presentation b. Structuring c. Technical Drawing d. Photograph

Fig. 4. System of applications.

8. A GRADED SYSTEM OF EXERCISES FOR BUILDING UP INDIVIDUAL COMPETENCE

Our system of exercises allows every student to individually adapt his or her learning curve. Students start acquiring knowledge via entering given steps into the program. Watching the complete video of a unit (Figure 4a) before carrying out the entire step on one's own yields an optimal learning effect. Working and watching simultaneously might seem quicker to many students but has a much smaller learning effect. Entering all steps of a lesson once again - now based on the structuring (Figure 4b) without using the video - consolidates the acquired knowledge. Further repetitions will build up routine. A successful training implies a safe transfer by the student: Each partner in the group will be given different tasks accompanied by instructions but without videos. Further exercises with construction drawings (Figure 4c) or photographs (Figure 4d) only will reveal whether the participants are now completely independent from support. For participants frequently encountering problems it is advisable to invest into building up a certain routine by using our system of useful repetitions [3].

9. A SYSTEM OF INDIVIDUAL SUPPORT FOR THE STUDENTS

In order to maintain the students' motivation their progress should be delayed by problems only briefly. Since all students work on similar tasks, fast solutions will easily be achieved via the following graded system: The lecturer emphasizes that watching the complete video including the discussion of common mistakes will solve most problems (Figure 5a). In addition, the team partners are often able to assist due to their unbiased view (Figure 5b). Finally, a discussion among the members of the learning group will solve 95% of the problems arising (Figure 5c). Therefore, the teaching assistant (Figure 5d) has to deal with only few problems and the lecturer can concentrate on the genuinely individual assistance instead of being kept by predictable questions. The participant, thus, will be swiftly supported in problems of any degree of difficulty order.

a. Self-help b. Partner c. Learning Group d. Teaching assistant

Fig. 5. Different types of individual support.

10. USING TEAMWORK FOR ALL INDIVIDUAL LEARNING PHASES

Collaborating within a team can have positive effects in all learning phases [2]. To help freshmen build up a positive learning atmosphere they are encouraged to choose their own partners for groups of four. While watching the videos and working at the computer they are sitting close enough to be able to help one another with questions and problems promptly. Every participant contributes the parts he or she has created during the transfer exercises to the common project (Figure 6a-d). At a practical level, the team members jointly assemble single files to a common unit. Transfer tasks are at hand to develop and optimize construction ideas within the team. Collaboration within the team will help the students to reasonably assess, reflect and specifically enhance their own performance at any time via the modules offered. It also pays off for the lecturer to support cooperation through his or her own assistance.

Fig. 6. Different tasks for each partner.

As quality control of the software competence acquired a final project will be created. Without being given new contents in videos, the four team members will create a model of the New National Gallery in Berlin within 90 minutes (Figure 7). Based on the given structuring the project will be implemented in four phases in direct cooperation.

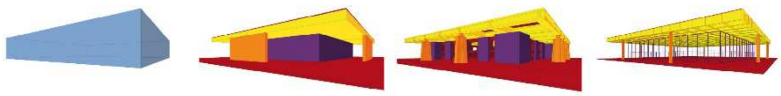


Fig. 7. Final team project: New National Gallery (Berlin).

11. COURSE FORMATS

This course can be adapted to various circumstances while maintaining the didactic concept:
In Aachen, we run a compact course for one week with 248 students working in parallel in 4 rooms from 9 to 5. During these times the students watch the videos and work on the tasks. The students report that they feel looked after very well even though 32 students have to share one teaching assistant.
In Göppingen (University of Applied Sciences), three professors run the course on a weekly basis for 200 students with only 1-2 teaching hours/week. Thus, they have reduced the size without changing the didactic concept. The professors report that their work has been tremendously facilitated by taking up the course and students come up with better results.
In Munich (Technical University), the course is being implemented for 1500 students. They prepare the course at the home with the help of videos and exercises. Every fortnight they have to work on selected elements of the pallet truck in the classroom in form of an examination.
The teaching evaluations show that all parties profit from switching to the new course.

12. CONCLUSIONS

Applying the pedagogical concept has shown that it is possible to enable a large group of students to implement a demanding CAD project in a very short time. In spite of the high standard, a single lecturer is sufficient to support 250 students very well. By way of future cooperation with other colleagues, we will further optimize key elements of the concept. Involving other colleagues will reduce start-up costs and will provide suggestions for improving both the approach and the material. If colleagues wish to adapt this course to an alternative engineering software, the service range for the students can be multiplied with significantly less effort.

13. REFERENCES

1. Bauer J. Prinzip Menschlichkeit. Warum wir von Natur aus kooperieren, 2009, Hamburg, Heyne.
2. Cohn R. Von der Psychoanalyse zur themenzentrierten Interaktion, 1997, Stuttgart, Klett-Cotta.
3. Covey St.R. The 7 Habits of Highly Effective People, 2004, New York, Free Press.
4. Feldhusen J., Brezing A., Pütz C., Wählisch G. Multi-System CAD-Teaching in Large Classes, 2010, Proceedings of the International Conference on Engineering and Product Design Education, Norway, 204-209
5. Pütz C., Schmitt F. Introduction to spatial-geometric cognition - CAD for 500 participants, 2004, Proceedings of the International Society on Geometry and Graphics, China, 501-507.
6. Rogers C. R. On Becoming a Person. A Therapist´s View of Psychotherapy, 2004, Constable.

STUDENT MOTIVATION IN ENGINEERING GRAPHICS LEARNING

Sonata Vdovinskienė[1]

1. ABSTRACT

Student motivation is a particularly important factor in the learning efficiency. We can find the growing number of the articles that mention the importance of motivation in learning and teaching, but they have not enough information about the value of motivation in adult learning context, little is said about improvement opportunities of it. The aim of the article is to find theoretical aspects of student motivation and to give the practical examples of the motivation in engineering graphics training.

KEYWORDS: Intrinsic Motivation, Extrinsic Motivation, Psychologically Friendly Learning Environment

2. INTRODUCTION

Few teachers would deny that motivated students are easier to teach, or that students who are interested in learning, in fact, learn more. But not every lecture thinks about how to motivate students working under the rules of university. The best lessons, books and materials in the world won't get students excited about learning and willing to work hard if they're not motivated. Motivation is a key factor in the success of students at all stages of their education, and teachers can play a main role in providing and encouraging that motivation in their students. Every motivated teacher has the individual task - to look for effective ways to get his students excited about learning. So, first it is important to find out basic factors of motivation that could help teachers to discover methods of encouraging motivation in their students.
Lectures of engineering graphics are also faced a problem - most of students have low motivation to study, so it is necessary to look for stimulation methods of motivation in engineering graphics learning.

3. THEORETICAL ASPECTS OF MOTIVATION

Motivation is a theoretical construct used to explain behavior. It gives the reasons for people's actions, desires, and needs. Motivation can also be defined as one's direction to behavior or what causes a person to want to repeat a behavior and vice versa (*Elliot and Covington 2001).* A motive is what prompts the person to act in a certain way, or at least develop an inclination for specific behavior (Pardee 1990). Motivation is a word that is part of the popular culture as few other psychological concepts are (*Maehr and Mayer 1997).* It plays the crucial role in student learning. However, the specific kind of motivation that is studied in the specialized setting of education differs qualitatively from the more general forms of motivation studied by psychologists in other fields.

Motivation in education can have several effects on how students learn and how they behave towards subject matter (Ormrod 2003). It can:

1. Direct behavior toward particular goals;
2. Lead to increased effort and energy;
3. Increase initiation of, and persistence in, activities;
4. Enhance cognitive processing;
5. Determine what consequences are reinforcing;
6. Lead to improved performance.

Generally, motivation is conceptualized as either *intrinsic* or *extrinsic*. Intrinsic motivation (internal) occurs when people are internally motivated to do something because it either brings them pleasure, they think it is important, or they feel that what they are learning is significant (Ryan and Deci 2000). Extrinsic motivation (external) comes into play when a student is compelled to do something or act a certain way because of factors external to him or her (like money or good grades). Internal motivation - a desire to be efficient and work on the same activities; extrinsic motivation - is the aim of external rewards or the desire to avoid punishment (Harter 1981). External rewards may even weaken or strengthen the intrinsic motivation - it depends on whether it seeks to control or to advice (Myers 2000). According to I. Lehmann (2009), “the motivation profile" develops from genetic assumptions and childhood experiences. E. Jensen (2001) states that many of the features of the student motivation are formed under his home environment, which almost cannot be influenced by us. Motivation definitions are numerous, but they mean the same - it is both internal and external incentive to do the best in a chosen job.

