Requirement Specification

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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
1.1	2021-10-14	Renegotiated requirement 34	The project group	RM
1.0	2021-09-27		The project group	The project group
0.4	2021-09-24	Small fixes and clarifications	The project group	Supervisor
0.3	2021-09-23	Typos and some movement of content.	The project group	Supervisor
0.2	2021-09-20	Reshuffle of content, clarifications.	The project group	Supervisor
0.1	2021-09-14	First draft.	The project group	Supervisor

1 INTRODUCTION

The use of channel state information (CSI) to detect human interaction and motion is an interesting concept. We want to explore the possibility to detect different types of motion in an otherwise static environment. By collecting training data in a controlled environment, machine learning (ML) can be used to train an algorithm that can classify different events that take place in the monitored area. This could be, for example, detecting a burglar breaking in or a person falling down.

1.1 Project Information

The goal of the project is to develop a detector that can detect dynamic activities in an indoor environment. For this purpose, the project has been provided with several ADALM Pluto Software-Defined Radio (Pluto SDR) devices [1]. Two of these devices are shown in Figure 1. The detector functionality is as follows: the detector will first estimate the channel and evaluate the quality of the channel estimate. If the quality of the estimate is not good, it will make another channel estimate and reevaluate. Then it will pass on that information to an algorithm which will do a classification based on the collected information and present the result through a user interface. The algorithm uses ML and is trained in a controlled lab environment, which will be referred to as the training environment.

1.2 Project Organisation

This project is part of a Concieve-Design-Implement-Operate (CDIO) course given at Linköping University. The name of the course is "Project course in Signal Processing, Communication and Networking CDIO" and is given by the Division of Communication Systems (KS) at Linköping University. The project group consists of seven students taking the aforementioned course and partners to the project is the customer Danyo Danev from KS and two supervisors, who are also from KS. The project is conducted according to the LIPS model. The LIPS model specifies what should be done during the different phases of the project. It also defines the format and content of the documents to be delivered during the project and a number of tollgates that denote the transition between different parts of the project [2].

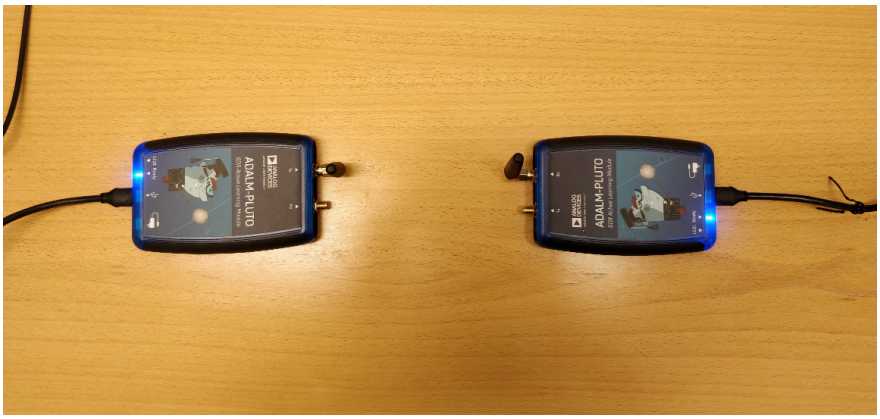

Figure 1: The figure shows the hardware used for the project, two Pluto SDR devices.

1.3 Purpose of the Requirement Specification

The aim with this document is to define the set of requirements that the final product should fulfill. The goal is that the project group and customer should have a shared opinion of what the final product will be and achieve. It should also be easy to specify a number of tests that will prove that the product meets the requirements set in this document.

1.4 Requirement Definitions

The requirements will be described in the tabular form exemplified below. The requirement number is found in the first column. The version is contained in the second column, it can either be of type "Base" or "Renegotiated". A description of the requirement is contained in the third column and the priority of it in the fourth. Requirements labelled with priority 1 must be fulfilled and those with priority 2 may be fulfilled. Requirements with priority 3 are to be worked with if the project group has time left after completion of the priority 1 and 2 requirements.

Requirement	Version	Description	Priority
Number	Version	Description of the requirement.	1/2/3

2 SYSTEM REQUIREMENTS

The objective of the system is to detect activities in an indoor environment. The system consists of two Pluto SDR devices that send and receive signals, and are connected to a host computer. The system operates by first estimating the channel between transmitter and receiver in a static environment, and then analysing the CSI. Several ML algorithms that have been trained to recognise different types of events is used for classification of the CSI. The system has been split into three subsystems: a hardware subsystem, a software subsystem and a user interface.

In this section all requirements for the final product are listed. First a general requirement for the detector and then follows more specific requirements linked to the different subsystems and the performance of the detector.

Requirement	Version	Description	Priority
1	Base	The system can discriminate between a static and a dynamic indoors environment.	1

2.1 Hardware Subsystem

The hardware subsystem is responsible for controlling the Pluto SDR devices and performing the channel estimates, as well as evaluating the estimates' quality. The system evaluate the quality of channel estimate by sending Binary Phase Shift Keying (BPSK) symbols and evaluating the bit-error rate (BER), which is equivalent to the symbol error

rate when using BPSK. If the BER is too high, the hardware subsystem will redo the channel estimate and re-evaluate its quality. The hardware subsystem collects the data which is sent to the software subsystem.

