TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING

Department of Electrical Power Engineering and Mechatronics

Department of Mechatronics

Chair of Mechatronics Systems

MASTER THESIS

HANDGUN USAGE MONITORING DEVICE

MECHATRONICS PROGRAM

Student Olev Vaher

Student code 132237

Supervisor Maido Hiiemaa

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SUMMARY

The interest of thesis topic “Handgun monitoring device” came from Department of Mechatronics. Goal was to prove a system at prototype level that is capable of distinguishing gunshots from other impacts using commercially available products.

In order to implement detection mechanism sample data was gathered using two firearms a revolver Taurus 82B4 and a semi-automatic pistol Beretta 21A. Test data was analyzed and compared with each other to find key points for detection. Tests were carried out by two accelerometers, analog sensor ADXL377 and H3LIS331DL with digital interface. ADXL377 was chosen for prototype because of slightly better data output rate compared to H3LIS331DL.

Two mounting positions were tested one on top of the weapon barrel and under grip. Depending on mounting position results varied greatly. When sensor was mounted on top of weapon barrel then results were more consistent with lower deviation in template matching. It was noted that if system is commissioned for different weapon models then each model needs to be calibrated separately. Although two different types of weapons were used for testing it did not give understanding how much results can vary between different weapons of same model.

Method to differentiate gunshots from other impacts have been implemented using template matching technique. Template was generated from ten samples and then tested against rest of data. In order to find if it is possible to generate false positive readings impacts on different surface hardness were generated by practical tests. While evaluating rejection rate of template matching it was noted that up to 12% of impacts were misclassified as gunshots, this was due to evaluating only global minimum. To improve detection rate it was suggested to compare gunshot expected matching position local minimums to global minimum. This decreased misclassification rate significantly and with sample set produced no misclassifications were observed.

System was able to differentiate gunshots from other impacts with high accuracy and classified gunshots as intended. In future longer period for testing should be carried out to find if there is any performance degradation due to the wear of weapon components.

In order to understand how much alignment of sensor axis plays role in detection rate up to 10° of misalignment was introduced to system setup. It was discovered that below 10° of misalignment was still within the limits for system to be able to detect gunshots. While template matching classified all the gunshots correctly it also increased false positives in detection when impact test was performed. Only small number of samples were gathers. This limited the accuracy of thresholds for matching techniques. It is not known how much different shooting stances, hand orientations affect accuracy of template matching because test samples were not separated. This did not affect detection rate when.

All the tests were carried out where sensor board is attached to MCU via cable. This limited the ability to evaluate performance of some key areas like noise from analog sensor. A design solution is proposed with components. The design would carry as development board to test all the components on single board solution. Main components which impact power were analyzed.

Solution for data communication was offered, but transmission quality should be tested near metal. Although target weapon body is made of composite then magazine could affect performance of reading negatively because of its metal construction.

Main goal of thesis was achieved in most areas when showing that it is possible to use simple techniques to differentiate gunshots from other impacts with high accuracy. Next goal is to make first development board for further testing.

KOKKUVÕTE

“Käsirelva kasutuse jälgimisseade” magistritöö teema tuli Tallinna Tehnikaülikooli Mehhatroonikainstituudi poolt. Eesmärk oli luua prototüübi tasemel lasuloendur kasutades hetkel saadaolevaid componente.

Tuvastusüsteemi hindamiseks kasutati revolvrit Taurus 82B4 ja poolautomatset püstolit Beretta 21A. Mõlema relva katseandmeid võrreldi omavahel, et hinnata kui sarnased on saadavad tulemused. Leiti, et vastavalt relva tüübile varieerub tulemus märgatavalt ja ei ole võimalik kasutada üldistatud meetodid kõikidele relvadele. Lasu analüüsiks katsetati kahte andurid. ADXL377 kolmeteljeline analoog väljundiga kiiredusandur ja digitaalse liidesega kolmeteljeline kiirendusandur H3LIS331DL. ADXL377 parema kiiruse tõttu tehti otsus kasutada seda ülejäänud testides.

Loomaks arusaama kuidas mõjutab anduri paigutus tuvastust ja üldist tagasilöögi graafiku kuju tehti katsed kahes erinevas relva positsioonis, relva toru peal ja käepideme all. Leiti, et graafikute kujude erinevus vastavalt kust seda mõõdeti ei võimaldanud kasutada samu piirväärtuseid tuvastualgoritmis. Katseandmed ei võimaldanud hinnata kuidas erinevad tagasilöögi graafikud sama mudeli erinevatel relvadel.

Eristamaks laske teistest võimalikest löökidest või kukkumistest kasutati keskmistatud referentsi lasu profiilist. Referentsi ja lasu absoluutväärtuste summa võeti klassifitseerimise tingimuseks. Analüüsimisel leiti, et kuni 12% löökidest klassifitseeritakse laskudena kui need toimuvad pikku lasu telge. Suvalistel löökidel ja kukkumistel esines miinimum küll lasuga sarnases kohas kuid see oli lokaalne miinimum, globaalne minimum asus väljaspool oodatavad asukohta. Vea vähendamiseks pakuti välja lisakriteeriumi kasutamine kuna alati on teada asukoht kus peaks esinema globaalne miinimum kui tuvastamise algoritm rakendatakse.

Hindamaks kuidas mõjutavad seadme tootmisprotsessist või käikvõtust tulenevad vead tuvastusüsteemi muudeti anduri nurka nii, et anduri orientatsioon oleks kuni 10° erinev referentslaskudest. Leiti, et kuigi algoritm suutis tuvastada lasu varieerus tulemus esialgsega rohkem ja klassifikatsioonivigade arv kus teljesihilised löögid tuvastati lasuna. Samuti

katsetati erinevaid laskeasendeid ja laskekäe vahetust, mis ei mõjutanud lasu tuvastamise täpsust.

Kuna kõikides katsetes oli mikrokontroller ja anduri plaat eraldi süsteemidena, mis olid omavahel ühendatud kaabliga ei olnud võimalik adekvaatselt täpselt hinnata analooganduri müra. Disaini lahendus on välja toodud, mis võimaldaks testida ühtset süsteemi. Aku kestvusele kõige enim mõjuvate komponentide voolutarvet hinnati ja pakuti välja lahendusi selle optimeerimiseks.

Pakuti välja disaini lahendus juhtmevabaks laadimiseks ja andmete edastamiseks RFID lahendust kasutades. RFID lahenduse võimekust ei hinnatud metallpindade lähedal.

Magistritöö eesmärk teha prototüüp lahendus, mis oleks võimeline tuvastama laske ja neid eristama teistest võimalikest häiringutest või löökidest. Edasine eesmärk on teha valmis arendusplaat mille peale on võimalik täiendavad testid teostada.