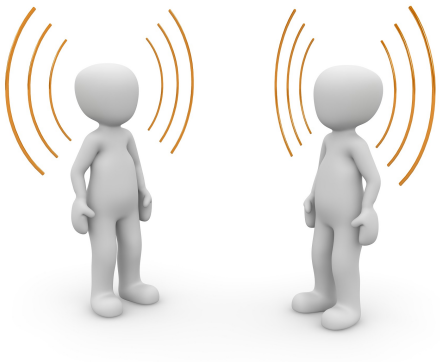
After Study

Henrik Ahlinder, Sebastian Andersson, Martin Dahl, Christian Gustavsson,
Joel Henneberg, Tiger Kylesten.

December 21, 2022

Version 1.0



Status

Reviewed	Martin Dahl	2022-12-xx
Approved	Danyo Danev	TBD

Project Identity

Group E-mail: CDIOProjektgrupp@liuonline.onmicrosoft.com

Homepage: wavecounter.xyz

Orderer: Danyo Danev
Phone: +46 (0)13 28 13 35
E-mail: danyo.danev@liu.se

Customer: Danyo Danev
Phone: +46 (0)13-28 13 35
E-mail: danyo.danev@liu.se

Supervisor: Sai Subramanyam Thoota
Phone: +46 (0)13-28 68 59
E-mail: sai.subramanyam.thoota@liu.se

Course Responsible: Danyo Danev
Phone: +46 (0)13-28 13 35
E-mail: danyo.danev@liu.se

Participants of the group

Name	**Role**	**E-mail**
Christian Gustavsson	Project Manager, PM	chrgu102@student.liu.se
Henrik Ahlinder	Interface Manager, IM, and deputy CD	henah490@student.liu.se
Joel Henneberg	Chief of Hardware, CH, and deputy PM	joehe862@student.liu.se
Martin Dahl	Documentation Manager, DM	marda545@student.liu.se
Sebastian Andersson	Test Manager, TM	seban218@student.liu.se
Tiger Kylesten	Chief of Design, CD	tigmo832@student.liu.se

CONTENTS

DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
0.1	2022-09-06	First document skeleton	PM	NA

1 EXPENDITURE OF TIME

For the project part of the course TSKS23, each group member is expected to spend 240 hours. Consisting of six members, this equates to 1 440 hours in total. This section will cover how these hours were spent and how the planning worked out in reality.

To structure the project, a Project and Time plan was devised and submitted to the customer for approval. In the plans, the project tollgates and relevant activities were defined, together with an allocation of time. Every week a report was sent to the customer detailing progress and time spent by group members.

1.1 Division of workload

In planning the project, all members participated in discussions on how to devise the work. In the project implementation, a single member or in smaller groups often performed work. At least one project meeting was held every week to discuss progress and regroup when necessary. This seems to have worked out quite well. Some had more fixed responsibilities during the project, but most group members also switched somewhat and worked on whatever was most needed.

A general plan on how much time each member had to spend on the project for each week was made as a benchmark for personal use. Since the project is in parallel with other courses, each group member had to take responsibility for making the best use of their time. Some had a higher workload before midterms, and others had a higher workload during the latter part of the semester. The group aimed to get a lot of work done before midterms, which was to our benefit later.

Group members have reported their time on a Numbers sheet, available to the customer.

All-in-all, every member has some time left when the project is completed. When everything is turned in and the project finished, this will be about 20-40h, depending on the member. Considering the project scope, the results, and individual differences in how time was reported - the discrepancy should be acceptable. It's also hard to factor in the last stretch before the demonstration and presentation. In our case, this went fine - but it could also have required an extra 20 hours for every member to troubleshoot. The differences in time spent between the members have a least not created any discussions within the group.

1.2 Time use compared to Time Plan

Making a detailed plan at the beginning of a project that you know very little about is not easy. Looking back at the Time plan and how time was actually spent, there are some noticeable differences.

The most striking problem with the time plan is the activities we did not consider during the initial planning. Every activity is made a discrete part of the project, but in general, no activities were created for integrating the parts into a product. This is perhaps the biggest mistake in the planning. This accounts for some of the larger over-shoots of time, like ML algorithms, GUI, testing, and hardware setup.

