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Gesture Recognition for Human-Robot Interaction: An approach based on skeletal points tracking using depth camera

Masterarbeit
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Statement of Authorship

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Abstract

Human-robot interaction (HRI) has been a topic of both science fiction and academic speculation even before any robots existed [?]. HRI research is focusing to build an intuitive and easy communication with the robot through speech, gestures, and facial expressions. The use of hand gestures provides an attractive alternative to complex interfaced devices for HRI. In particular, visual interpretation of hand gestures can help in achieving the ease and naturalness desired for HRI. This has motivated a very active research concerned with computer vision-based analysis and interpretation of hand gestures. Important differences in the gesture interpretation approaches arise depending on whether 3D based model or appearance based model of the gesture is used [?].

In this thesis, we attempt to implement the hand gesture recognition for robots with modeling, training, analyzing and recognizing gestures based on computer vision and machine learning techniques. Additionally, 3D based gesture modeling with skeletal points tracking will be used. As a result, on the one side, gestures will be used command the robot to execute certain actions and on the other side, gestures will be translated and spoken out by the robot.

We further hope to provide a platform to integrate Sign Language Translation to assist people with hearing and speech disabilities. However, further implementations and training data are needed to use this platform as a full fledged Sign Language Translator.

Keywords

Human-Robot Interaction (HRI), NAO, Computer Vision, Depth Camera, Hand Gesture, 3D hand based model, Skeleton tracking, Gesture Recognition, Sign Language Translation, Naive Bayes Classifier, Gesture Recognition Toolkit (GRT)

Acknowledgements

Der Punkt Acknowledgements erlaubt es, persönliche Worte festzuhalten, wie etwa:

- Für die immer freundliche Unterstützung bei der Anfertigung dieser Arbeit danke ich insbesondere...
- Hiermit danke ich den Verfassern dieser Vorlage, für Ihre unendlichen Bemühungen, mich und meine Arbeit zu foerdern.
- Ich widme diese Arbeit

Die Acknowledgements sollte stets mit großer Sorgfalt formuliert werden. Sehr leicht kann hier viel Porzellan zerschlagen werden. Wichtige Punkte sind die vollständige Erwähnung aller wichtigen Helfer sowie das Einhalten der Reihenfolge Ihrer Wichtigkeit. Das Fehlen bzw. die Hintanstellung von Personen drückt einen scharfen Tadel aus (und sollte vermieden werden).

Contents

Chapter 1

Evaluation

We have used a machine learning toolkit named as GRT to recognize hand gestures using skeletal points tracking algorithm and Adaptive Naive Bayes classifier (ANBC) for classification and prediction.

The classifier is based on a statistical model of x,y,z coordinate positions of static hand gestures and provides a likelihood measure for recognized gesture. Furthermore, the gesture recognition pipeline uses two post processing modules such as Class Label Filter and Class Label Change Filter to exclude lower frequent spikes in the prediction results and trigger an output only when there is a change in prediction.

In this chapter, we present the experiments carried out to evaluate and validate our system to recognize hand gestures using skeletal points. The goal is to demonstrate the effectiveness of the classifier and to evaluate its potential for real time input at 30 fps. In the classification phase, input samples are normalized using Min-Max Scaling and Null Rejection is enabled to detect non-gestures. Therefore, the evaluation consists of computing the prediction accuracy for various null rejection coefficient and compare it with other supervised learning classifiers such as Support Vector Machine (SVM).

1.1 Mean and Standard Deviation

ANBC is a supervised learning algorithm that can be used to classify any type of N-dimensional signal. It fundamentally works by fitting an N-dimensional Gaussian distribution to each class when it is trained.

During the training phase, first all the input samples are normalized using Min-Max Scaling with the range from 0 to 1 and then GRT computes mean μ and standard deviation σ to create a model for each class. During the prediction phase, it basically computes the maximum a posterior probability of an input vector belonging to any of