[1] *Department of Engineering Graphics, Vilnius Gediminas Technical University, Saulėtekio ave. 11, LT-10223, Lithuania, e-mail: sonata.vdovinskiene@vgtu.lt*

4. FACTORS OF STUDENT MOTIVATION

Learning motivation is a complex and changing phenomenon depends on many different factors, which are influenced by the different specialties.
For example, students of economics specialties recognize that the greatest influence on the motivation is the desire to learn more and become a good professional, and at least they are encouraged when the work is obligatory (Čapienė, Merkienė 2014). The most important internal learning motivation factor for the art students is the inner feeling of satisfaction after the creative work, and the biggest external learning motivation factor is surrounding assessment (Kaluinaitė, Žutautienė 2007).
The analysis of the relationship between students' learning process, study success and the nature shows that the assessment is not one of the most important motivating factors and does not reflect the actual quality of education (Asikainen *et al*. 2013). People are most creative when they first of all are promoted by interest, joy, satisfaction - but not by pressure from the outside, so intrinsic motivation is essential. The mostly identified factors are: curiosity, learning skills, emotions, desires and objectives perception, inner joy which is accompanied by acquisition, self-respect promotion, emotional and physical security, adequate training examples, frequent feedback and variety of learning forms and methods (Šakauskienė 2013).
Adult (student) learning motivation comes when are summarized four factors: success, voluntary, worthiness and pleasure (Knowles 2007).
Lithuanian psychologist Juozaitis (2005) presents four basic principles of preparation the adult learning programs: principle of adaptability, principle of clarity, principle of interest and "hidden content" principle.

5. MOTIVATION AND ITS STIMULATION IN ENGINEERING GRAPHICS TRAINING

Lithuanian psychologist Juozaitis (2005) states that first of all lectures have to create a psychologically friendly learning environment, which is influenced by good knowledge of the chosen topic, being ready to hear others, self-improvement, versatility, attention to details, personal maturity and etc. Lectures of engineering graphics must pay an attention to these aspects too.
As hours for this discipline significantly decreased, the task for every lecturer has become very difficult – he has not only to present and explain the all content of learning materials (the basic principles of engineering graphics, standards requirements and computer programs and etc.), to assess students' works on time, but also to look for stimulation methods of student motivation.
The easiest way to reinforce learning motivation is offering students to choose themselves the task of several of its variants. It would take a little more time for creating extra new tasks, but this opportunity would be one of the psychologically friendly learning environmental factors, which incites a student to trust his instincts as both a teacher's goodwill.
One of the most powerful motivation factors is newsworthiness. Obviously, creation of interesting and original tasks and their presentation take a lot of time, but it certainly would provoke students to master the material with a higher willingness, especially when the tasks are presented by games. One of the goals of these games is to develop students' spatial imagination. The first figure presents the example of the task game, which requires to guess hidden parts and to combine shapes. The solution is evaluated and students can revise their answers repeatedly until their correction (Gergelitsova, Holan 2008).

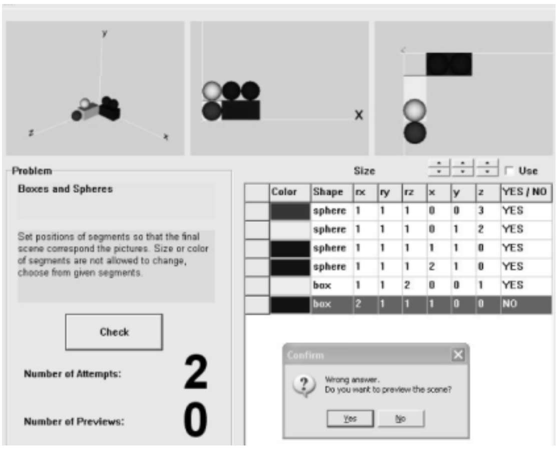


Fig. 1. The task – a game that requires the correct setting of positions of given segments

One of the basic tasks of engineering graphics is presenting objects views. The task about the cube wall formation could be used instead usual standard tasks (Fig. 2 a). Playfully colored cube walls would stimulate students' curiosity and positive emotions and would help students to understand the task.

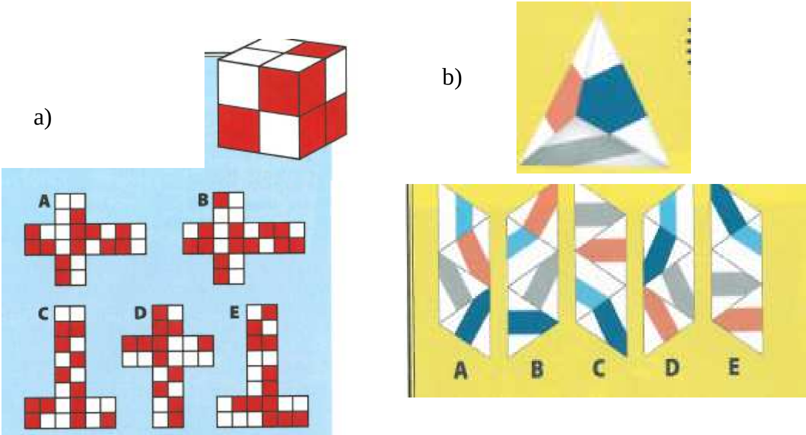


Fig. 2. The tasks of presenting objects views (a) (Illustrated Science 2012/7) and creating developments (b) (Illustrated Science 2012/9). One of the most important tasks of engineering graphics discipline is to create objects developments. Often the lack of spatial imagination prevents students to solve this task. The example (Fig. 2 b) illustrates the unusual and colorful task, which with its playfulness could also be interesting for students and could help them understand the essence of the theme.

Students learn with satisfaction when they have opportunities to create and express their skills. Surface modeling tasks obviously prove it.

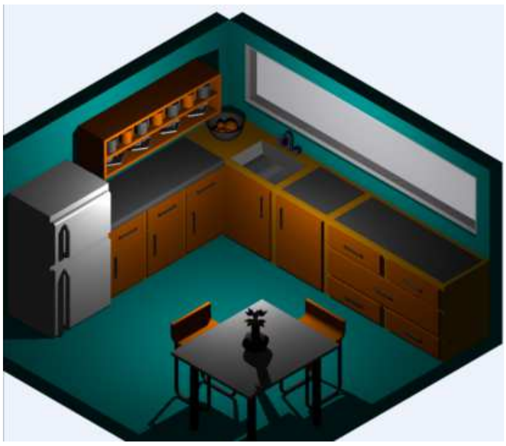


Fig. 3. The example of the surfaces modeling task in Autocad programm

Despite the lack of time, students do the task with great interest. They create a topic of the task, select objects for it by themselves and creatively carry out the task (Fig. 3). Unfortunately, in most cases this task is not necessary because there is not enough time for it. Therefore, in order to develop student intrinsic motivation, it is necessary to look for opportunities how to add such tasks to the list of mandatory tasks, or how to change them into new and more creative tasks.

One of the ways to encourage students' creativity is taking part in exhibitions of students' works. In addition, such assessment of the work would include external motivation. Unfortunately, the troubles of organizing exhibitions or other reasons prevent these significant activities for learning motivation.

A very effective way of stimulating both intrinsic and extrinsic motivation is participating in engineering graphics students' competitions. Students themselves decide to take part or not. In this way, they understand that their freedom of choice is related to their responsibilities. Preparing themselves for the contest, students develop their learning skills, have the ability to expand their knowledge, experience success and inner joy, strengthen assuredness. In addition, they could be able to ask for a teacher help. It also extends the positive emotions towards a common goal. Unfortunately, due to lack of time or disbelief competitions efficiency, students' competitions are not popular enough in our higher schools.

Nowadays we can see the rapid development of information and communication technologies, so the distance learning becomes more and more popular. It is different from the traditional not only in the learning material presentation method, but also in the learning process control and assessment features. Distance learning is little controlled by a lecturer, so students' learning outcomes depend more on their internal motivation. So, this learning method requires particular attention to intrinsic motivation factors.

Only such a program, which reflects knowledge and understanding based on the humanistic values, can contribute to a new quality of life (Juozaitis 2005).

6. CONCLUSIONS

- Every teacher who wants to motivate students first has to create psychologically friendly learning environment and, according to the specific job requirements, to find out the most appropriate stimulation methods of student intrinsic motivation.
- The most effective engineering graphics student motivation factors can be determined only after a detailed survey analysis of learners of this discipline.

7. REFERENCES

1. Asikainen, H. *et al.* 2013. The Relationship between Student Learning Process, Study Success and the Nature of Assessment: A Qualitative Study. *Studies in Educational Evaluation* 39: 211–217.

2. Čapienė, A.; Merkienė, R. 2014. Studentų motyvavimo veiksniai ir priemonės, užtikrinančios aktyvų dalyvavimą verslumo ugdymo praktikoje [Students Motivation Factors and Measures to Ensure Active Participation in Entrepreneurship Educational Practice]. *Management Theory and Studies for Rural Business and Infrastructure Development* 36(2): 245–254.

3. Elliot, A. J. and Covington, M. V. 2001. Approach and Avoidance Motivation. Educational Psychology Review 13(2): 73–92.

4. Gergelitsova, Š.; Holan, T. 2008. Development of Spatial Abilities by means of Didactic Computer Games. *The Journal of Polish Society of Geometry and Engineering Graphics* 18: 32–38.

5. Harter, S. 1981. A New Self-Report Scale of Intrinsic versus Extrinsic Orientation in the Classroom: Motivational and Informational Components. *Developmental Psychology* 17(3): 300–312.

6. *Iliustruotasis Mokslas* [Illustrated Science]. 2012/7. Vilnius. 67 p.

7. *Iliustruotasis Mokslas* [Illustrated Science]. 2012/9. Vilnius. 67 p.