The most prominent under-shoots of time planned for individual activities are a consequence of one of two things. One, time was set aside for some priority three requirements that were not implemented. This time was instead used for requirements with priority one and two. And two, some things just took less time than expected. In general, the

documentation part of the project was more efficient than we had planned. Time left on the activities Requirement specification, Test plan, and Presentation could account for almost all the time left when finishing the project.

Some reallocations of time between activities can be explained by renegotiating the System requirements mid-way. This did not lead to any changes in the time plan but changed how the group prioritized its use of time. This should warrant a revision in a larger and more complex project. In our case, it seemed manageable without adding extra administrative work.

2 ANALYSIS OF PROJECT WORK

The project had three different phases, which will be described in this section. This section will also cover the project model used and what the group thought of it. How the collaboration within the group and towards both the customer and the supervisor went will also be covered in this section.

2.1 Project phases

The project was divided into three different phases, a before, during and after phase. With this division of the project it was easy to know what was supposed to be done during which phase, and it felt natural.

2.1.1 *Before phase*

During the before phase the group produced a Requirement Specification [1], Design Sketch [2], Design Specification [3], Project Plan [4] and a Test Plan [5].

The Requirement Specification, Project Plan and Test Plan were all pretty straight forward to write, since the contents were obvious. What was more confusing for the group however was the difference between the Design Sketch and the Design Specification. Since these two were both part of the before phase, the group was unclear with why a Design Sketch even had to be created. It was however created in the early stage of the before phase and this was later used as a template for the Design Specification. Both the Requirement Specification and the Test Plan was revised later in the project when requirements and tests specified in these documents became unnecessary for the progress of the project.

Reading research articles was also done during this phase to get a foundation for the documents that were produced.

2.1.2 *During phase*

The work done in the during phase was implementing the system, troubleshooting and data collection. Most of the troubleshooting being done was somewhat connected to the hardware used (the ADALM-PLUTO devices). At least relative to the software part of the system, troubleshooting the hardware took many working hours. Also, collecting all the data needed for the project took a lot of time. Luckily, this was something that the group already knew about early in the project, so the time plan was created with this in mind.

In the beginning of every week there was a meeting to discuss what had been done the previous week and what has to be done the coming week. During this meeting work was distributed as evenly as possible between the members of the group. There were also discussions on how certain implementations was going to be done so that everyone were on the same page going into the week.

2.1.3 *After phase*

During the after phase a website, poster, presentation, User Manual and Technical Report were created. We are pleased with how the presentation went, although the live demonstration that we had prepared did not really work out because of hardware issues.

2.2 The Project Model - Use & Comments

According to the course that the project was a part of, it is mandatory to use the LIPS Project Model. Although the group felt that it was nice having a project model to follow, we felt that the use of having a project model faded away during the project. One of the perks of having a model to follow is so that one can fulfill tollgates and get confirmation that the project is unfolding in the right direction, but this was something that the group felt was being forgotten from the customer/examiner. This lead to that a bunch of documents being created, with the group not really knowing to what use.

When writing the Technical Documentation, the group found it difficult to know whether this document were to contain a discussion and conclusions (as the structure of a research article), or if it was going to be more of a data sheet. After some discussion, we decided to include results and discussion. We would however like to raise a suggestion for coming years that this is clarified.

The members of the group also agrees that having a Project Model to work around is good, but during five years of studies we have all only encountered the LIPS-Model. It would be fun to try following another model during this project, so that one can get a feeling for which project model one prefers to follow.

2.3 Group collaboration

At the start of the project, the group members got assigned different areas of responsibility. These areas of responsibility changed a bit as the project progressed. This was not all that bad since the walls between the different modules in the project were torn down by this, and the project became more transparent for all members of the group.

We had a standing lunch meeting every Monday between 12:15 and 13:00, and on certain weeks when there was a lot to do we added more meetings into the later part of the week so that we could finish the week knowing what was going on within the project. The main form of communication was going to be Microsoft Teams, and then we were going to use a group chat in Facebook's Messenger application for non-work-related conversations or for fast and urgent matters. In reality, however, the group experienced trouble with the notifications in Microsoft Teams. This led to the messenger chat taking over the communications completely, which worked surprisingly well to be honest (not counting the week when ChatGPT was the biggest talking point on the internet, then things got a little out of hand in the messenger chat).