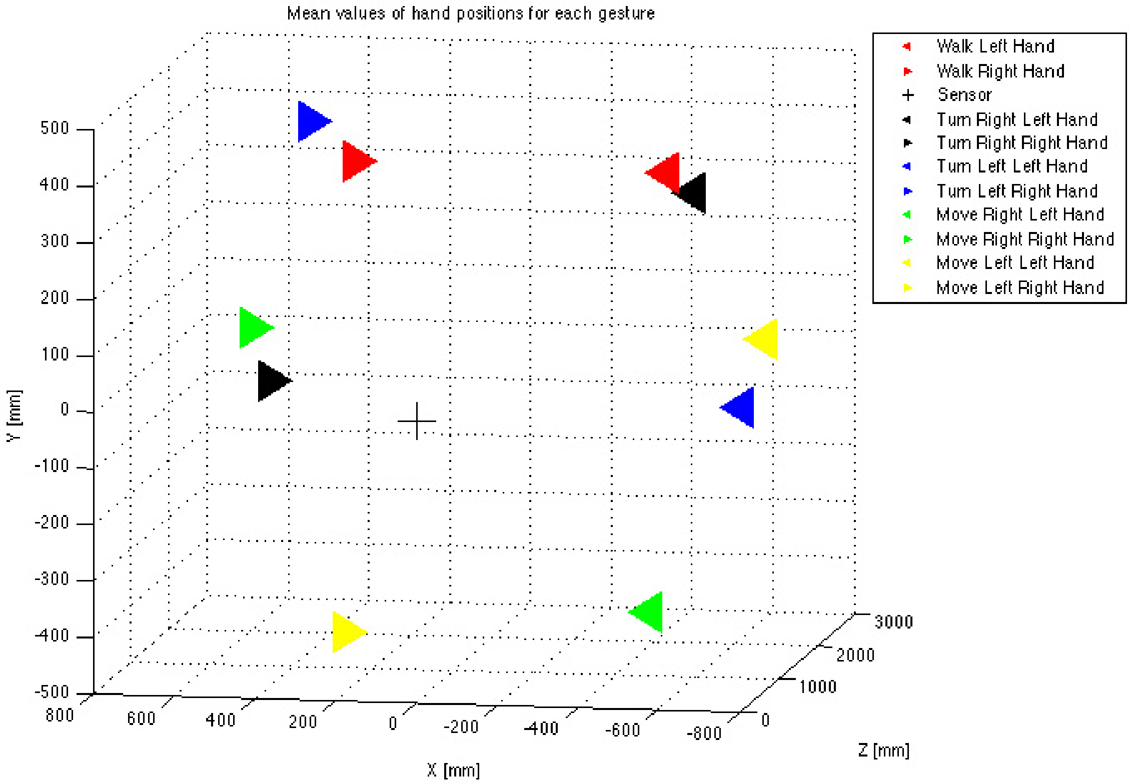


Figure 1.1: Mean values of hand positions for each gesture

the trained class. Figure 1.1 shows the mean positions of left and right hand for every gesture. Table 1.1 and 1.2 show mean and standard deviations of the labeled training data of all the five classes.

Class Label	Left X	Left Y	Left Z	Right X	Right Y	Right Z
1	0.55	0.76	0.76	0.57	0.76	0.78
2	0.48	0.73	0.78	0.75	0.51	0.79
3	0.36	0.42	0.78	0.67	0.8	0.8
4	0.58	0.13	0.73	0.79	0.57	0.79
5	0.29	0.52	0.79	0.58	0.24	0.72

Table 1.1: Normalized mean values of 3 dimensions of left and right hand

1.2 Classification and Prediction

Our gesture recognition pipeline is trained with 11918 input samples of 6 dimensional vector for 5 classes. Class 1,2,3,4,5 are mapped to Walk, Turn Right, Turn Left, Move

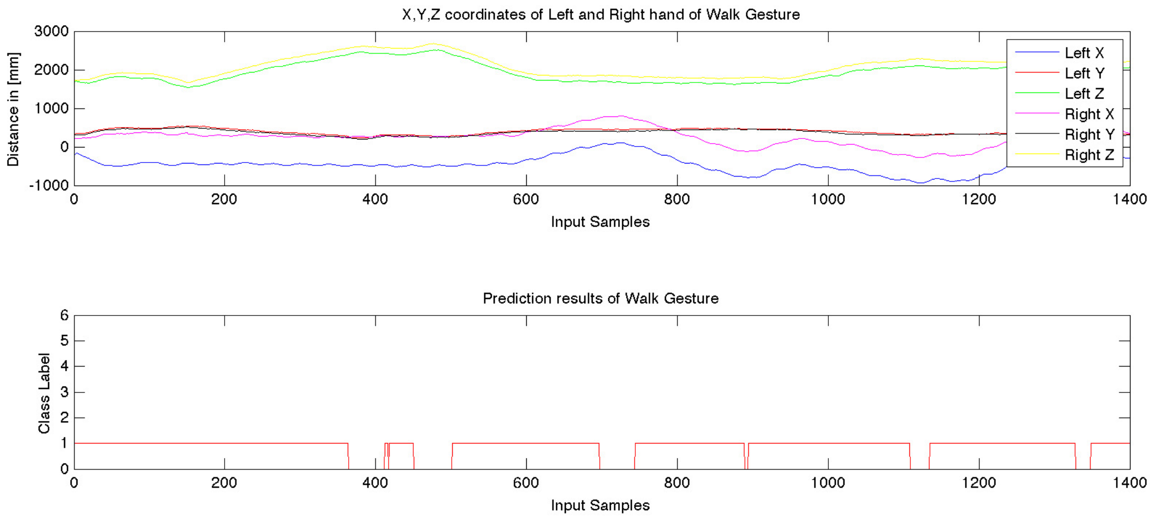
Class Label	Left X	Left Y	Left Z	Right X	Right Y	Right Z
1.000	0.261	0.116	0.079	0.225	0.092	0.083
2.000	0.189	0.086	0.075	0.149	0.053	0.080
3.000	0.178	0.072	0.088	0.141	0.079	0.093
4.000	0.182	0.060	0.076	0.159	0.070	0.089
5.000	0.128	0.102	0.088	0.114	0.061	0.083