8. Jensen, E. 2001. *Tobulas mokymas* [Perfect training]. Vilnius. 48 p.

9. Juozaitis, A. M. 2005. *Besimokantys suaugusieji. Prieš einant į suaugusiųjų auditoriją* [Adult Learners. Before Going to an Adult Audience]. Vilnius.

10. Kaluinaitė, K.; Žutautienė, E. 2007. *Meno srities studentų dailės mokymosi motyvacijos veiksniai* [Motivation Factors of Studying Fine Arts of Students in Art]. Available from Internet

<http://www.elibrary.lt/resursai/Mokslai/VIKO/PF_050422/PF_050422_04.pdf>.

11. Knowles, M. S. 2007. *Suaugęs besimokantysis: klasikinis požiūris į suaugusiųjų švietimą* [An Adult Learner: The Classic Approach to Adult Education]. Vilnius.

12. Lehmann, I. 2009. *Motyvacija: kaip tėvai galėtų padėti savo vaikams* [Motivation: How Parents Can Help Their Children]. Vilnius. 150 p.

13. Maehr, M. L. and Mayer, H. A. 1997. Understanding Motivation and Schooling: Where We've Been, Where We Are, and Where We Need to Go. Educational Psychology Review 9(4): 371–409.

14. Myers, D. G. 2000. *Psichologija* [Psychology]. Kaunas. 816 p.

15. Ormrod, J. E. 2003. Educational Psychology: Developing Learners. 4th Edition. Merrill Prentice Hall, Upper Saddle River, NJ.

16. Pardee, R. L. 1990. *Motivation Theories of Maslow, Herzberg, McGregor & McClelland.* A Literature Review of Selected Theories Dealing with Job Satisfaction and Motivation. ERIC.

17. Ryan, R. M and Deci, E. L. 2000. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology* 25(1): *54–67.*

18. Šakauskienė, R.; Vdovinskienė, S. 2013. Studentų mokymosi motyvacija ir jos skatinimas [Student Motivation in Learning and Incentives], iš *Inžinerinė ir kompiuterinė grafika* [Engineering Computer Graphics]: konferencijos pranešimų medžiaga. Kaunas : Technologija, 89–96.

THE COMPARISION OF GRAPHIC PROGRAMING LIBRARIES

Ana Usovaitė[1]

1. ABSTRACT

At this moment there are two main graphics programming libraries: Directx12 and OpenGL. These libraries are the powerful programming tools and are widely used to create graphical applications. It is clear, these libraries are different manufacturers, but the library has different and similar features. The article compared the graphic libraries according to their functionality and programming capabilities.

KEYWORDS: Graphics programming, Graphics libraries, DirectX and OpenGL capability comparison

2. INTRODUCTION

Microsoft DirectX is a collection of application programming interfaces (APIs) for handling applications related to multimedia, game programming and video and audio processing, bet only on Microsoft platforms. Direct3D (the 3D graphics and other parts API within DirectX) is widely used in the development of video games for Microsoft Windows and the Xbox products of consoles. Direct3D is also used in CAD/CAM engineering and other software applications for processing visualization and graphics tasks. As Direct3D is the most widely used component of DirectX, it is common to see the names "DirectX" and "Direct3D" used interchangeably [1, 2, 4].

Open Graphics Library (OpenGL) is a cross-language, cross-platform application programming interface for processing and rendering 2D and 3D vector graphics and other multimedia components. The API is typically used to directly interact with a graphics processing unit (GPU), shaders and to perform hardware-accelerated rendering.

OpenGL is the premier environment for developing portable, interactive 2D and 3D graphics cross-platform applications and games for PC and mobile devises. Since its introduction in 1992, OpenGL has become the industry's most widely used and supported 2D and 3D graphics application programming interface, making millions of applications to a variety of different computer platforms. OpenGL graphics library promotes novelty and fast application development by include a broad set of rendering, texture mapping, sounds, special effects, and other powerful visualization functions. Developers can leverage the power of OpenGL across all popular desktop and workstation platforms, ensuring wide application deployment.

Created applications have high visual quality and performance. Any graphical computing application demanding maximum performance-from 3D animation to CAD to visual simulation-can operate high-quality, high-performance OpenGL capabilities. These capabilities permit developers in various markets such as broadcasting, CAD/CAM/CAE, entertainment, medical imaging, and virtual reality to produce and display incredibly irresistible 2D and 3D graphics [3, 5].

The main differences between DirectX and OpenGL:

1) Microsoft is whole and sole company that designs and develops DirectX APIs and not to mention underlying drivers. Whereas OpenGL is maintained by Khronos. Underlying drivers are developed by individual dealers like Nvidia and other.

2) Microsoft is a commercial and profit making international organization but Khronos is not.

3) OpenGL has a subset known as OpenGL ES targeted at Embedded devices. Right now it is the most widely accepted graphics standard for Embedded devices. OpenGL wins over DirectX here.

4) DirectX needs only Windows operating system, OpenGL is operation systems independent

5) Talking about graphics performance DirectX wins the race over OpenGL (why not.microsoft is shelling out so much money on its products).

6) Desktop games will be most effective on Windows than on other operation systems like Linux which uses OpenGL rendering pipeline.

Except the differences OpenGL and DirectX API have plenty of analogy as well. First, both of them use programable graphics pipeline, both support 3D and other operations. Very important, that convert graphics code from OpenGL to DirectX and vice versa should not be a problem.

3. A COMPARISION *OPENGL* VS *DIRECTX*

The meeting between OpenGL and DirectX is perhaps as well known as the disputes between AMD and Intel video cards enthusiasts. This talk has generated the fires of many flame discuses throughout the years. Bet it is don't predict that changing in length of time. It is clear that really cannot be excluded than one program.

Presumably the most obvious and main difference is that DirectX, as against to OpenGL, is more than just a graphics library for API. DirectX possesses tools to investigate with such units and nodes of a game as input, networking, sound, music and multimedia. On the other hand, OpenGL is exactly a graphics programing tools or API. So it is the main aspect of deference between OpenGL and DirectX graphics component

[1] *Vilnius Gediminas Technical University, Department of Graphical Systems, Saulėtekio al. 11, LT01132 Vilnius, Lithuania, e-mail: ana.usovaite@vgtu.lt*

Can safely say that both APIs rely on the use of the traditional graphics pipeline for images rendering. This is the same pipeline that has been used in computer games since the early days of computer graphics. Though it has been changed in small ways to adapt with progress in computer hardware, the main idea remains inviolate.
Both OpenGL and DirectX characterize vertices as a set of data occurring of coordinates in space that describe the vertex location, colour, normal and any other vertex related data. Graphics primitives, such as points, lines, and triangles, are defined as an ordered set of vertices. There is a difference in how DirectX and OpenGL API attends primitives how vertices are composited to form primitives.
There are a variety of differences in the DirectX and OpenGL APIs, so I will list a few of those Table 1 [5]:

Feature:	OpenGL	DirectX
Vertex Blending	N/A	Yes
Multiple Operating Systems	Yes	No
Extension Mechanism	Yes	Yes
Development	Multiple member Board	Microsoft
Thorough Specification	Yes	No
Two-sided lighting	Yes	No
Volume Textures	Yes	No
Hardware independent Z-buffers	Yes	No
Accumulation buffers	Yes	No
Full-screen Antialiasing	Yes	Yes
Motion Blur	Yes	Yes
Depth of field	Yes	Yes
Stereo Rendering	Yes	No
Point-size/line-width attributes	Yes	No
Picking	Yes	No
Parametric curves and surfaces	Yes	No
Cache geometry	Display Lists	Vertex Buffers
System emulation	Hardware not present	Let app determine
Interface	Procedure calls	COM
Updates	Yearly	Yearly
Source Code	Sample	SDK Implementation

Table 1 DirectX and OpenGL capability comparison

Now is possible DirectX 12 version. Most recently released a new version of the DX, it differs significantly from the previous version. The new version has the following features [1, 2]:

- Only supports Windows and Xbox One
- Massive reconstruct and overhaul of the DirectX 11 version
- Developed to Reduce Driver overhead similar to AMD's Mantle
- Achieve "console-level efficiency, and improved CPU Parallelism
- Only supports Windows and Xbox One
- Closed source

As usual, admitted and analogy VULKAN. It is a strong product. its main characteristics:

- Cross-platform API supports Windows, OSX, Linux/SteamOS and mobile/embedded devices
- Derived from and built upon components of AMD's Mantle
- Offers lower overhead, more direct control over the GPU and lower CPU usage
- Direct access to the GPU for maximum console-like performance
- SPIR-V built into API's core (also in OpenCL 2.1), as native intermediate language, making it easier for developers to take advantage of multiple shading language front-ends
- In the process of being implemented into the major game engines (Unreal, Crytek, Unity and Source).
- Open source library [3, 5].

4. CONCLUSIONS

- To promote the development of games on Windows, Microsoft needed a uniform API that would be low-level, would work on Windows without loss of performance, and would be compatible with various hardware. Direct X is a single API for graphics, sound and input devices.
- OpenGL is an open standard developed by the nonprofit organization Khronos Group with the participation of the community. All major manufacturers of GPU (nVidia, AMD, Intel), one way or another, influenced OpenGL. Unlike Direct3D, it is available on a very large number of platforms. In particular, OpenGL is the main API for interacting with GPUs on Linux and Mac OS.

