NTNU
Kunnskap for en bedre verden

Department of Engineering Cybernetics

IELET2920 - Bachelor Thesis: Automation and Robotics

Preliminary Project Report

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Oppgavetittel (norsk og engelsk): Next generation hand grip trainers Neste generasjons håndgrepstrenere		
Forfattere: Ole Einar Kværnsveen Belboe Elias Loe Eritsland Admir Meta	**Prosjektnummer:**	
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Sammendrag (norsk og engelsk):

Håndgrepstrenere er typisk brukt for trening innenfor klatring/buldring, men også brukt som rehabiliteringsutstyr for å gjenopprette styrke etter skader. Typisk er de passive gjenstander, lagd av et elastisk element som man må trykke eller komprimere på et vis. Elastisiteten på slike utstyr kan bli regulert for hånd i noen «avanserte» gripere, men per nå finnes det ingen utstyr som implementerer tilbakekobling og digitalisering. Vi ser for oss derimot en responsiv, aktiv gjenstand som består av sensorer som føler hvor mye en person trykker, samtidig som en «intelligent» estimator som tilrettelegger for automatisk kontroll via tilbakekobling

Hand grip trainers are typically used for training at becoming better climbers – but are actually also rehab tools that may be used to restore strength after some injury (e.g., broken wrists, etc.). Typically, grip trainers are mechanically passive objects – comprising some elastic element that one has to compress. The elasticity of such objects may be regulated by hand in some ‘advanced’ grippers, but no device is now implementing feedback and digitalization.We envision instead a responsive active object comprising sensors which sense how much a person is pressing, as well as some intelligent estimator which allows for feedback-based automatic control.

Stikkord norsk:	**Stikkord engelsk:**
Sensorer, aktiv gjenstand, tilbakekobling, estimator, programmering	Sensors, active object, feedback, estimator, programming

1 Introduction

1.1 Background

There is currently a gap in the market for handgrip trainers that document and measure data. The purpose of this project is to create exactly this; a handgrip trainer that can measure and be used to give feedback to whoever is using it. The employer has two previous prototypes for this project, but they both were designed without a suitable filter, measurement storage and measurement access, since they referred to different projects. The first prototype is a 3D-printed cylinder which has been retrofitted with a pressure cuff and isolated with silicon. This model, in addition to an air pump for inflating the cuff, and a sensor array for receiving measurements, were used in the previous attempt. However, this solution is a prototype, and improvements can be made upon it. Note that this prototype was used in a different project, and only the design principle was used as a starting point.

Side image (left) and top-down image (right) of the previous prototype created by Otto-von-Guericke-Universität Magdeburg, Fakultät für Elektrotechnik und Informationstechnik

There is also another prototype (Grasp™), made by Grasp AS, which is a commercial handgrip sensor which can do data measurement. However, this sensor is not yet available for the public and the data cannot be recovered from its operation, since it is still in its prototype phase. Since the data cannot be recovered, it is difficult to use this sensor from a data-oriented perspective.

Grasp sensor, developed by Grasp AS

Apart from these two prototypes, there are no currently known sensors that measure grip strength and process the data for later usage.

1.2 Assignment

The assignment for the project is to provide a proof of concept for a simple grip sensor and get clear data from the sensors. On a more specific level, this means that the project is made up by multiple parts, the first being creating the hand grip trainer itself, and the main part of the project, which is to get data from the sensors, and design (as well as tune) a suitable filter in order to produce accurate estimates from the measurement data.

1.3 Definitions

When we use the words "physical model", "handgrip trainer", "grip sensor" and "prototype" we refer to the physical device that is the hand grip trainer. "Mathematical model" refers to the mathematical definition of the hand grip trainer.

1.4 The structure of the report

The report consists of three main parts:

- The introduction, where a short summary of the project goal is given.
- The technical part, where the details of the project are detailed.
- The project organization part, where the plan for the project's completion is further elaborated.