Table 1.2: Standard deviations of 3 dimensions of left and right hand

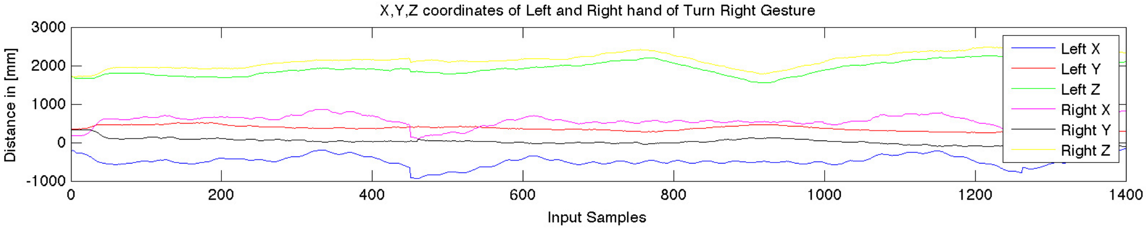
Right, Move Left gestures respectively. We have carried out experiments to evaluate the classification, prediction and post processing efficiency of our system. Graph 1.2 show change is positions of left and hand in Cartesian coordinates while test data was recorded and corresponding prediction for every input sample.

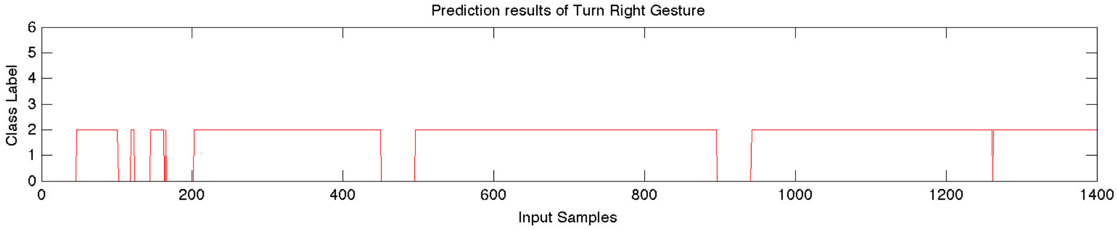
Test data consists of 1400 samples which are recorded under supervised arrangement. Input vectors that is not containing left and right hand are removed from the test data. Furthermore, input vectors which were recorded when the hand is at the field of view of the camera are also excluded. A program was implemented with GRT to read all the test data and execute prediction on every input sample and then results are stored to CSV file. Finally results are plotted using MATLAB.

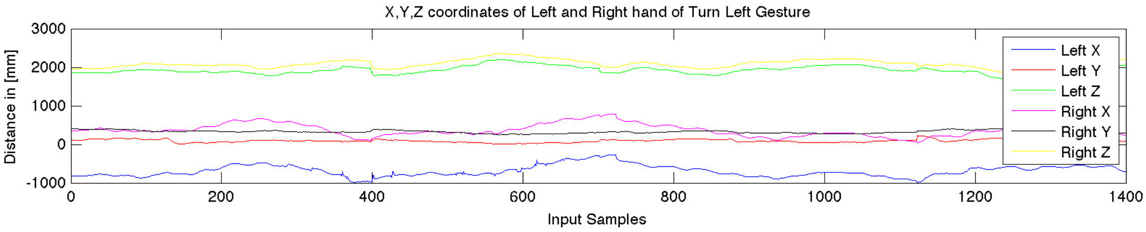
Prediction results shown in the graph 1.2 frequently falls down to Class Label 0 that is reserved for non-gestures. Non-gestures are detected with the help of Null Rejection thresholds. Therefore, this prediction is based on normalized classification data for Adaptive Naive Bayes classifier with Null rejection coefficient of 1.0.

