Test Protocols

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Reviewed	The project group	2021-12-16
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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
1.0	2021-12-16	Fixed comment from supervisors.	The project group	Supervisors
0.1	2021-12-15	First draft.	The project group	Supervisors

1 INTRODUCTION

The objective of the system implemented in this project is to detect activities in an indoor environment. The system consists of several ADALM Pluto Software-Defined Radio (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 different environments, and then analysing the channel state information (CSI). Several machine learning (ML) algorithms that have been trained to recognise different types of events are used for classification of the CSI. The system has been split into three subsystems: a hardware subsystem, a software subsystem and a user interface subsystem.

This document will outline the results of the series of tests from [1] that have been performed to determine and ensure that the final product lives up to the requirements detailed in [2]. Observe that only tests regarding priority 1 requirements have been considered. The data used to perform the tests was collected in the environment shown in Figure 1.

Figure 1: The antenna setup used in the tests. The transmitter (Tx) and the three receivers (Rx) are marked in the picture.

2 TEST 1

Date: 2021-10-13.

Performed by: Martin Andersson, Emma Beskow, Joel Nilsson.

Related requirement(s): 2.

2.1 Test description

Test if the channel in a single-input single-output (SISO) scenario can be estimated.

2.2 Test performance

A SISO channel was set up, i.e., only one of the receivers in Figure 1 was used. The transmitter sent a constant baseband signal of a positive real number and the receiver received 100 baseband samples. Equation 7 from [2], with the SNR put to 1, was used to estimate the channel for these 100 samples. Observe that this gives the channel estimate up to a scaling factor depending on the real SNR (which depends on the power of the sent signal and the receiver noise). However, since there is no need to know this scaling factors for the purposes in this project, this is acceptable.

2.3 Test result

The channel between a single transmitter and a single receiver could be estimated, up to an unnecessary scaling factor.

3 TEST 2

Date: 2021-11-11.

Performed by: Martin Andersson, Ella Grundin.

Related requirement(s): 3.

3.1 Test description

Test if the hardware subsystem can handle different carrier frequencies.

3.2 Test performance

A SISO communication setup was used. Some carrier frequencies between 500 MHz and 2.4 GHz were tested, and it was possible to use all of them. However, only frequencies around 1 GHz (±0.2 GHz) gave convenient results.

3.3 Test result

The hardware subsystem could handle different carrier frequencies. Carrier frequencies in the interval [800, 1200] MHz are preferred.

4 TEST 3

Date: 2021-12-07.

Performed by: Martin Andersson, Joel Nilsson, Jianxin Qu.

Related requirement(s): 4.

4.1 Test description

Test if Binary Phase Shift Keying (BPSK) symbols can be used to evaluate a channel estimate.

4.2 Test performance

1024 BPSK modulated data bits (plus a known pilot sequence) were sent in a static environment from the transmitter to one of the receivers in Figure 1.

4.3 Test result

It can be seen in Figure 2, that all the received BPSK symbols are clustered close to ± 1 with a small phase shift. The BER could be calculated from the received signal (zero in this example).