2 Technical Part

The new grip sensor is supposed to measure the whole hand, be fairly lightweight, small and portable, and also document its own use. Given these specifications, as well as the previous designs provided by the external supervisors, it has been decided to make minimal changes in hardware, and focus more on the design of the estimator as well as programming of the real time measurement system. There is room for other changes, and these requirements can be altered through the rest of the project's duration. The most important part is for the data to be accurate and usable. All these points will be detailed further below in this section.

2.1 Issue

There are currently no commercially available products that can measure a user's progress of handgrip strength and exercise. There are a few prototypes (listed in section 1), but they do not contain a way to measure the hand strength. We will therefore attempt the development of this trainer, to make it able to measure strength, as well as process the data gathered from these measurements.

The system to be designed consists of 4 main parts:

- A 3D-printed frame
- A pressure cuff
- Electronics
- A program which processes the data

2.2 Project goal

It has been determined during discussion with the client and consultation with the supervisor that the first result of the project should be learning. In this regard, the main focus up until now has been reading and extending our knowledge on the subject of state estimation and Kalman filters. In order to hasten this learning process, weekly meetings between the group members have been arranged. In addition to this, another weekly meeting with the supervisor has been organized, where we give a status report on what we have learned and what we are currently working on. To conclude, a meeting with the client is set up every 3rd week, where a detailed plan is discussed and the way forward is decided.

In addition, one of the main objectives is to achieve a functioning prototype. To clarify, this means a system that works, but is not optimized for mass production. To achieve this, the group needs to build a physical model, integrated with a sensor array and programmable electronics. This model shall then be adjusted for measurement and processing, by implementing a real-time measurement program through an Arduino. This measurement program will include a Kalman filter for processing of the measured data.

The different goals can be summarized to:

- Create a physical model, with around 4 pressure sensors, to get data from each individual finger (thumb finger excluded).
- Get sensor data out of the physical model.
- Create filters and models for the sensors, to get clear and productive data.

2.2.1 Project outcome

The outcome for the project is to be able to document the progress of grip exercising, so that people in need of rehabilitation can get customized feedback for their personal progress. This would result in more effective rehabilitation or training of grip strength. In addition, it should be possible to implement this concept idea and the prototype in the field of automatic control.

2.2.2 Performance goals

The finished model is supposed to be a proof of concept, meaning it won't be sturdy enough for production. It must however be sturdy enough to resist different types of testing. In addition, the model must produce accurate measurements and work in real-time. The model is also supposed to be fairly light and portable, and also cheap. All of these requirements are necessary in order to have a fairly lightweight, portable and functional grip trainer.

2.2.3 Process goal

The process goals for the group are broadly defined, but they can be summarized as follows. The group shall:

- extend their knowledge on systems theory, state estimation and, specifically, Kalman filters.
- improve their project organizing skills.
- improve their technical skills in areas like measurement technique, 3D-printing, programming and real-time systems.
- improve their cooperation skills and "soft" skills (communication, planning, teaching, management).
- aim for a good character in the final evaluation.
- aim for an equal distribution of the tasks listed at section 3.

2.3 Project description

To reach the final product, the group will first need to focus on studying Kalman filters. These filters are the most suitable for the task, given the nature of the system, its dynamics and the specified goal. It is necessary to reach a design consensus for the trainer itself, while also finding optimal sensor positions. The sensors and some of the equipment will be ordered online, while the 3D-model will be printed at a student organization within NTNU (MAKE NTNU). After these components are received, the assembly of the trainer, the mathematical model and the Kalman filter will be embedded into a single system, where the physical model is retrofitted with sensors, which in turn communicate the data to an Arduino Uno. Within the Arduino, both the Kalman filter and the measurement logic will be implemented. This is the projected final design of the trainer. When this final design is completed, it will be necessary to tune the filter in order to get clear data from the sensors.

2.4 Specifications

The first relevant specification we will use is the design report from Otto-von-Guericke-Universität Magdeburg, which is the starting point for the design of the 3D-model. This was the work of Fakultät für Elektrotechnik und Informationstechnik, out of which the mechanical design and circuitry will be referred to. The rest of the report is deemed irrelevant.