5. REFERENCES

1. Direct3D 12 Programming Guide. https://msdn.microsoft.com/en-us/library/windows/desktop/dn899121(v=vs.85).aspx
2. Direct3D 12 vs OpenGL: A quick Test. http://www.geeks3d.com/20160105/direct3d-12-vs-opengl-a-quick-test/
3. https://www.khronos.org/vulkan/
4. James D. Foley. Computer graphics: principles and practice. ISBN-10: 0321399528, Addison-Wesley, 2000, 1175 p.
5. OpenGL vs. DirectX: A Comparison. http://www.cprogramming.com/tutorial/openglvsdirectx.html

OVERVIEW OF THE GRAPHIC PROGRAMMING TEACHING EXPERIENCE

Ana Usovaitė[1]

1. ABSTRACT

The graphic programming often taught for informatics students. The course is linked to the graphics library OpenGL or Directx12 use. In short, this course consists of computer graphics-based uptake and programming skills. This course is quite challenging. The main reason for this difficulty is that the need to reconcile two things: modern graphics and programming skill. In the paper described the 10 years of teaching experience.

KEYWORDS: Computer Graphics course, DirectX, Modelling, Graphics programming, obj file format

2. INTRODUCTION

Computer graphics subject is taught in almost all universities. This is quite a complicated thing. Graphic Technology evolving very rapidly.
Therefore, the teaching material necessary is changed and improved too. The author proposes in the teaching of computer graphics sure to pay attention to such things as text file of modelling objects understanding and file structure are C ++ understanding and using.

3. OBJECT MODELLING

or the modelling programs packages usually export format we will use the .OBJ format as it is easily good for beginners to start with and readable in graphics libraries.
The .OBJ exporter in Blender, 3D Max and Maya you must first enable to export your model in the .obj format. For example, you must click "*Window*", then "*Settings/Preferences*", then "*Plug-in Manager*". Scroll down to objExport.mll and select both "*Loaded*" and "*Auto load*". In other programs (Blender, 3D Max) it is same. Then you must to export your model in this format click on "*File*" in menu, then "*Export All*". Now at the menu you can select "*Files of type:*" and scroll down and select for .obj format "*OBJexport*". Give it a file name for model in obj format and hit "*Export All*" and model will export it to a text file with a .obj extension. To look at the file you can right click and select Open With and choose any text redactor to look or read the file. Similar actions in other modelling programs. In the .OBJ file with model you will then see something that looks like the following:
This particular .OBJ model file represents a simple 3D cube. It has 8 vertices coordinates (x, y, z). The 6 sides of cube made up of 12 triangles or faces and 36 indices indexes in total. Also the cube described by 24 texture coordinates and normal vectors. When analysing the file content, you can disregard, every line unless it starts with a "V", "VT", "VN", or "F". The additional information in the file will not be needed for converting .obj to other file format. Below described what each of the important lines means:
1. The "V" lines are for the vertices coordinates (x, y, z). The cube is made up of 8 vertices for the eight corners and six side of the cube. Vertices listed in X, Y, Z coordinates float format [3]:
v -1.000 -1.000 1.000
v 1.000 -1.000 1.000
v -1.000 1.000 1.000
2. The "VT" lines are for the texture coordinates. The cube has 24 texture coordinates and most of them are duplicated since it records them for every vertex in every triangle in the cone model. They are listed in TU, TV float format.
vt 0.997 0.00199
vt 0.00199 0.997
vt 0.997 0.997
vt 0.00199 0.00199
3. The "VN" lines are for the normal vectors. The cube has 24 normal vectors and most of them are duplicated again since it records them for every vertex in every triangle in the cube model. They are listed in NX, NY, NZ float format.
vn 0.000 0.000 1.000
vn 0.000 1.000 0.000
vn 0.000 0.000 -1.000
vn 0.000 -1.000 0.000
4. The "F" lines are for each triangle (face) in the cube model. The values listed are indexes into the vertices, texture coordinates, and normal vectors. The format of each face is:
f Vertex1/Texture1/Normal1 Vertex2/Texture2/Normal2 Vertex3/Texture3/Normal3
So a line that says "f f 2/5/17 8/6/18 4/7/19" then translates to "Vertex2/Texture5/Normal17 Vertex8/Texture6/Normal18 Vertex4/Texture7/Normal119".
The order the data is listed in the .obj file is very important. For example, the first vertex in the file corresponds to Vertex1 in the face list. This is the same for texture coordinates and normals as well.

[1] *Vilnius Gediminas Technical University, Department of Graphical Systems, Saulėtekio al. 11, LT01132 Vilnius, Lithuania, e-mail: ana.usovaite@vgtu.lt*

Looking at the face lines in the .obj file notice that the three index groups per line make an individual triangle. And in the case of this cube model the 12 total faces make up the 6 sides of the cube that has 2 triangles per side [3].

4. C++ PROGRAMMING FOR GRAPHICS

C++ classes (classes descriptions and often function prototypes) are normally split up into two files (header .h and source .cpp). The header file has the extension of .h and contains definitions of class elements and functions. It is typical for programming, especially in C++. The implementation of the class or function goes into the .cpp file. By doing this, if your class functionality implementation doesn't change then it won't need to be recompiled project. In addition, program code is easy readable. As a rule, most IDE's will do this for you – they will only recompile the classes that have changed. Very impotent, that this is possible when they are split by two file up this way, but it isn't possible if programme code is in one file (or if the implementation is all part of the header file). Simple example [1,5]:

```
Header File: Class.h
class Class
{
private:
 int Class;
public:
 Class(int n);
 int getElement();
};
File: Class.cpp
#include "Class.h"
Class::Class() : Class(0) { }
Class::Class(int n): Class (n) {}
int Class::get Class ()
{
return num;
}
File: main.cpp
#include <iostream>
#include "Class.h"
using namespace std;
int main()
{ Num n(35);
 cout << n.getElement () << endl;
 return 0;}
```

Common program structure you can see in Fig. 1.

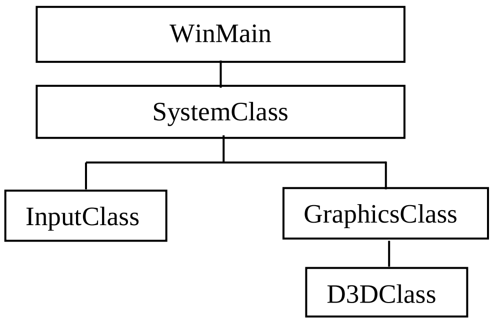


Fig. 1. Project structure

WinMain class have Main function to start programme. Input Class processes input date and devices. Now that we have a D3DClass member we will start to fill out some code inside the GraphicsClass to initialize and shutdown the D3DClass object. We will also add calls to D3DClass::Render in the Render function so that we are now drawing to the window using Direct3D [2, 4].

In D3DClass class is created objects:device, commandQueue, swapChain, renderTargetViewHeap, backBufferRenderTarget, backBufferRenderTarget, commandAllocator, commandList, pipelineState, fence, fenceEvent.

5. CONCLUSION

DirectX is quite complicated graphics library. For teaching computer graphics subject is necessary connection with other subjects.

Especially important for modelling and programming in C ++ subjects. Students need to explain .obj file structure. In addition, it is important to understand the program code division into separate files meaning.

6. REFERENCES

1. Allen Sherrod, Wendy Jones. Beginning DirectX 11 Game Programming. ISBN-10: 1435458958, Course Technology PTR, 2011, 372 p.
2. Frank D. Luna. Introduction to 3D Game Programming with DirectX 12. ISBN-10: 1942270062, Jones & Bartlett Publishers, 2016, 900 p.
3. http://www.rastertek.com
4. James D. Foley. Computer graphics: principles and practice. ISBN-10: 0321399528, Addison-Wesley, 2000, 1175 p.
5. Jason Zink, Matt Pettineo, Jack Hoxley. Practical Rendering and Computation with Direct3D 11. ISBN-9781568817200, A K Peters/CRC Press, 2011. 648 p.

DESCRIPTIVE GEOMETRY COURSE AND MULTI-CULTURAL ENVIRONMENT

Tea Hunt[1], Harri Annuka[2]

ABSTRACT

The article describes an experience of organizing a descriptive geometry course in a multicultural setting. The target group is an international community of students with different cultural backgrounds and lifestyles enrolled in the “Integrated Technologies” specialty of the Faculty of Engineering. The aim of the study was to map and analyze the experience and to present practical guidelines for developing more effective attitudes to learning through the subject of descriptive geometry. It should also facilitate the students’ faster adjustment to the ways studies are organized in Tallinn University of Technology. The recommendations address the students’ practical needs and reflect their suggestions received through feedback questionnaires.

KEYWORDS: descriptive geometry, methodology, multicultural, supervision, learning guideline

INTRODUCTION

The TTÜ lecturers of Engineering Graphics have three years of experience in teaching students [1] whose linguistic background, country of origin and even level of education vary considerably. Previous education was mainly represented by secondary schools, colleges and vocational schools. The 97 enrolled students came from four continents and 25 countries (see Table 1). The language of instruction was English.