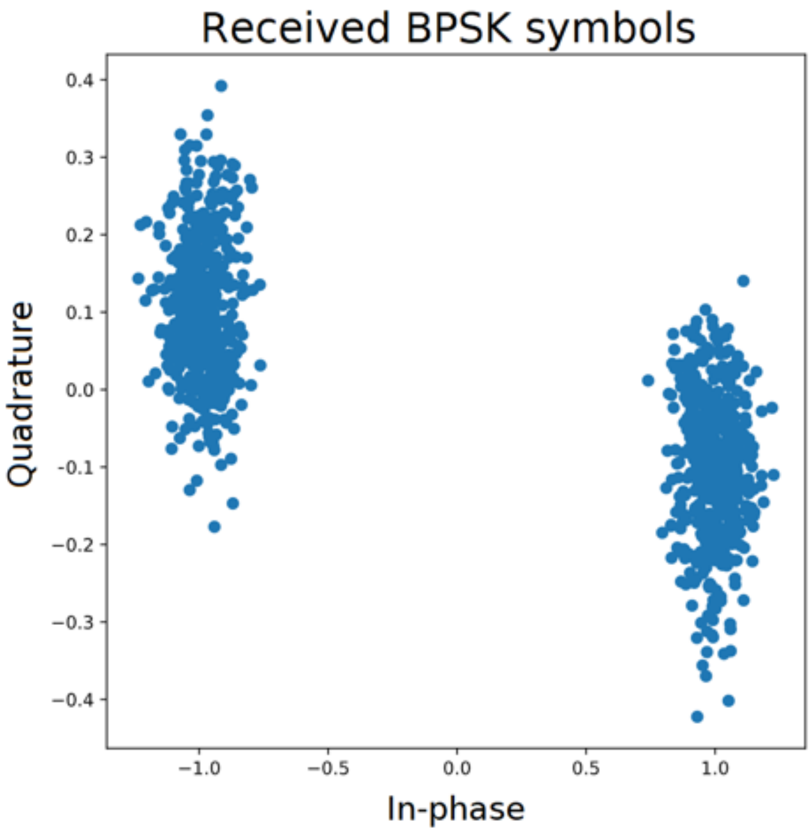

Figure 2: Received BPSK symbols.

5 TEST 4

Date: 2021-11-11.

Performed by: Martin Andersson.

Related requirement(s): 5.

5.1 Test description

Test if the channels in a multiple antenna scenario can be estimated.

5.2 Test performance

A single-input multiple-output (SIMO) scenario with one transmitter and three receivers was set up. The test was performed as in Test 1, but the channel was estimated at all receivers simultaneously.

5.3 Test result

All three channels between the transmitter and the receivers could be estimated, up to an unnecessary scaling factor.

6 TEST 5

Date: 2021-12-08.

Performed by: Martin Andersson, Emma Beskow.

Related requirement(s): 1, 12, 13, 14, 18.

6.1 Test description

Test if the system can identify a static environment.

6.2 Test performance

A total of 20 minutes = 1200 seconds of data was gathered with the SIMO setup in Figure 1. The environment was static during half of the time and dynamic during the other half. The data was split into batches of five seconds each. 70% of the batches were used for training and 30% for testing. The variance and the maximum amplitude difference of the channel estimates during each training batch of five seconds were used as features to train the following algorithms: K-means clustering, hidden Markov model (HMM), support vector machine (SVM), decision tree, Gaussian mixture model (GMM), random forest and deep neural network (DNN).

6.3 Test result

The test data was used to evaluate the trained models, which gave the confusion matrices in Figure 3. As can be seen, the accuracy is great. Also, this was done using less than the maximum allowed time of 10 seconds per batch.