Whenever design choices were to be made, the group had discussions during meetings on how things would be done. Sometimes these discussions got somewhat stuck because of disagreements on how to interpret the project model, but we got around these issues quite fast by looking at the work from previous years' students and by asking the customer/examiner.

The majority of the work, especially in the during-phase, was done in pairs of two. This was very convenient since one always had someone to brainstorm ideas with and to share responsibility and knowledge with. But when more group members were needed for certain activities, there were no problems in finding a time that suited everyone.

2.4 Collaboration with Customer

Collaboration with the customer worked quite well. We feel that there was an interest in what we did. When vital, it was easy to get a response via mail or in person. This might somewhat be in response to the group being very much present in the ISY KS corridor, making it easy to ask questions on the fly.

The group would suggest that the project in the course are given more clear deadlines and instructions. That would save time for the examiner and create less confusion for the students. One specific suggestion would be clearer guidance on handling the LIPS model. In the introduction, it's made clear that the groups can simplify the documentation part, but then it's pretty hard to understand what this really means. Another suggestion could be to set a date for the project conference early on. It could be risky business to leave this part to the project managers.

2.5 Collaboration with Supervisor

Except for a few brief sessions with the supervisor, the collaboration could be described as non-existing. We had little understanding of what to expect, and the supervisor seemed to have little understanding of what to do with us. With that said, this did not create an issue for the project. The questions we put forward got answered, and we appreciated his comments passing by in the corridor.

As the group stated in the after-talk, more hands-on support on the Pluto devices could have been appreciated. This was in some part covered by a Ph.D. student previously taking the same CDIO course.

3 TECHNICAL PROBLEMS AND SUCCESSES

In this section, technical problems and successes in the project are briefly reviewed. Note however that a more thorough discussion of the system can be found in the Technical Documentation [6].

3.1 Successes

The team developed an easy to use, aesthetically pleasing graphical user interface (GUI). This allowed the project group to collect data and test the system in an efficient manner.

Because of the ease of collecting data, a large dataset could be constructed early. This allowed the machine learning part of the team to evaluate and select machine learning models at an early stage of the project. Furthermore, a sufficiently representing dataset allowed for data exploration to give an idea of what could be done with the CSI signals. This was important for the presentation and report to describe the problem that the project tried to tackle.

Another success was the machine learning research performed at the beginning of the project. Papers within CSI sensing was reviewed and the models used in the papers could quickly be implemented, directly leading to proficiently performing models.

Finally, the team implemented a simple threshold based passage detection system. Because of its simplicity, it could quickly be understood by the entire team, required few computational resources and thus a low execution time which was of high importance for the live detection mode.

3.2 Problems

It was quickly noticed that the system is sensitive to changes in the environment and could vary in performance over different days. To tackle this problem it can be helpful to estimate CSI over several channels and carrier frequencies instead of only one as done in this project.

4 GOAL FULFILLMENT

Here we discuss how well our goals have been achieved and our thoughts on what worked well and not.

4.1 Summary of Achievements

All the project's base requirements have been fulfilled and also several level two requirements. Our final product can detect if a person is walking through the doorway with an accuracy of 93%, and then detect in which direction the person is walking with 90% accuracy which is high above our target of 75%.

With our user interface it is easy to collect new data which is automatically labeled and stored in a convenient way so that it is easy to set up the devices and train a new model adapted for a new environment.

The requirements that were not fulfilled are related to model training in the user interface, detecting the speed of the object passing through the door, and using no more than 3 seconds of data for classification.

The possibility to train models in the UI was not prioritized because the gain from implementing this was not that great since this is not done very often. Detecting the speed of an object could have been an interesting extension to the project but given the short time of the project, this was not deemed possible and more effort was put into making the existing models and functionality better. It would probably be possible to only use 3 seconds of data instead of the 5 seconds currently used since a lot of the 5 seconds signal used is static.

4.2 Delivery

The product and User manual were delivered as a demonstration for the examiner. Except for this After study, all other project documentation was ready for delivery on the date of the project conference. The After study will, after group approval, be submitted via a Gitlab repo to which the examiner has permission to access.

4.3 Study situation

The project group consisted of six members were each member had different courses alongside the project course. This meant that on certain occasions it became difficult to schedule times when each member was available. Fortunately, the group was split into subgroups which meant that it often was sufficient that at least one person from each subgroup was present. There were still some difficulties to schedule these meetings though, mainly in the first part of the semester. This was because of the fact that more members had higher amounts of credits to finish than in the second part of the semester.