Regarding the circuitry, the sensor documentation will also be used for calibrating the sensors, so that they follow their reference characteristics. Eventually, it might be necessary to implement additional electronics (for example, operational amplifiers or electronic integrators).

The Arduino documentation, which is an open-source documentation shall be used to program the measurement logic and the Kalman filter. It might be necessary to develop a user-designed library for the Arduino framework, which abstracts the Kalman filter mathematical framework within the Arduino programming language. This is however, not the main focus of this report, nor the main focus of the thesis as a whole.

2.5 Problem areas

The first and the most obvious problem is the lack of commercial products to use as a starting point for the thesis. Reverse-engineering a commercial product is a generally good practice which helps learning and improves technical capabilities. Since this is impossible to do, the project will take a significantly longer time to produce a result.

In addition, the group's current theoretical knowledge is not sufficient to complete this project. Given the lack of estimation theory present in the current lecture plan in the bachelor program, it is necessary to learn the basics of statistics, Luenberger observers, Kalman filters and other algorithms that constitute this engineering field of study. This is, as of this moment, the top priority of the group. Without this knowledge, the project cannot be completed.

A problem which might not be obvious at first glance is the chip shortage problem which has been around for some time now. This might result in the sensor acquisition take longer than originally expected, and somewhat more expensive. Therefore, ordering of the sensors should be done as soon as possible.

3 Project organization

The project group consist of three members:

- Ole Einar Kværnsveen Belboe
- Elias Loe Eritsland
- Admir Meta

The official internal supervisor is:

- Roya Doshmanziari

There is also another supervisor from NTNU:

- Damiano Varagnolo

There are two external guidance counselors from Technische Universität Berlin:

- Steffi Knorn
- Roxanne Jackson

3.1 Work packages

In order to clarify the project organization, it is necessary to divide the project into smaller functional units (so called work packages). The list below defines the work packages we have defined:

- Mechanical design of the grip trainer
  - Build a 3D-model which is lightweight, portable, easy to use.
  - Print the 3D-model.
  - Perform stress testing of the 3D-model.
- Find suitable sensors and electronic components.
  - Read up on the sensor documentation
  - Design the necessary electronic circuits for the measurements.
- Design the mathematical model for the grip trainer
- Design the Kalman filter
  - Read up on estimation theory and Kalman filter design.
  - Design the Kalman filter.
- Finalize the design by merging all of the points above.
- Tune the Kalman filter in order to achieve better performance.

3.2 Equipment and Resources

- Pressure sensor for measurements
- Pressure sensor for the pressure cuff
- Low power air pump
- Pressure cuff
- Arduino UNO
- A suitable integrated development environment (IDE)
- 3D printer

3.3 Project delivery list

- Project report
- Hand grip trainer
- Library framework for the measurement (if applicable)

3.4 Timetable and Budget

A timetable has been planned in order to have better control on the different tasks to be completed. Note that this timetable is prone to change in case design problems show up. Therefore, a more detailed, finished timeplan will be attached to the final report.

- January
  - Research the current market
  - Begin with the Kalman filter research
- February
  - Finish filter research
  - Begin filter design
  - Research and buy sensors
  - Research and find a suitable handgrip trainer design.
- March
  - Finalize handgrip trainer design and sensor placement.
  - Finalize filter design
  - Begin writing final report
- April
  - Finalize report
  - Finalize tuning of the Kalman filter

3.5 Quality Assurance

The main part of the project is to create a proof of concept. There will be a great amount of testing and tuning in order to assure functionality and robustness, but, given the nature of the project (research and development), there cannot be any guarantees for a grip trainer that can be industrially manufactured and mass produced. The product must assure functionality and a certain degree of robustness is also called for. Apart from this, there is no need for further quality assurance.

The handgrip trainer must provide the correct measurements. This means that the mathematical model must make the right assumptions, and the Kalman filter must be properly tuned. In addition, the handgrip trainer must pass the mechanical tests, in order to not break under usage.

3.6 Risk assesment

The project will be both a theoretical research task as well as an engineering design. Given the low risk and high reliability rate of every work package listed in 3.1, the only risk is whether the project will be completed properly or not.

Bibliography

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