Requirement specification

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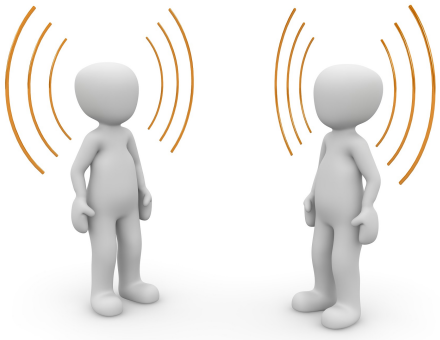

Status

Reviewed	Martin Dahl	2022-09-19
Approved	Danyo Danev	~~2022-09-26~~ Revised 2022-11-14

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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
1.2	2022-11-14	Revised version.	Christian Gustavsson	Martin Dahl
1.1	2022-09-26	Minor corrections after comments by orderer.	Joel Henneberg	Martin Dahl
1.0	2022-09-19	Final version.	Joel Henneberg	Martin Dahl
0.1	2022-09-12	First draft.	Joel Henneberg	Martin Dahl

1 INTRODUCTION

Being able to count the number of people walking in and out through doorways comes in handy in numerous applications. This came to be even more important when COVID-19 struck the world with its pandemic and came with restrictions on how crowded certain areas could be. With the use of received RF (Radio Frequency) signals and machine learning algorithms, it should be possible to classify in which direction an object is traveling through a doorway using the ADALM Pluto Software-Defined Radio (Pluto SDR) devices.

Figure 1: The system in its surroundings

1.1 Project Information

The goal of the project is to develop a system that can detect the direction of movement of an object passing through a doorway at walking speed in an indoor environment. The project has been supplied with a number of Pluto SDR devices which will be used to collect the data necessary for classification. With the use of collected training data, a machine learning algorithm will be trained to determine whether there is an object approaching the doorway or not. If an object is approaching the doorway, data will be sent to another machine learning classification algorithm to determine the object's direction of movement. The result from the algorithm will be displayed to the user through a user-friendly GUI. The algorithm will operate on a few seconds worth of data collected in a controlled lab environment indoors.

1.2 Project Organisation

This project is being performed by six students from the University of Linköping, all taking part in a Conceive-Design-Implement-Operate (CDIO) course. The course's full name is "Project course in Signal Processing, Communication and Networking CDIO" (course code TSKS23) and is given by the division of communication systems. Partners to the project are Danyo Danev and Sai Subramanyam Thoota from this division. Danyo Danev is the project's customer and Sai is the supervisor of the project. The project is to follow the LIPS model [1] which specifies the different phases of the project and which documents should be provided to the customer during which phase. In this LIPS model, there

are a number of tollgates that comes with deadlines, where each tollgate denotes the transition between different parts of the project.

1.3 Purpose of the Requirement Specification

The purpose of this document is to specify the requirements of the system so that both the project group and the customer have a realistic view of what the final product will look like and how it will perform. The goal is for the requirements to be phrased in a way so that they are easy to test independently from one another.

1.4 Requirement Definitions

The requirements will be described in the form of tables exemplified below. In the first column, the number of requirements can be found. In the second column, the version of the requirement can be found. The version of a requirement can either be of type "Base " or "Renegotiated". A brief description of the requirement is contained in the third column, and the priority of the requirement is in the fourth column. Requirements of priority 1 must be fulfilled, and requirements with priority 2 may be fulfilled. Requirements with priority 3 are only to be worked with if the economy of the project allows it after all other requirements have been fulfilled.

Requirement	Version	Description	Priority
1	Base	Description of requirement	1/2/3

2 RESTRICTIONS

Some restrictions need to be defined to clarify under which circumstances the system requirements must hold. In this section, these restrictions will be listed.

Definition: By passage through the system, we mean crossing a straight line fixed on the ground in a direction orthogonal to the line.

Example: This line could be the bottom of a door frame and we detect if a person passes through the door.

Counter example: The line can not be a circle or S shaped. A person cannot pass the line diagonally.