Requirement	Version	Description	Priority
2	Base	The hardware subsystem can estimate a channel.	1
3	Base	The hardware subsystem can select between multiple frequencies.	1
4	Base	The hardware subsystem can evaluate the quality of channel estimate by calculating the BER of the transmitted BPSK symbols.	1
5	Base	The hardware subsystem can estimate the channel between each pair of transmitter and receiver in a multiple antenna setup.	1
6	Base	The collected data can be stored in a format accessible by the other subsystems.	1

2.2 Software Subsystem

The software subsystem contains all the software used for the classification of the environment. This includes code for making a binary (and optionally a multiple) hypothesis classification, as well as code for training and testing these algorithms. The ratios for training and test data will be 70% for training and 30% for testing. All testing will be done in the training environment unless stated otherwise. Accuracy is defined as the number of correct classifications divided by the total number of cases.

Requirement	Version	Description	Priority
7	Base	The detector can discriminate between a moving balloon wrapped in aluminium foil and a static environment with 90% accuracy.	1
8	Base	The detector can discriminate between a walking human and a static environment with 75% accuracy.	1
9	Base	The detector can discriminate between a dancing human and a static environment with 75% accuracy.	1
10	Base	The detector can discriminate between a jumping human and a static environment with 75% accuracy.	1
11	Base	The software subsystem can read data collected and stored by the hardware subsystem.	1
12	Base	Implement a k-means clustering method for classification.	1
13	Base	Implement a hidden Markov method for classification.	1
14	Base	Implement a support vector machine method for classification.	1
15	Base	Implement a multi-hypothesis classification method.	2
16	Base	Implement at least one additional classification method.	2
17	Base	Implement a Deep Neural Network (DNN) for classification.	3

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Requirement	Version	Description	Priority
18	Base	The system can discriminate between a static environment and a dynamic environment using ten seconds of data.	1
19	Base	The system can discriminate between a static environment and a dynamic environment using three seconds of data.	2
20	Base	The system can discriminate between a static environment and a dynamic environment using one second of data.	3
21	Base	The system can discriminate between a static environment and a dynamic environment in real-time.	3

2.3 User Interface

To achieve a more user friendly interaction with the product, a graphical user interface (GUI) should be implemented. Through it, the user can control the other two subsystems and show results in an intuitive way.

Requirement	Version	Description	Priority
22	Base	The user can control the hardware parameters through the GUI.	1
23	Base	The user can start a classification through the GUI.	1
24	Base	The user can select from the available algorithms through the GUI.	1
25	Base	The GUI can display the classification decision of the sampled signal.	1
26	Base	The GUI shows the current carrier frequency in use.	1

3 ECONOMY

To ensure that the project does not consume too much time and resources, there is a guideline for how many hours the project should take.

Requirement	Version	Description	Priority
27	Base	Each project member is expected to work 240 hours with the project.	1
28	Base	The project is given 15 hours of supervision.	1
29	Base	The project is given 25 hours of expert consultancy.	1
30	Base	All necessary hardware and licences are provided by the customer.	1

4 DELIVERY

During the project, a number of documents should be delivered along with the technical solution. The table below defines when they should be finished and delivered.

Requirement	Version	Description	Priority
31	Base	September 6: Project group formed and project idea decided.	1
32	Base	September 17: A first draft of the Requirement Specification will be sent to the supervisor.	1
33	Base	September 24: A first draft of the Project Plan and the System Design Specification will be sent to the supervisor.	1
34	Renegotiated	October 15: A final version of the Project Plan, Requirement Specification and the System Design Specification will be sent to the customer.	1
35	Base	November 5: A final version of the Test Plan will be sent to the supervisor.	1
36	Base	December 10: A final version of the Technical Report and User Manual will be sent to the customer.	1
37	Base	December 17: A final version of the poster and website will be sent to the customer.	1
38	Base	December 17: A final version of the Afterstudy will be sent to the customer.	1
39	Base	No later than December 17: An oral presentation of the project is given by the project group.	1
40	Base	Each Monday: A weekly report is sent to the customer.	1

4.1 Website

To present the final product and demonstrate the result of the project, a website is built.

Requirement	Version	Description	Priority
41	Base	The website has a page introducing the product.	1
42	Base	The website has a page introducing the project group.	1
43	Base	The website include all the final versions of the project documents.	1
44	Base	The website has a demonstration video of the product.	2

5 DOCUMENTATION

Within the project there are several required documents that will be produced. These are listed in the table below.

Document	**Purpose**	**Target Group**	**Format**
Project Plan	Describe the project and its different phases.	Customer	PDF
Requirement Specification	Specify what will be included in the finished product.	Customer	PDF
Design Specification	Give an overview description of the products subsystems design and how they work.	Customer	PDF
Test Plan	Specify the tests that will be carried out to make sure that the requirements are fulfilled.	Customer	PDF
Meeting Protocols	Show when and which decisions that has been made during the project.	Project group	PDF
Technical Report	Thoroughly explain how the product works and how to operate it.	Customer	PDF
User Manual	In a straight-forward way explain how to use the product.	Customer	PDF
Afterstudy	Compile the whole groups experiences from the project.	Customer	PDF

The requirements imposed on the documents are described in the table below.

Requirement	Version	Description	Priority
45	Base	All documents intended for the customer is based on the LIPS project model [2].	1
46	Base	All documents should follow the IEEE reference system [3].	1

REFERENCES

[1] *ADALM-PLUTO for End Users.* Wilmington, MA, USA: Analog Devices, 2021, Accessed: Sep. 17, 2021. [Online]. Available: https://wiki.analog.com/university/tools/pluto/users

[2] T. Svensson and C. Krysander, *Projektmodellen LIPS*, 1st ed. Stockholm, Sweden: Liber AB, 2011.

[3] *IEEE Reference Guide.* Piscataway, NJ, USA: IEEE Periodicals, 2018, Accessed on: Sep. 17, 2021. [Online]. Available: https://ieeeauthorcenter.ieee.org/wp-content/uploads/IEEE-Reference-Guide.pdf