The primary aim of the university descriptive geometry course has been set as the development of students’ manual and computer-aided drawing skills. The course has been administered by means of all the traditional teaching methods: lectures, practice lessons, seminars, group work, independent

Country	Numbe r of Student s	Country	Numbe r of Student s
Georgia	20	The Republic of Azerbaijan	1
The United Republic of Nigeria	11	The United Democratic Republic of Ethiopia	1
Finland	8	Japan	1
Ukraine	8	The Republic of Camerun	1
The Russian Federation	8	The Republic of Kazachstan	1
The Republic of India	7	The Kyrgyz Republic	1
The United States	5	The French Republic	1
The Republic of Turkey	5	The Kingdom of Sweden	1
The Arabian Republic of Egypt	4	The United Republic of Germany	1
The Republic of Latvia	4	The Slovak Republic	1
The National Republic of Bangladesh	2	The United Republic of Tansania	1
The Islamic Republic of Iran	2	Turkmenistan	1
		The Belarus Republic	1

Tabel 1

learning, and individual supervision, including tutorials. Students’ feedback is collected at the end of the course.

The course materials along with the WEB support consist of study materials, learning guidelines and informative materials.

The descriptive geometry study materials are presented as modules, each of which can be looked at as a whole on its own.

The created learning guidelines are topic-based (see Learning Guideline No 1); they contain all that is necessary for achieving the learning outcome. The learning guidelines comprise:

– the aims of the module, the knowledge and skills to be acquired – i.e. the learning outcomes, - a short description of the topic, the notions and the contents of the module

[1] *Academy of Architecture and Urban Studies, Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia; e-mail: Tea.Hunt@ttu.ee*
[2] *Academy of Architecture and Urban Studies, Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia; e-mail: Harri.Annuka@ttu.ee*

- problem-solving tasks (exercise book; practice session and independent work)
- independent work guidelines (what is to be read and where it can be found) along with the questions to be answered
- independent graphic work home assignment (the task, paper size A3; formatting requirements)
- test.

The action plan provides an overview of the learning process by linking schedules, course activities, topics, teaching materials, tasks, and assignments to be submitted for assessment.
The plan is presented in the form of a table, which presents the student's weekly schedule of attending lectures, practice sessions, independent homework, and the list of assignments to be submitted for assessment.
The three-year average academic achievement of the descriptive geometry course students of integrated engineering has been 49.4%. Better achievers came from vicinity countries of the European continent, such as Ukraine (85.7%), Latvia (66.5%) and the Russian Federation (57.1%).

PROBLEMS

Students, who come to study the named specialty, come from schools of very different regions with very uneven quality [2] of basic education. The difference is conditioned by dissimilarity in educational systems and attitudes to work and studies. For example,

- attendance of practice sessions and lectures is not consistent from the very beginning of studies
- students do not begin asking questions and attending tutorials before the second part of the term
- independently found literature sources offer information which differs from that of Europe
- independent graphic home assignments are not submitted on time
- the acquired level of English language skills is not adequate for self-expression.

Another problem is that some students arrive with a delay of two to three weeks and assume that the drawing tools will be provided by the university.
The main reasons for students' drop-out are quitting on the basis of a personal application (10%), low achievement (7.1%) and absenteeism (4.3%). The rest 29.2% will repeat the course in some other academic year via the Open University.
The answers to the feedback questionnaire of the course indicate that organizing studies in a multicultural environment requires greater emphasis on supervision.

SUPERVISION

Considering the above an action guideline (see Focusing attention – the important factors) and learning guideline (see Learning Guideline No 1. Projection) have been compiled to facilitate acquiring the subject and adjusting to the new environment [3]. Both of them perform a guiding and supervising function for the student and are available on a hard copy and on the WEB.

(1) FOCUSING ATTENTION – THE IMPORTANT FACTORS

Thinking – creating connections – is based on notions. That is why it is very important to know exactly the meaning of every notion. Descriptive geometry uses the notions of mathematics. Some of them are quite new for the learners while others have already been studied. In case the meaning of some formerly studied notion has been forgotten, it is necessary to revise its contents independently with the help of a handbook of mathematics.
In the first half of the course, students learn to identify and design simple space elements, as well as the ways of solving space problems. In the second half of the semester, based on the formerly acquired knowledge, mainly multiple-part tasks are solved. As the separate parts of the course are interconnected, all the subsequent being based on the previous, it is necessary to study the subject regularly, acquiring the knowledge step by step, in the order it was taught at a lecture, paying attention, first of all, to understanding the meaning of the notions, as well as their interconnections. The study material that is planned for every week, has to be studied in due time. Neglecting the schedule or inadequate acquisition of some part of the study material will cause problems of coherence in the future.
Some useful tips:
1. Studying descriptive geometry can only be successful, if conscious attention is being paid to every part of the course from the point of view of theory, space and drawing. The most important issues which should be kept in mind are the following: notion, object imaging and marking, general or special case, in other words, - location of the object in relation to the screens, its characteristics in a two- and/or three-view image, derivation (there may be more solutions than one), possible application (examples).
For example, the smallest object of descriptive geometry is a space point. Based on the above, it is necessary to formulate and answer the following questions: What is a space point? How is it possible to show and mark a space point in a drawing? In what situation is the position of a point in relation to the screens considered as a general or special case? By what sign in the drawing a decision can be made on whether the point is in a general or special position? How to make a drawing of a given space point? What initial data are required to make a drawing of a space point? More questions arise in case a point is, for example, on some surface. How to derive the missing projection of a point based on its given projections?
2. Solving every descriptive geometry task should start with a thorough analysis of the primary data and factors, in the course of which, first of all, the location of geometric objects in space and their position in relation to each other are

determined, and after that their position in relation to the screens. In other words, based on the drawing, it is necessary to create in your mind an image of the situation in space. Such an analysis of the primary data will help you to draw up a plan for solving the task, so you can start drawing the constructions.

3. It is imperative to study thoroughly at home every part of the study material before a lecture or practice session, using, in addition to your notes, the recommended course literature. It is advisable that you should copy by your own hand the majority of construction drawings given in the course book. This will supply you with good feedback on your knowledge and skills, so you will know what you already know and can and what is still lacking.

4. Remember that that success in designing space can be achieved only if you devote enough time to the theory of the topic and to practice. It is advisable that you practice solving tasks, for example, by finding various solutions to several graphic home tasks before a test. The problems arising in descriptive geometry are not limited to a certain number of tasks. Comprehensive training for professional work requires studying and solving a great variety of problems in many different situations.

It is recommended that, in addition to independent work, solving problems and formulating the process of finding answers to questions should be practiced with group mates and other students on the course, referring to similar ways of solving problems described in lecture notes and study literature. In case it is impossible to solve a problem independently, it is necessary to consult a lecturer.

5. While studying the theory and solving tasks of descriptive geometry, it is necessary to try, as vividly as possible, to imagine in a room the objects shown in a drawing. Resourcefulness will help, - any simple object at hand can be used as a model. Thus, an open book in the position of a right angle may represent two screens, pencils can be used as straight lines, a drawing triangle – as a plane. A polyhedron, a cone or a cylinder can be made of paper. Plasticine can be used to make more elaborate models with openings and cut-outs etc.

The key to understanding the subject of descriptive geometry lies in the need for imagination.

In each topic, please, follow the given study algorithm: learn the meaning of the notion (notions), designing and marking the object, *its* characteristic in two- or three-view, position in relation to the screens – general or special case, deriving and marking images of the object (there may be more than one solution) and the possible applications.

In the course, drawing tools are used, which, if kept in good working order, make drawing a pleasant activity and are a prerequisite for producing a precise drawing. It is important to have personal drawing tools in lectures and at practice sessions.

Recommendations for managing studies

- Do it now!
- Revise it and it will be remembered! Revise the studied in class on the same day.
- Communicate and discuss the topics of the subject with group mates and other students on the course.
- Try to imagine the situation in space; if necessary, make a space model of the situation.
- Train independently. Compare your answers with those of your group mates. Ask yourself and answer other students' questions – deal with the topic.
- Plan real time for studies.
- Recommendation for scheduling the work of a final-year student: calculate the total time for studies. Add one third and reserve this time for yourself realistically. For example, a descriptive geometry course is worth of 4 ECTS credits. The estimated time consumption is calculated by multiplying the course volume by 26 academic hours of student work. Thus, 104 academic hours should be planned for studies. In case the subject feels quite difficult, add one third, i.e. multiply the result by 1.3, so it will be reasonable to plan 135.2 academic hours for studying the subject.
- Communicate with your lecturer(s) when you have questions. Actively use the tutorial time or write an e-mail.

Communication with a lecturer by e-mail

To communicate with your lecturers in case of necessity you can use an e-mail. A professional e-mail should contain all the necessary information: title (subject, content reference), content (a notification/ report/ question), the author of the e-mail (name, student code and student group No).

(2) LEARNING GUIDELINE No1. PROJECTION

The first chapter explains what projection is, what is needed to get a projection and what is the role of spacial imagination in making a drawing.

To exactly understand what is being said, it is necessary to know the meaning of the words. In the learning material, such words are called concepts or notions. The notions of this chapter, on which the hole descriptive geometry course is based, are the following:

central projection, parallel projection, object, projecting ray, screen, projection/(image), (types of projections: central and parallel projection; orthogonal and oblique projection), distortion factor, inclination angle, quote, coordinates of point, scale (numerical scale, scale bar, comparison scale), kinds of axonometric projection (orthographic axonometric projection, oblique axonometric projection; orthographic isometric projection, standard dimetric projection, oblique dimetric projection (frontal oblique dimetric projection)), axonometric axes and distortion factors of axes, congruent, parallel, perpendicular, oblique.