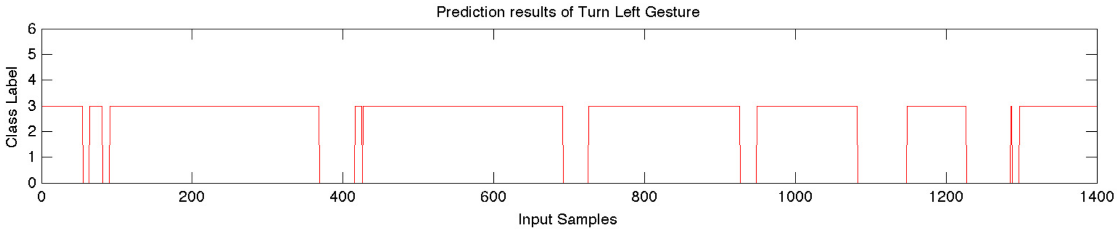


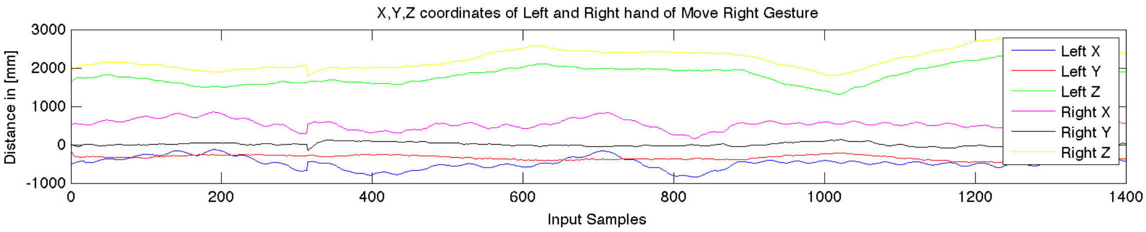
1.3 Prediction Accuracy Vs Null Rejection Accuracy

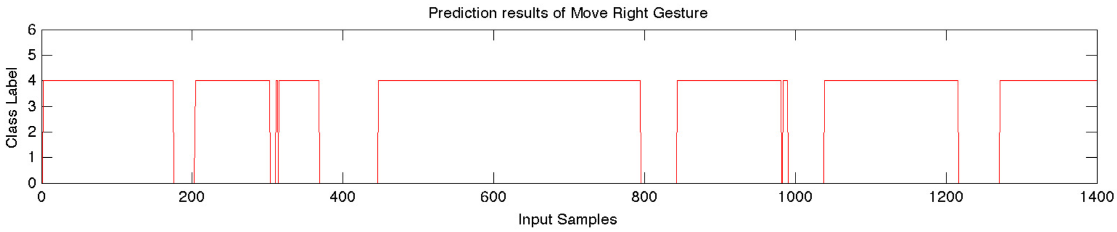

X,Y,Z coordinates of Left and Right hand of Turn Right Gesture
Distance in [mm]
Input Samples
Left X
Left Y
Left Z
Right X
Right Y
Right Z