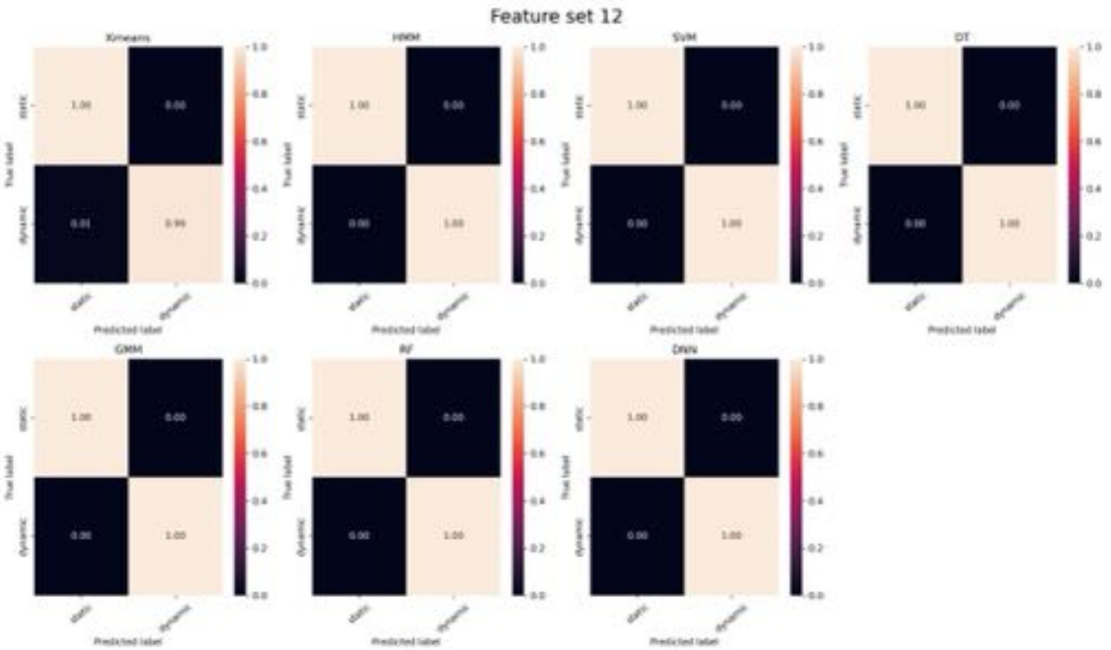

Figure 3: The detection performances when using different classification algorithms to discriminate between a static environment and a dynamic environment.

7 TEST 6

Date: 2021-12-08.

Performed by: Martin Andersson, Emma Beskow.

Related requirement(s): 7, 12, 13, 14, 18.

7.1 Test description

Test if the system can discriminate between a static environment and an aluminium foiled balloon.

7.2 Test performance

A total of 20 minutes = 1200 seconds of data was gathered with the SIMO setup in Figure 1. The environment was static during half of the time and dynamic with an aluminium foiled balloon being waved in the room during the other half. The data was split into batches of five seconds each. 70% of the batches were used for training and 30% for testing. The variance and the maximum amplitude difference of the channel estimates during each training batch of five seconds were used as features to train the following algorithms: K-means clustering, HMM, SVM, decision tree, GMM, random forest and DNN.

7.3 Test result

The test data was used to evaluate the trained models, which gave the confusion matrices in Figure 4. As can be seen, the accuracy is clearly higher than the required 90%. Also, this was done using less than the maximum allowed time of 10 seconds per batch.

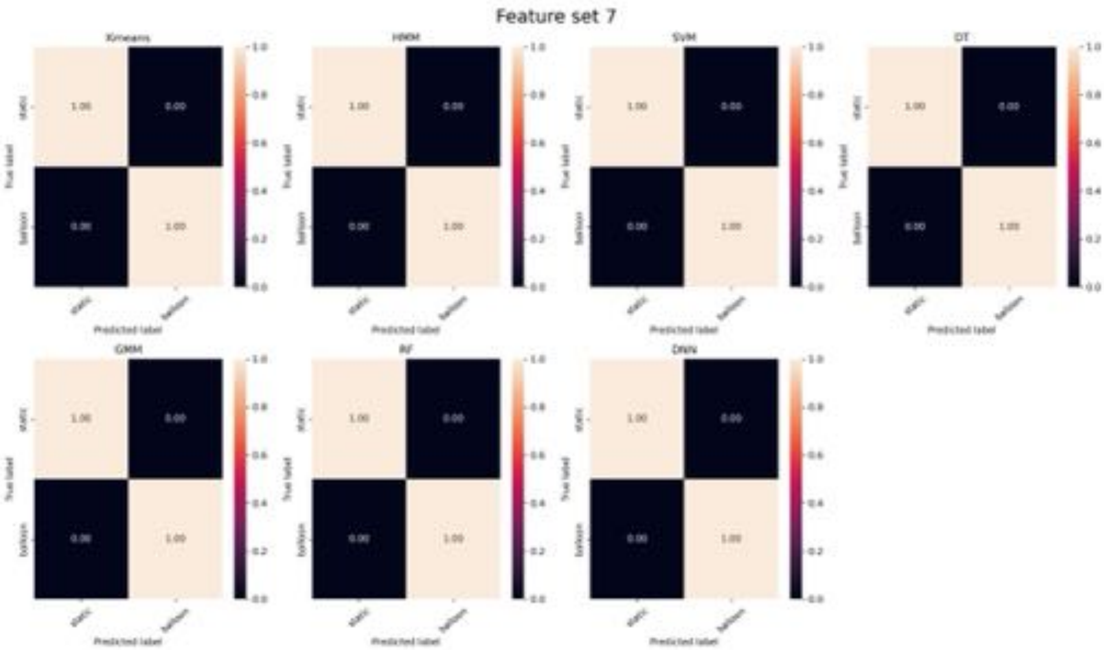

Figure 4: The detection performances when using different classification algorithms to discriminate between a static environment and an aluminum foiled balloon being waved.