1. Requirements only apply indoors
2. Requirements only apply for an object passing the system in walking speed (1 - 2 m/s)
3. The physical placement of the transmitter and receivers has to be fixed
4. Object to be detected must be outside of the systems area of detection when the measurement is started
5. Object must be a human
6. Objects speed must be approximately constant
7. The environment is assumed to only contain one moving object at a time

3 SYSTEM REQUIREMENTS

The goal is for the system to detect movement, and preferably if the direction of movement occurs in or out through the system. This will be done using two Pluto SDR devices that can both send and receive signals, so one will transmit signals that the other one will receive. Machine learning algorithms trained on training data (most likely CSI data, although this is to be investigated) will then analyze this received data and give the user a proper classification through a UI. The system is divided into subsystems, so there is a hardware subsystem, a software subsystem, and a user interface.

Requirement	Version	Description	Priority
2	Base	System can detect in what direction an object passes through it with an accuracy of 75%, given the information that something passes through the door	1
3	Base	System can detect if something passes through it with an accuracy of 75%	2
4	Base	System can detect with what speed an object passes through it with an error margin of +/- 1 m/s	3

3.1 Hardware Subsystem (HS)

The hardware subsystem consists of the Pluto SDR devices and a host computer. This subsystem is responsible for data collection and data storage, so that data can be easily accessible for the software system.

Requirement	Version	Description	Priority
5	~~Base~~	~~System consists of a transmitter and more than one receiver, where the transmitter can send to the receivers~~	~~1~~
	Revised	System consists of a transmitter and one or more receivers, where the transmitter can send to the receiver(s)	1
6	~~Base~~	~~The transmitter can be controlled by the software subsystem~~	~~1~~
	Revised	The transmitter can be controlled by the UI	1
7	~~Base~~	~~The receivers can be read by the software subsystem~~	~~1~~
	Revised	The receivers can be read by the UI	1
8	Base	The physical placement of the transmitter and receivers can be changed dynamically	3

3.2 Software Subsystem (WS)

The software subsystem consists of code for training the machine learning algorithms as well as code for the final classification algorithms the project is going to use. The data will be divided into training, validation, and test data. The accuracy of classification will be defined as the number of correct classifications divided by the total number of classifications.

Requirement	Version	Description	Priority
9	~~Base~~	~~Software subsystem has a running mode~~	1
	Revised	Hardware subsystem has a running mode	1
10	~~Base~~	~~Software subsystem has a calibration mode~~	~~1~~
	Revised	Hardware subsystem has a calibration mode	1
11	~~Base~~	~~Software subsystem can switch between its two modes~~	~~1~~
	Revised	Hardware subsystem can switch between its two modes	1
12	Base	Software subsystem can read data collected and stored by the hardware subsystem	1
13	~~Base~~	~~Software subsystem can control the hardware subsystem~~	~~1~~
	Revised	UI can control the hardware subsystem	1
14	Base	Software subsystem can use an ML-classification algorithm to classify the movement direction of an object passing between the sensor	1
15	Base	Software subsystem can use an ML-classification algorithm to classify if there is an object between the sensors	2

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Requirement	Version	Description	Priority
16	Base	Software subsystem can classify if an object has passed through it using no more than 3 seconds of data	3

3.3 User Interface (UI)

The user interface is of use to simplify the handling of the system. This subsystem will be used to control both the hardware subsystem and the software subsystem by changing parameters used by the classification algorithms and by starting and stopping data collection. A user should also be able to calibrate the system using this interface. The UI is also a tool for the user to easily interpret the result to see in which direction the moving object passed through the door.