The knowledge to be acquired during the course is:

1) ways of deriving object projections,

2) kinds of projections,
3) basic methods of descriptive geometry.

The skills to be acquired during the whole course are:

1) determining the drawing method by given image,
2) determining the kind/type of projection by given projection,
3) constructing axonometric axes (orthographic isometric projection, frontal oblique dimetric projection),
4) deriving the axonometric projection by point coordinates.

Read Lecture 0 in ÕIS. There are slides of the introductory lecture that will take place in the orientation week.
Work through the slides of Lecture 1, following the action plan for learning week 1-2, fill in the exercise book exercises 1 to 6 and do the independent graphical home assignments. It is recommended that you also see how drawings are born by watching the video lectures (you will find the link at the end of the action plan).
Find the answers to the following revision questions – these will help you to pass the tests and the exam successfully.

1. What is the first and most important aim of descriptive geometry?
2. What is the difference between central and orthogonal projection?
3. What are the types of parallel projection and how do these projections differ from each other?
4. Why can a one-view drawing not determine an object without any additional data?
5. In what case a straight line projection is a point?
6. In what case a planar object parallel projection is a straight line?
7. What is the distortion factor of a straight line segment?
8. In what limits may the distortion factor of a straight line segment become: 1) an orthogonal projection, 2) a parallel projection?
9. What shape will the circle parallel projection take, if it is: 1) parallel to rays 2) parallel to the screen?
10. How does the length of a straight line segment orthographic projection manifest through the line segment angle and the length of the section?
11. What is the inclination angle of a straight line segment?
12. To what limits can the value of an acute angle vary in orthogonal projection?
13. Express the length of the line segment a, if its length in parallel projection a' and the distortion factor m are known.
14. Formulate a sentence about the right angle orthographic projection.
15. What requirements should a drawing meet?
16. List the basic methods of creating drawings.
17. What does the concept of "reading the drawing" mean?

NB! While making drawings it is necessary to follow the formatting rules.

CONCLUSION

Descriptive geometry is a unique subject in which every drawing has a special significance – the drawing is the main tool by which a solution can be found. A graphic solution is based on two synchronic and simultaneous activities – the manual and the intellectual. Success is achieved by students who have mastered both.
Organization of studies in a multicultural environment needs more supervision [4] – written and/or oral. It is most relevant to create a friendly and supportive atmosphere of learning to maintain and raise the students' motivation. To achieve this, it is necessary to:

– introduce both orally and visually the main points at the beginning of the lesson
– facilitate communication between group mates in the classroom while keeping understanding of what is being taught under control
– encourage students to ask questions and take initiative in clarifying misunderstandings and difficult points
– give students from a different cultural background more time to articulate their answers /react to class or group discussions more time than usual
– explain the new vocabulary
– use examples and analogies comprehensible to people from other cultures
– frequently repeat and explain the main points.

REFERENCES

1. Lewis, R. L. Kultuuridevahelised erinevused. Tallinn 2007. Tea
2. Muldma, M., Nõmm, J., Kebbinau, M., Aja, U., Koostaja: Kukk, A. Õppimine ja õpetamine mitmekultuurilises õpikeskkonnas. TLÜ 2011
3. BANKS, JAMES A. Cultural Diversity and Education: Foundations, Curriculum and Teaching, 4th edition. Boston 2001, Allyn and Bacon.
4. Pruvli, E. The effectiveness of intercultural persuasive communication in an organisational context: influencing factors: thesis of the degree of Doctor of Philosophy (Doctoral thesis in management; 2015/20), Estonian Business School, Instructor: Ruth Alas

REPRESENTION FORMS OF PLANNED PRODUCTS FROM THE SEMIOTIC POINT OF VIEW

Harri Lille[1], Aime Ruus[2]

1. ABSTRACT

The technical engineering idea usually occurs in the head (*vox dei*). It means that through spatial thinking in the process of visualization and implementation of design ideas they are understood and their function and form are planned. The design idea must be unambiguously transmitted (communicated) using the engineering drawing, or the so-called design (intercultural) language, which is learned within the Engineering Graphics course. The development of engineering graphics is influenced (besides others theories) by semiotics (theory of signs). There exist the following signs. The signs that denote things (icons: in our case, three-dimensional (3D) drawings (models); symbols: in our case, highly schematized pictures). The active signs according to which things are made (indexial symbols: in our case, working drawings (shape, dimensions, symbols, letters); specifications (texts and numerals). The report deals with the design process from semiotic point of view with the aim to improve graphic literacy in engineering education.
KEYWORDS: Engineering Graphics, design idea, form, semiotic aspect, sign, product

2. INTRODUCTION

When a freshmen has experienced, that an image of a concrete natural object or phenomenon can be created in his/her mind when reading a novel the images created by the reader and by the author may not (always) be the same. Moreover, it appears that this spatial imagination ability may also be different among readers. As usual, the technical engineering idea occurs in the head. This idea must be correctly transmitted (communicated). To minimize this above mentioned description, a system of standard of signs, symbols and text, i.e. the co-called intercultural universal design language (used across languages and cultures) with two dialects within the frame of orthographic projection has been developed [1]. These are The First- angle orthogonal projection and the Third-angle orthogonal projection, which make it possible to understand the engineering drawing unambiguously. Engineering Graphics is taught within the undergraduate engineering curriculum. It was developed as a practical subject closely related to construction (design aspect) and manufacturing (technological aspect), i.e. the co-called design process. The engineering drawing, as one part of the design process serves to allow realization, formalization and logic, in order to minimize errors for communication between engineers. The various schemes of the product design process are presented.

3. FORM AND FUNCTION: DESIGN ASPECTS OF THE PLANNED PRODUCT

When a certain problem has been identified the perceived technical idea is often difficult to communicate in the verbal form. It can be presented graphically using an engineering drawing in which the images and the object are connected through the same internal structural logic and can be analysed functionally (Figure 1). A technical engineering idea is the source of the future planned real object, but not the source of only its shapes.

We take it for granted that the design is not the drawing but the idea that the drawing (always practically) represents [3]. Ideas and concepts and graphics form the so-called intellectual product (indication-recognition, understanding, application, analysis). A form of graphics is applied to analyse the relationship between the elements that make up an engineering drawing in the semiotic aspect.

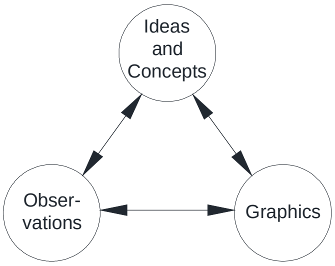


Fig. 1. Triangular model of observations, ideas and graphics [2].

In Preice´s model a sign is made up of three parts: the representamen, the object and the interpretant (Figure 2) [4, 5]. It should be mentioned that interpretant is richer and broader than the interpretation. It also includes action (incorporate semiotic activities) and feeling.

[1] *Department of Rural Building, Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Fr. R. Kreutzwaldi Street 5, 51014, Tartu, Estonia*
[2] *Department of Sustainable Technology, Tartu College, Tallinn University of Technology, Puiestee 78, 51008,Tartu, Estonia*
E-mail: harri.lille@emu.ee (*corresponding author)*

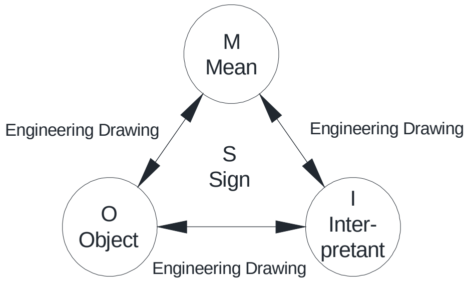


Fig. 2. Peirce's triadic model (edited by Bense, Lille et al.) for transferring the data of the design object [4, 5].

The representamen (sign) designates the meaning, i.e. assumed mental drawings, schemes, maps, diagrams, which allows communication by means of signs. There exist the following signs. The signs that denote things (icons: in our case, three-dimensional (3D) drawings (models); symbols: in our case, highly schematized pictures). Symbols are conventional, related to the object; they are representations which act through codes and other regularities [1]. Conventional graphic symbols are used in engineering drawings, diagrams, plans, maps and other documents of technical products. The symbolic nature of representations requires specific technical knowledge (hence learning) for their interpretation [6]. An iconic and symbolic relationship is such where the representamen and the object are sometimes established through language and culture and cannot therefore simply transmit a message [7]. The active signs according to which things are made (indexial symbols: in our case, working drawings (shape, dimensions, symbols, letters); specifications (texts and numerals). Indexial signs usually actualize some other existence. The index is directly related to the object through actual contact, environmental impact or marks of the object. On the other hand, the working drawing is more complex and has several semiotic layers, including graphic and textual annotations (dimensions, words, symbols; chemical composition of the material; mechanical and physical parameters of the material etc.). An index relationship is such where the representamen and the object are established across languages and cultures.
The different forms of the representation of an object are integrated in the semiotic bundle [8]. The three forms of signs are not separate or distinct; a complex sign may represent a combination of several kind signs.