8 TEST 7

Date: 2021-12-08.

Performed by: Martin Andersson, Emma Beskow.

Related requirement(s): 8, 12, 13, 14, 18.

8.1 Test description

Test if the system can discriminate between a static environment and a walking person.

8.2 Test performance

A total of 20 minutes = 1200 seconds of data was gathered with the SIMO setup in Figure 1. The environment was static during half of the time and dynamic with a person walking around in the room during the other half. The data was split into batches of five seconds each. 70% of the batches were used for training and 30% for testing. The variance and the maximum amplitude difference of the channel estimates during each training batch of five seconds were used as features to train the following algorithms: K-means clustering, HMM, SVM, decision tree, GMM, random forest and DNN.

8.3 Test result

The test data was used to evaluate the trained models, which gave the confusion matrices in Figure 5. As can be seen, the accuracy is clearly higher than the required 75%. Also, this was done using less than the maximum allowed time of 10 seconds per batch.

9 TEST 8

Date: 2021-12-08.

Performed by: Martin Andersson, Emma Beskow.

Related requirement(s): 10, 12, 13, 14, 18.

9.1 Test description

Test if the system can discriminate between a static environment and a jumping person.

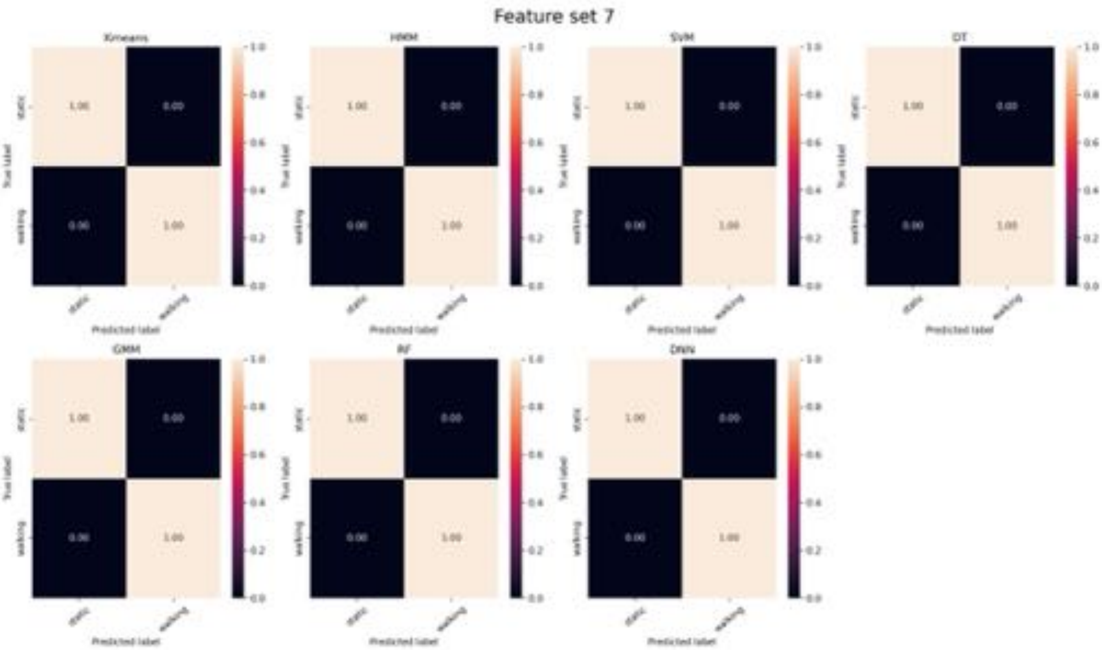

Figure 5: The detection performances when using different classification algorithms to discriminate between a static environment and a person walking around.

9.2 Test performance

A total of 20 minutes = 1200 seconds of data was gathered with the SIMO setup in Figure 1. The environment was static during half of the time and dynamic with a person jumping around in the room during the other half. The data was split into batches of five seconds each. 70% of the batches were used for training and 30% for testing. The variance and the maximum amplitude difference of the channel estimates during each training batch of five seconds were used as features to train the following algorithms: K-means clustering, HMM, SVM, decision tree, GMM, random forest and DNN.