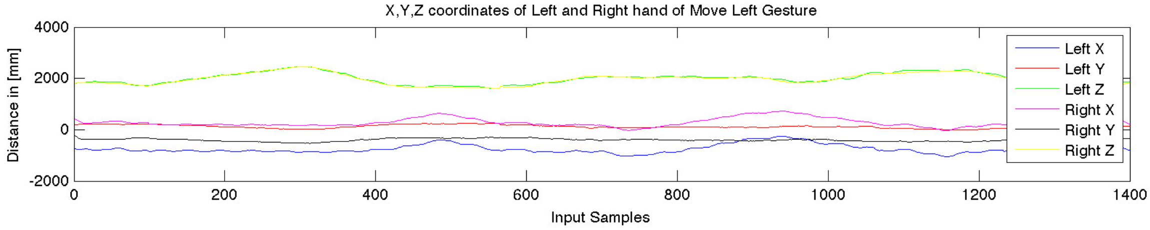

Prediction results of Turn Right Gesture
Class Label
Input Samples

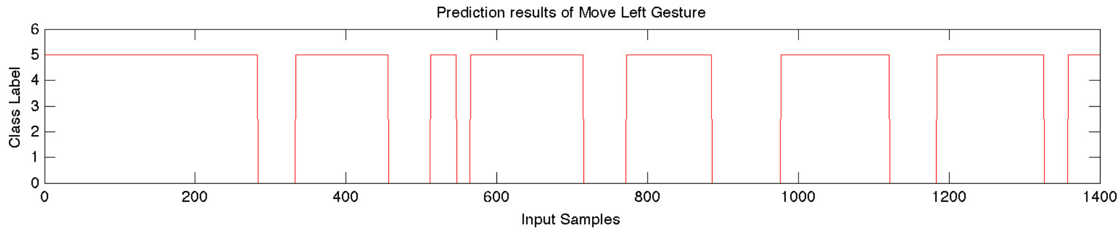

X,Y,Z coordinates of Left and Right hand of Turn Left Gesture
Distance in [mm]
Input Samples
Left X
Left Y
Left Z
Right X
Right Y
Right Z