Requirement	Version	Description	Priority
~~21~~	~~Base~~	~~The user can select between calibration and running mode~~	~~1~~
	Remove	*Comment: This will be done automatically, not a relevant requirement.*	
22	~~Base~~	~~The user can select the model type to train in the UI~~	~~1~~
	Revised	The user can select the model type to train in the UI	2
23	Base	The user can select model file used for evaluation	1
24	Base	The user can select which gathered data to use when evaluating a model	1
25	Base	The user can gather and label data in the UI	1
26	~~Base~~	~~The user can train a model using automatic hyperparameter optimization~~	~~1~~
	Revised	The user can train a model using automatic hyperparameter optimization	3
27	~~Base~~	~~The UI displays relevant model metrics after training~~	~~1~~
	Revised	The UI displays relevant model metrics after training	2
28	Base	The UI displays relevant model metrics after evaluation	1
29	Base	The user can select hyperparameters and start model training in the UI	2
30	Base	The UI displays relevant model metrics during model training and evaluation	2
31	~~Base~~	~~The UI displays relevant metrics about a model on selection~~	~~2~~
	Revised	The UI displays relevant metrics about a model on selection	1
32	Base	The UI saves a log of predictions over time	2
33	Base	The user can select to run models on live-gathered data in the UI	2

4 ECONOMY

To ensure that the project does not consume too much time and resources from the students working on the project, there are guidelines for how many hours the project should take from each group member.

Requirement	Version	Description	Priority
34	Base	Every member in the group is expected to work 240 hours with the project	1
35	Base	15 hours of supervision is given to the group	1
36	Base	25 hours of expert consultancy is given to the project group	1
37	Base	Every necessary hardware license is provided by the customer	1

5 DELIVERY

Alongside the system and its technical solution, a number of documents should be delivered during the project. Table 7 below defines when each of the documents in Table 7 should be delivered to the customer, all documents in Table 7 are required to be delivered with priority 1.

Table 7: Documents to be produced.

Item	Purpose	Target	Date
Project Plan	Describe plan to deliver on requirements	Customer	2022-09-19
Requirement Specification	Describe what must be delivered to customer	Customer	2022-09-19
System Design Sketch	Describe how to implement the technical parts of the Project Plan	Customer	2022-09-19
System Design Specification	Detailed description on how to implement the technical parts of the Project Plan	Customer	2022-10-07
Test Plan	Describes how the project system will be tested	Customer	2022-10-14
User Manual	Describes how to use the system	Customer	2022-12-09
Final product	A study on how the project was performed and what could have been better	Customer	2022-12-09
Technical Documentation	Describes in detail how the final system works	Customer	2022-12-16
Website	A study on how the project was performed and what could have been better	Customer	2022-12-16
Poster	A study on how the project was performed and what could have been better	Customer	2022-12-16
Meeting Protocols	For reference on what has been said during meetings with Project Group	Project Group	2023-01-08
After study	A study on how the project was performed and what could have been better	Customer	2023-01-08

5.1 Website

As a tool for presenting the final product, a website will be built. In the table below the requirements of this website are listed.

Requirement	Version	Description	Priority
38	Base	Website has a page introducing the project	1
39	Base	Website introduces the project group	1
40	Base	Website includes the final versions of all project documents	1
41	Base	Website includes video demonstrating product	1

6 DOCUMENTATION

Table 9 lists all documents that shall be produced in the project.

Table 9: Project documentation

Document	Purpose	Target group	Format	Storage
Project Plan	Describes the project and its phases.	Customer	PDF	Overleaf
Time Plan	Activities and allotted time.	Customer	PDF	Google Drive
Requirements Specification	Specifies the requirements on the product.	Customer	PDF	Overleaf
Design Specification	A detailed description of the product design.	Customer	PDF	Overleaf
Test Plan	Specifies the tests to be carried out in order to ensure that stated requirements are met.	Customer	PDF	Overleaf
Meeting minutes	Documentation of project group meetings and decisions	Project Group	Google Docs	Google Drive
Technical Report	Detailed description of the product and how it operates.	Customer	PDF	Overleaf
User Manual	A easy-to-use description on how to operate the product.	Customer	PDF	Overleaf
Poster	A Presentation of the product.	Customer	PDF	-
After study	A compilation of the group's experience working on the project.	Customer	PDF	Overleaf

REFERENCES

[1] T. Svensson and C. Krysander, *Projektmodellen Lips*, 1st ed. Liber AB, Stockholm, 2011, iSBN9789144075259.