It is worth noting that the previously mentioned issue only happened on rare occasions. When a whole-group-testing session had to take place it was almost always possible to find some place in schedule were everyone was available. This was a result of the project course taking one block in the schedule but not having any scheduled times. That meant that there was always some time intervals in the schedule were no one in the group should have had a schedule time in another course (of course people can have other things schedule that are not course related but that were not a major issue in this group).

Another things that was notable was that in the start the workloads were not evenly spread out. Some worked far less than others. This was, as mentioned above, due to some members having more credits that needed to be done. This

was not a issue for the group though since each set milestone was still met on time. This unevenness in the hours spend across the members balanced out in the second part of the semester when the burden on other courses was reduced for many members.

This project was conducted after the restriction for the COVID-19 pandemic were lifted. This meant that all the meetings and testing could be done on-site which greatly increased the efficiency of the project. The knowledge that was gathered from the pandemic though helped the group to easily contact members if they could not attend. Even for meetings, members could connect via a link to attend the meeting in case they could not be present in person. This resulted in all members being relatively updated on what was happening internally in every subgroup and the project as a whole at all times.

5 SUMMARY

This section aims to summarize the afterstudy by providing the most important experiences from the project and give some advice if someone were to do this project in the future.

5.1 Our three most important experiences

1. We started working on the project early by setting up the ADALM-PlutoSDR units. This was in retrospect a really good idea. Many unforseen errors were found and caught early on, before it had a chance to become a bottleneck for the whole project group. This was extra important in this project since almost everything anyone does depends on having *any* data to evaluate.

2. The radios turned out to be *very* sensitive to the environment they are placed in. Much more sensitive than we anticipated or expected. If you attempt to repeat or generalize the results of this project, be sure to be very precise when placing the radios for each place you collect data.

3. Teamwork is important, and a vital part of that is communication. During our weekly meetings, all project members took special care to give an honest evaluation how long it would take them to complete their current task and whether they felt the task they were currently doing was something meaningful. Several times during this project these discussions provided new viewpoints from other project members on a particular issue which sped up solving them. Other times this allowed for efficient reallocation of resources to solve a problem which would otherwise cause a bottleneck in the work. Overall, this honest attitude strengthened our team and allowed us to rely on each other to solve otherwise very difficult problems.

5.2 Good advice for future projects

Finally, we will try to share the things we feel worked well for us and try and dissuade you from making the same mistakes we did:

- Make it easy to gather data. You will spend a long time doing it, and it is brutally boring. The goal is to make it so simple that you can gather data in your sleep.
- Start gathering data early. The more data you have to evaluate, the easier it is to develop the detection software. Remember, even if the first few samples aren't perfect, it is better to have slightly erranous data than none at all!
- In the same vein, spend the majority of the resources you are going to spend developing the GUI early in the project. Adding features to the GUI at the end of the project is rarely necessary or something you wish to do. It is much better devote extra time early on adding features to allow the project group to use the graphical interface to simplify tasks like gathering data.
- Be honest with your team members, whether you need help or feel that you lack meaningful tasks to do. Someone else might have too much on their plate, might notice a problem or solution you overlooked.
- Make sure to enable communication lines between project managers of all groups. There will be confusing parts of the project and sharing is caring when it comes to information about the course.

- Try to integrate your work continuously throughout the project. This helps you catch problems early on and ensures that you're all on the same page regarding implementation. It also reduces the bottleneck that integration otherwise can be in a project since you're dividing the work over several different instances.

REFERENCES

[1] H. Ahlinder, S. Andersson, M. Dahl, C. Gustavsson, J. Henneberg, and T. Kylesten, "Detection of an object movement direction indoors: Requirement specification, 2022."

[2] ——, "Detection of an object movement direction indoors: System design sketch, 2022."

[3] ——, "Detection of an object movement direction indoors: System design specification, 2022."

[4] ——, "Detection of an object movement direction indoors: Project plan incl. time plan, 2022."

[5] ——, "Detection of an object movement direction indoors: Test plan, 2022."

[6] ——, "Detection of an object movement direction indoors: Technical documentation, 2022."