9.3 Test result

The test data was used to evaluate the trained models, which gave the confusion matrices in Figure 6. As can be seen, the accuracy is clearly higher than the required 75%. Also, this was done using less than the maximum allowed time of 10 seconds per batch.

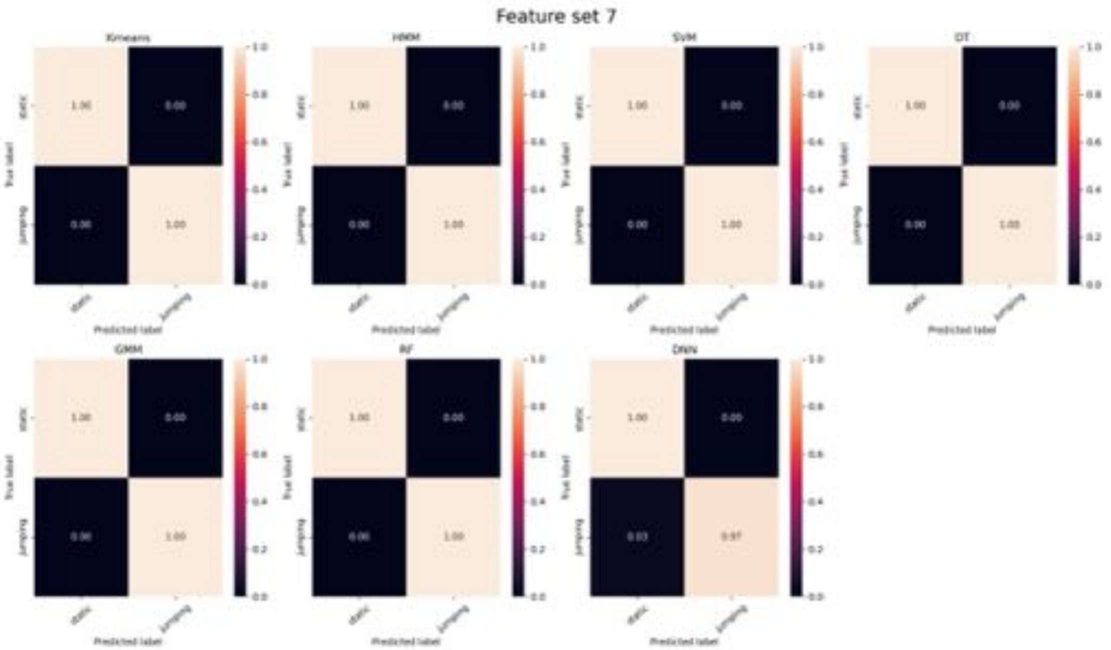

Figure 6: The detection performances when using different classification algorithms to discriminate between a static environment and a jumping person.

10 TEST 9

Date: 2021-12-08.

Performed by: Martin Andersson, Emma Beskow.

Related requirement(s): 9, 12, 13, 14, 18.

10.1 Test description

Test if the system can discriminate between a static environment and a dancing person.

10.2 Test performance

A total of 20 minutes = 1200 seconds of data was gathered with the SIMO setup in Figure 1. The environment was static during half of the time and dynamic with a person dancing in the room during the other half. The data was split into batches of five seconds each. 70% of the batches were used for training and 30% for testing. The variance and the maximum amplitude difference of the channel estimates during each training batch of five seconds were used as features to train the following algorithms: K-means clustering, HMM, SVM, decision tree, GMM, random forest and DNN.

10.3 Test result

The test data was used to evaluate the trained models, which gave the confusion matrices in Figure 7. As can be seen, the accuracy is clearly higher than the required 75%. Also, this was done using less than the maximum allowed time of 10 seconds per batch.