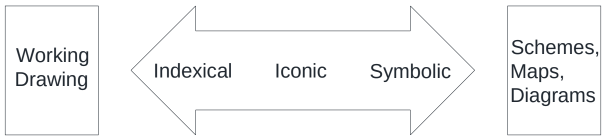


Fig. 3. The forms of representation as integrated in the semiotic bundle [8].

Note that the most appropriate method of learning drawing rules is repeated hand drawing, in which the brain is activated by the sensitivity of the fingertips [9]. In their professional life construction engineers commonly use freehand-sketches, which is the quickest and simplest way to converting design ideas.

4. MATERIAL AND TEHNIQUE: TECHNOLOGICAL ASPECTS OF PRODUCT MANUFACTURING

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 tools and operations takes place – it is the so-called technological aspect of design process (Figure 3). Requirements for technology (set-up characteristics and parameters of the product) determine the planned end product [10, 11]. Apart from the materials and tools, technologies are of equal significance in achieving desired final properties and characteristics of the planned product.

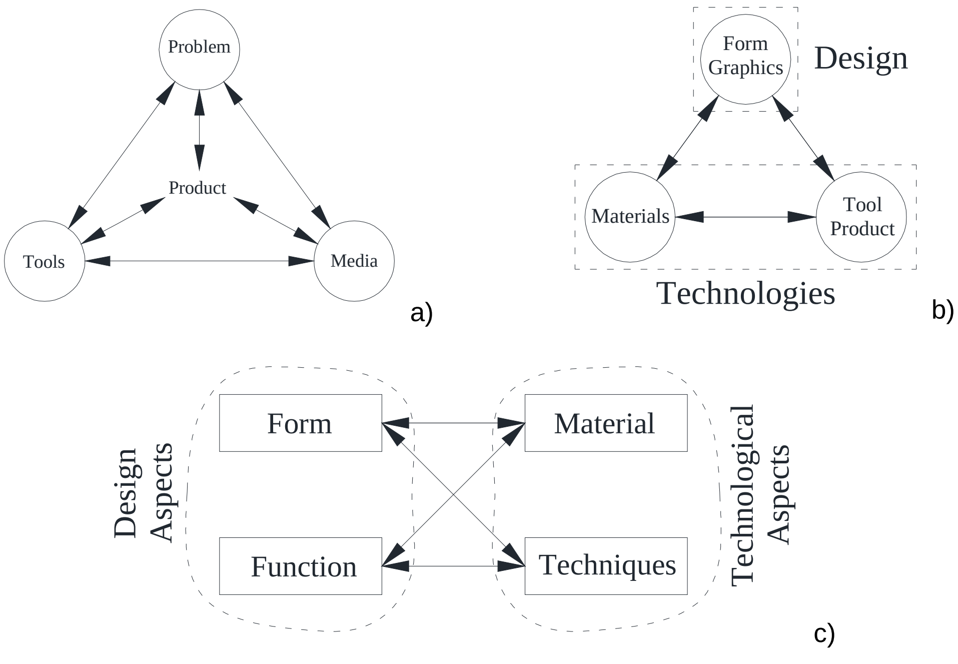


Fig. 4. Various design processes: a) triangular diagram of the problem, tools and media [10] ; b) triangular diagram of graphics, materials and tools; c) block diagram of the design and technological aspects [11]. As one part of the design process, students learn to express solutions to engineering problems by creating drawings (models) as messages to be communicated. A successful design helps to understand the way how the object is constructed in order to transmit it' as a message across languages and cultures. The ability to spatially visualize an object is an important instrument required of engineers in order to ensure labour efficiency.

5. CONCLUSIONS

- **A** certain problem is identified and it is given a graphic representation, using an engineering drawing, to manufacture a product.
- The graphic representation of an object can take different forms in consequent interpretations: icons as three-dimensional (3D) drawings (models) and symbols as graphic symbols that designate things.
- The working drawing is an active indexical sign according to which some other things existence is actualized - in our case the product.

ACKNOWLEDGEMENT

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

7. REFERENCES

1. ISO Standards Handbook: 2002. Technical drawings. Vol 1. Technical drawings in general. Vol 2. Mechanical engineering drawings. Construction drawing. Drawing equipment.
2. Bedward, John; Wiebe, Eric, N; Madden, Lauren; Carter, Mike; Minogue, James. 2009. Graphic literacy in elementary science education: Enhancing inquiry, engineering problem solving and reasoning skills. Presented at the ASEE Annual conference, Austin, TX. http://www4.ncsu.edu/~wiebe/articles/GEES-ASEE-Annual09F-ew0404.pdf
3. Medway, Pete and Clark, B. Imagining the building: architectural design as semiotic construction // J. Design Studies, Vol 24, No3, 2003. p. 255- 273.
4. Bense, Max. Das Universum der Zeichen: Essays Über die Expansionen der Semiotik // Agris Verlag, Germany. Baden-Baden, 1983. (in German).
5. Lille, Harri.; Ruus, Aime. 2015. Forms used for graphic representation of an object in Engineering Graphics // 13th International Conference on Engineering Graphics BALTGRAF-13; Conference Proceedings. June 25-26, Vilnius Gediminas Technical University, Lithuania, 2015.p. 58-61.
6. Boujut, Jean-Francois and Hisarcililar, Onur. Using a semiotic classification to characterise objects involved in collaborative design. J. Design Research, Vol 10, No3, 2012. pp. 155-169.
7. Risku, Hanna; Pirchner, Richard. Visual Aspects of Intercultural Technical Communication: A cognitive Scientific and Semiotic Point of View// Meta: Translators` Journal, Vol 53, No 1, 2008, p. 154-166. www.erudit.org
8. Sabena, Chistina. On the Semiotics of Gestures // Semiotics in Mathematics Education, Epistemology History, Classroom and Culture. L. Radford, G. Schubring, F. Seeger (Eds.). Rotterdam: Sense Publishers. 2008. p. 19–38.
9. Iwata, Ryo; Hirano, Shigeo. Concept of graphics thinking in graphics recognition// 14th International Conference on Geometry and Graphics. August 5-9, Japan. Kyoto, 2010, paper 312.
10. Barry, Ann Marie; Berry, Drew; Cunningham, Steve; Newton, Julianne; Sweppe, Marla; Spalter, Anne; Whiteley, Walter and Williams; Rick. Visual Learning for Science & Engineering // page 40, 2002. http://wiki.math.yorka.ca/images/3/3e/SIGGRAP.
11. Alaa El Anssary. An approach to support the design process considering technological possibilities // Inaugural – dissertation (Dr phil), Universität Druisburg, Germany. Essen, 2006.

BALTGRAF - ENGINEERING GRAPHICS IN BALTIC STATES

Rein Mägi[1]

1. ABSTRACT

The International Association BALTGRAF is created by engineering graphics departments of Estonia, Latvia and Lithuania 26 years ago 1991 in Vilnius Technical University. Regularly every two years are organized 13 BALTGRAF conferences in Vilnius, Tallinn and Riga. All articles are peer reviewed.
There are discussed Engineering Graphics problems and tried to find appropriate solutions. Topic area is varied - Graphics Educations, Descriptive Geometry, Engineering Drawing, CAD in Engineering, Standards of Technical Graphics etc.
During the meeting, exchanged experiences and teaching materials that are beneficial to both sides.
The efficient last of BALTGRAF uses to predict the same successful continue in future.

KEYWORDS: Engineering Graphics, BALTGRAF, Baltic States

2. INTRODUCTION

26 years ago on 5th November 1991after crash of Soviet Union representatives from engineering graphics departments of three Baltic States
met in Vilnius Technical University.
Representatives declared, considering:

- changed political status of our states,
- necessity to coordinate our efforts in engineering education,
- necessity to assure concordance of diplomas (bachelor's and master’s degree) of our states,

...to found the International Association BALTGRAF of engineering graphics departments of Estonia, Latvia and Lithuania.
The aims of BALTGRAF are:

- to coordinate our efforts in methodical and program equipment of departments of engineering graphics,
- to coordinate researches of our departments in sphere of engineering and computer graphics,
- to coordinate our efforts in adaptation of international standards of technical drawings,
- to organize international BALTGRAF conferences refer to problems of engineering graphics departments,
- to consolidate our efforts in sphere of named problems with other universities of Baltic region.

Professor **Petras Audzijonis** from Vilnius Technical University was selected as the **first president of BALTGRAF**.
BALTGRAF conferences are organized regularly in Vilnius, Tallinn and Riga Technical Universities.

3. BALTGRAF CONFERENCES

The **first conference** of BALTGRAF [1] took place in Vilnius Gediminas Technical University in 1992

- There were 17 presentations – about descriptive geometry, technical drawing and computer graphics
- The introduction of proceedings of the conference points out that the main goal of engineering graphics is graphical literacy – ability to create and understand technical drawing
- The serious problem for all participants was diminishing of capacity of graphic subjects in technical universities and secondary schools.

The **second conference** of BALTGRAF [2] took place also in Vilnius Gediminas Technical University in 1994

- 18 papers were presented
- One of the conference topics was transition from Soviet GOST-standards to international ISO.