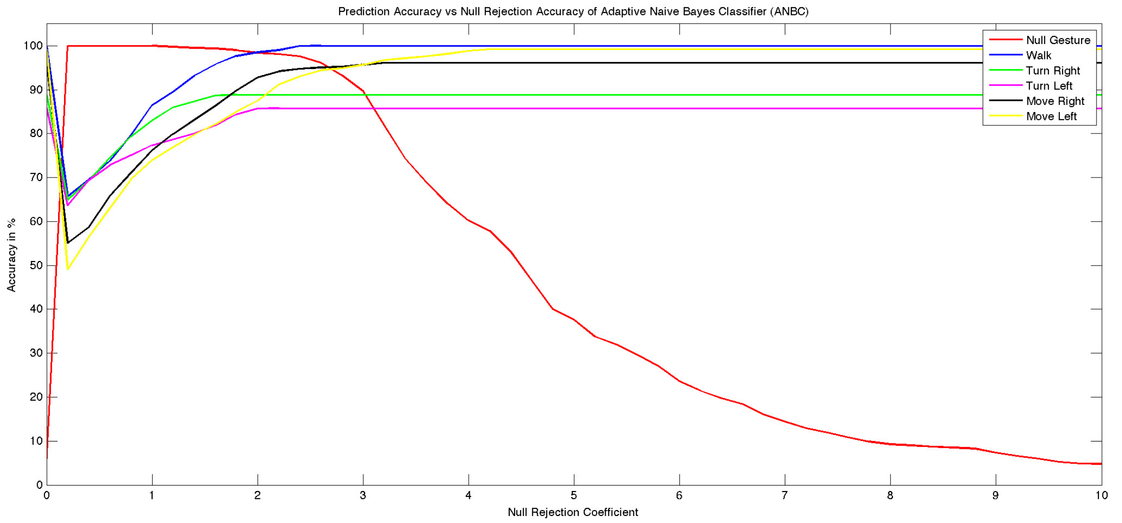

Prediction results of Turn Left Gesture
Class Label
Input Samples

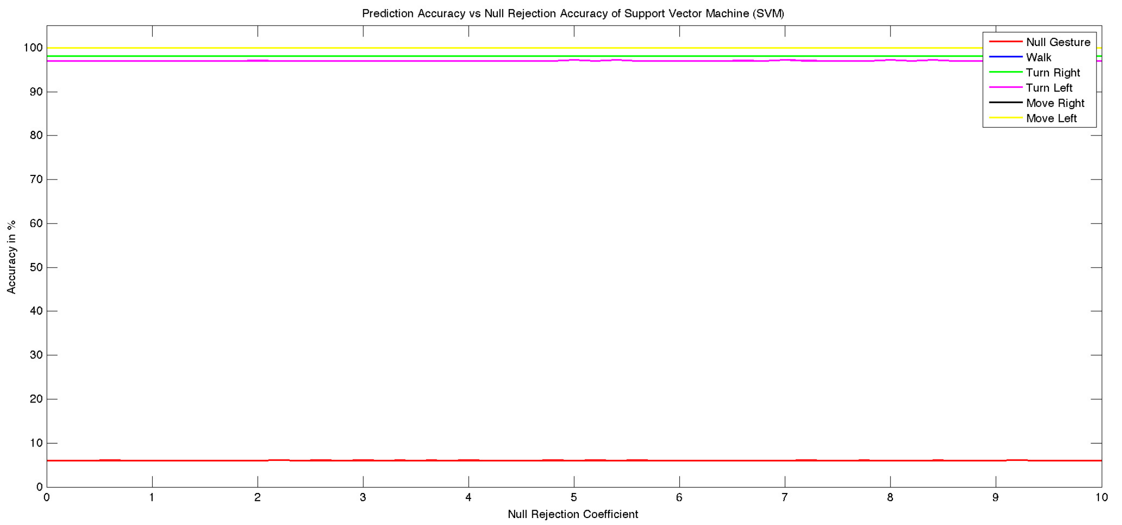

X,Y,Z coordinates of Left and Right hand of Move Right Gesture
Distance in [mm]
Input Samples
Left X
Left Y
Left Z
Right X
Right Y
Right Z

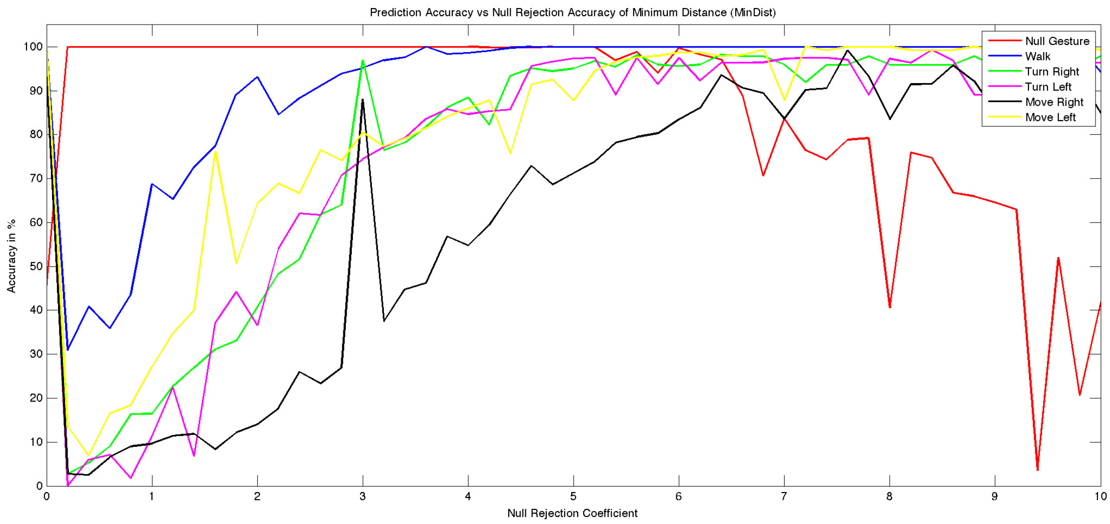

Prediction results of Move Right Gesture
Class Label
Input Samples


X,Y,Z coordinates of Left and Right hand of Move Left Gesture
Distance in [mm]
Input Samples
Left X
Left Y
Left Z
Right X
Right Y
Right Z


Prediction results of Move Left Gesture
Class Label
Input Samples


Prediction Accuracy vs Null Rejection Accuracy of Adaptive Naive Bayes Classifier (ANBC)
Accuracy in %
Null Rejection Coefficient
Null Gesture
Walk
Turn Right
Turn Left
Move Right
Move Left


Prediction Accuracy vs Null Rejection Accuracy of Support Vector Machine (SVM)
Accuracy in %
Null Rejection Coefficient
Null Gesture
Walk
Turn Right
Turn Left
Move Right
Move Left


Prediction Accuracy vs Null Rejection Accuracy of Minimum Distance (MinDist)
Accuracy in %
Null Rejection Coefficient
Null Gesture
Walk
Turn Right
Turn Left
Move Right
Move Left

Bibliography

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Abbreviations

HRI	Human-Robot Interaction
OpenNI	Open Natural Interaction
NiTE	Natural Interaction Technology for End-user
GRT	Gesture Recognition Toolkit
CC	Control Center
UDP	User Datagram Protocol
WLAN	Wireless Local Area Network
FOV	Field Of View
JSON	JavaScript Object Notation
DOF	Degrees Of Freedom
TTS	Text-To-Speech
API	Application Program Interface
DP	Dynamic Programming
MAP	Maximum A Posterior Probability
CSV	Comma Separated Values
DTW	Dynamic Time Warping
HMM	Hidden Markov Models
KNN	K-Nearest Neighbor
SVM	Support Vector Machines
PCA	Principal Component Analysis
GUI	Graphical User Interface
IDE	Integrated Development Environment