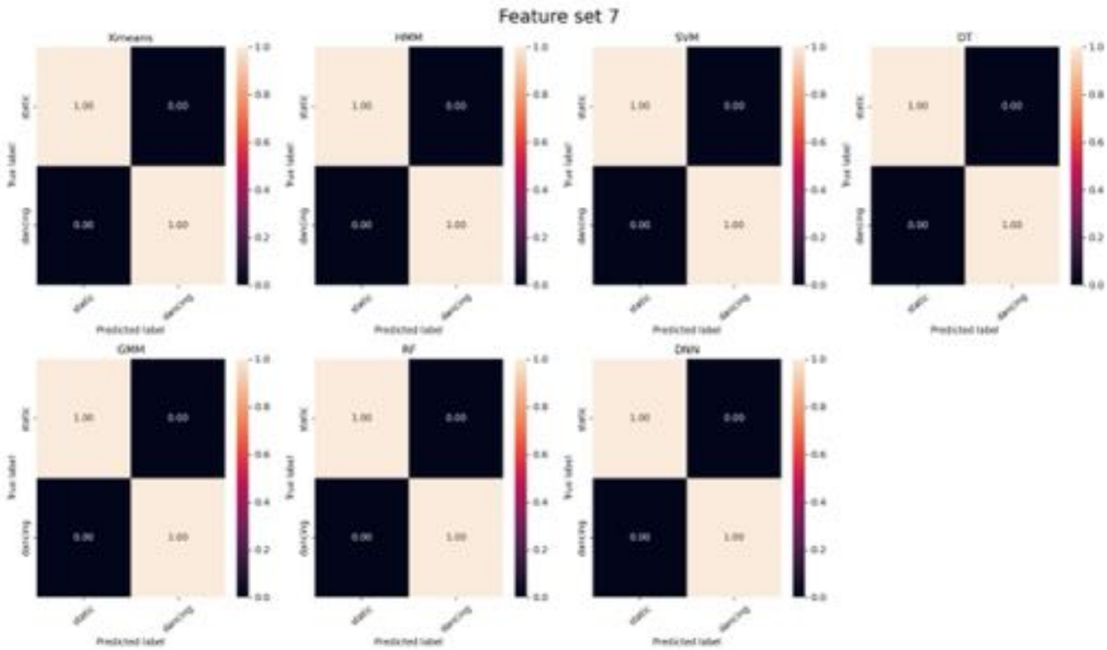

Figure 7: The detection performances when using different classification algorithms to discriminate between a static environment and a dancing person.

11 TEST 10

Date: 2021-12-01.

Performed by: Martin Andersson, Robin Mannberg.

Related requirement(s): 22, 23, 24, 25, 26.

11.1 Test description

Test if the GUI can control the individual subsystems.

11.2 Test performance

The GUI was used to create a new data set (a folder) and to collect data for one minute. The GUI was then used to collect data into the same data set for one more minute. The user could choose the hardware parameters (sample rate, carrier frequency). By using some collected data, a model was estimated. The user could select a data set, the activities to discriminate between, the features and the amount of the data that was to be used for training. Finally, the trained model was used to classify some test data.

11.3 Test result

The above described activities were successfully performed.

12 TEST 11

Date: 2021-12-15.

Performed by: Martin Andersson, Robin Mannberg.

Related requirement(s): 22, 23, 24, 25, 26.

12.1 Test description

Test if the GUI can control the entire system.

12.2 Test performance

All functionality in the GUI was tested. This included checking if the Pluto devices are connected, creating a data set, loading a data set, training a model, predicting, live prediction, opening the project web page and clearing the log window.

12.3 Test result

Everything worked.

13 TEST 12

Date: 2021-12-15.

Performed by: Martin Andersson, Robin Mannberg.

Related requirement(s): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 22, 23, 24, 25, 26.

13.1 Test description

Test if the whole system works and that it fulfills all priority 1 requirements.

13.2 Test performance

All functionality in the system was tested. This included checking if the Pluto devices could be connected to a host computer, opening the GUI, creating a data set, loading a data set, training a model, loading a model, testing the trained/loaded model by testing with new data, live prediction. The channel evaluation with BPSK also worked, but is a bit unstable and is not integrated into the final product.

13.3 Test result

The above explained activities worked as expected.

REFERENCES

[1] M. Andersson, E. Beskow, E. Grundin, R. Mannberg, J. Nilsson, G. Suihko, and J. Qu, "Detection of static and dynamic indoor environments: Test plan, 2021."

[2] ——, "Detection of static and dynamic indoor environments: Requirement specification, 2021."