All GOST-standards were absolutely obligatory – non-execution of them was even punishable (Несоблюдение стандарта преследуется по закону).
ISO standards are in principle voluntary to use, but they are obligatory for creating European and national standards.
Although any standard does not contain detailed argumentations, every requirement should be founded on. But the conception of any argument can change due to fast technical progress.

3rd BALTGRAF conference [3] was organised by Tallinn University of Technology in 1996.

- 18 presentations treated of didactic researches, international standards and also present and future of computer graphics.
- As the **second president** of BALTGRAF was selected **Rein Mägi** from Tallinn University of Technology.

4th BALTGRAF conference [4] took place traditionally in Vilnius Gediminas Technical University in 1998.

- 22 papers were presented.
- The purpose of some articles is to study specific features of CAD for making CAD-process not only modern but also comfortable, quick and economic one.

[1] *Centre of Engineering Graphics, Tallinn University of Technology , Ehitajate tee 5, Tallinn 19086, Estonia, e-mail: rmagi@hot.ee*

5th BALTGRAF conference (2000) took place in Tallinn University of Technology [5].

- There were presented 22 papers – 14 from Lithuania, 7 from Estonia and 1 from Latvia.
- Majority of presentations (80 %) were connected with computer graphics.
- Lithuanian technical drawing standards based on ISO were created.

BALTGRAF-5 decided:

- To contribute to enhance teaching level of engineering graphics disciplines in secondary schools.
- To stop the catastrophic decrease of the number of engineering graphics lessons in technical universities.
- To develop the effective trends of more contemporary info-technology - to innovate regularly computer graphics software and hardware.

Next conference BALTGRAF-6 [6] took place in Riga Technical University in 2002.
It was the most numerous one – 44 presentations.
Papers were divided to subsections:

- CAD in Engineering (14 papers).
- Graphics Educations (20).
- Descriptive Geometry and Engineering Drawing (6).
- Standards of Technical Graphics (4).

Professor **Modris Dobelis** from Riga Technical University was selected as **third president of BALTGRAF.** The new logo of BALTGRAF was selected (Fig. 1).

Fig. 1. The logo of BALTGRAF

7th BALTGRAF conference [7] was organised by Vilnius Gediminas Technical University in 2004.
41 presentations were divided to:

- Theoretical Aspects (8 papers);
- CAD and CAD Applications (12);
- Graphics Education (16);
- Standards in Engineering Graphics (5).

The new trend was **e-learning** of graphical subjects. E-learning will open new opportunities for lecturers and students due to wide extension of internet nowadays.

The 8th BALTGRAF conference [8] took place in Tallinn University of Technology (TUT) in June 2006
37 presentations were divided to :

- Descriptive Geometry (6 papers);
- Technical Drawing (6);
- Engineering Computer Graphics (15);
- Standards of Technical Graphics (3);
- Graphic Education (7).

Quite actual theme was the **visualization** problem. Visualization in engineering graphics can better help to understand the topic.

In the **9th BALTGRAF conference** [9] (2008) in Riga Technical University there were represented 43 papers

- 21 from Lithuania
- 8 from Estonia
- 6 from Latvia
- 6 from Poland
- 1 from Slovakia
- 1 from Germany

By themes these presentations were divided to :

- Applied Geometry and Graphics (6 papers.)
- Engineering Computer Graphics (15).

- Engineering Graphics (21).

Professor **Daiva Makuténiené** from Vilnius Gediminas Technical University was selected as **the fourth president of BALTGRAF**.

The 10th BALTGRAF conference [10] was organized extraordinarily in 2009 in cultural capital Vilnius.
Maybe due to economical crisis only 31 papers were presented:

- 16 from Lithuania
- 5 from Latvia
- 5 from Poland
- 4 from Estonia
- 1 from Slovakia

New visualization possibilities have appeared in 3D-modelling. For example simulation of videocamera moving by desirable trajectory.

The next **11th BALTGRAF conference** [11] took place in cultural capital Tallinn in 2011.
26 papers were presented:

- 9 from Lithuania
- 8 from Estonia (1 coauthor from Germany)
- 6 from Latvia
- 1 from Ukraine
- 1 from Poland
- 1 from Austria.

All participants celebrated the 20th anniversary of BALTGRAF!

The next **conference BALTGRAF-**12 [12] was held in Riga Technical University 2013.
33 papers were presented:

- 9 from Lithuania
- 6 from Latvia (1 coauthor from USA)
- 5 from Estonia
- 4 from Canada
- 3 from Poland
- 2 from Ukraine
- 1 from Serbia, St.Petersburg, Omsk.

New topics of BALTGRAF-12 were varied and interesting:

- Geometrical art
- BIM (Building Information Modeling)
- Architecture

The **last conference BALTGRAF-**13 [13] was organised by Vilnius Gediminas Technical University in 2015.
20 papers were presented:

- 11 from Lithuania
- 3 from Estonia
- 2 from Latvia
- 1 from Slovakia
- 1 from Serbia
- 1 from Germany
- 1 from Japan

Figure 2 can illustrate graphically the history of previous conferences.

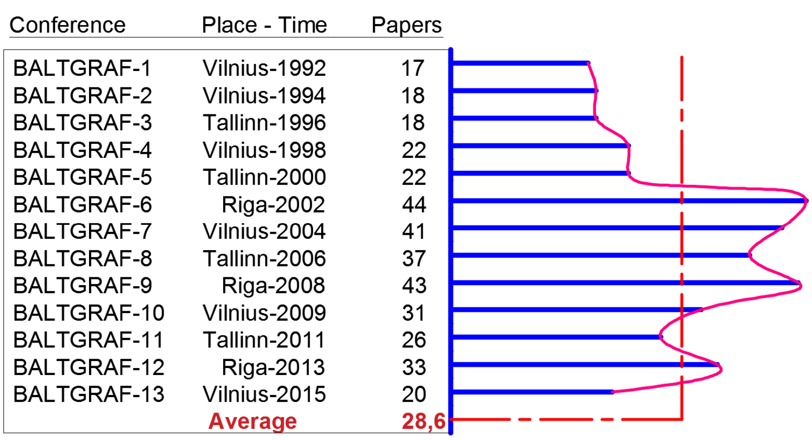


Fig. 2. Graphical history of BALTGRAF conferences

4. CONCLUSIONS

International Association BALTGRAF, founded 26 years ago, is like a symbol of the reestablishment of independence in Lithuania, Latvia and Estonia

Regularly organized conferences enable to meet lecturers and specialists of engineering graphics, to analyze the present situation and to plan new developments for future

5. REFERENCES

1. Инженерная и компьютерная графика. Вильнюс „Техника”, 1992, 120 стр. (Engineering and Computer Graphics. VTU, Technika, 1992, 120 p. in Russian).
2. Engineering and computer graphics 2. International association BALTGRAF, VTU, Vilnius, Technika, 1994.
3. 3rd Baltic Conference on Engineering and Computer Graphics, TTU, Tallinn, 20-21 June, 1996
4. Engineering and Computer Graphics-4, Vilnius Gediminas Technical University, Vilnius, "Technika", 1998.
5. Engineering Graphics Baltgraf-5. Abstracts of the International Conference Tallinn, Estonia, June 15-16, 2000; Tallinn, TTÜ, 2000, 104 p.
6. Engineering Graphics BALTGRAF-6. Proceedings of the Sixth International Conference, Riga, Latvia, June 13-14, 2002, 256 p.
7. Engineering Graphics BALTGRAF-7. Proceedings of the Seventh International Conference, Vilnius, Lithuania, May 27-28, 2004, 240 p.
8. Engineering Graphics BALTGRAF-8. Proceedings of the Eighth International Conference, Tallinn, Estonia, June 8-9, 2006, 184 p.
9. Proceedings of the Ninth International Conference on Geometry & Engineering Graphics, Riga, Latvia, June 5-6, 2008: Ninth International Conference on Geometry & Engineering Graphics, Riga, Latvia, June 5-6, 2008. Riga: Riga Technical University.
10. Proceedings: 10th International Conference on Engineering Graphics BALTGRAF-10, June 4-5, 2009, Vilnius.. Vilnius Gediminas Technical University Press "Technika",
11. Engineering Graphics BALTGRAF-11. Proceedings of the Eleventh International Conference, Tallinn, Estonia, June 9-10, 2011, p. 9-14: The Eleventh International Conference BALTGRAF-11, Tallinn, Estonia, June 9-10, 2011. Tallinn. http://www.ttu.ee/public/e/ehitusteaduskond/Instituudid/Insenerigraafika_keskus/Annuka_baltkonverents.pdf
12. Scientific Proceedings of the 12th International Conference on Engineering Graphics BALTGRAF 2013/ Riga Technical University, 2013: 12th International Conference on Engineering Graphics BALTGRAF 2013/ Riga Technical University, 2013. Ed. M. Dobelis. Riga http://www.baltgraf2013.rtu.lv/sites/default/files/baltgraf/baltgraf/baltgraf2013_The12thScientificProceedings.pdf
13. Scientific Proceedings of the 13th International Conference on Engineering Graphics BALTGRAF-13: The 13th International Conference on Engineering Graphics BALTGRAF-13; Vilnius Gediminas Technical University,June 25-26, 2015. Vilnius Gediminas Technical University: Vilnius Gediminas Technical University Press "Technika", http://baltgraf.vgtu.lt/uploads/BALTGRAF-13_Scientific_Proceedings.pdf