Smart Wearable Controlling System by Hand and Finger Gestures

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- Method
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- Conclusion & Future Work

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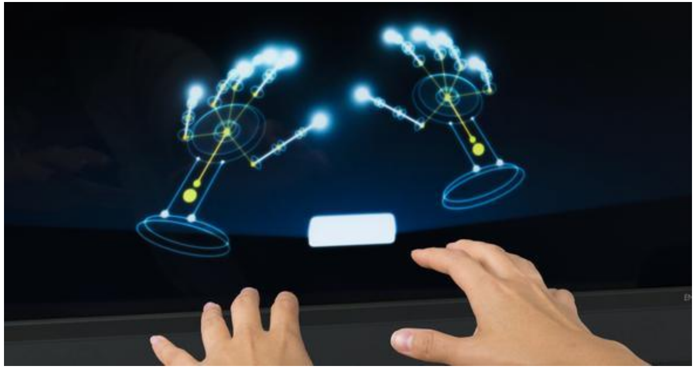
Gesture Recognition

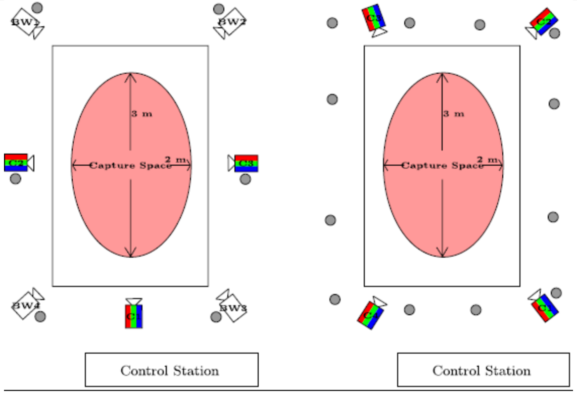
- Gesture recognition has become on of the popular research fields that served as an intelligent and a natural interface.

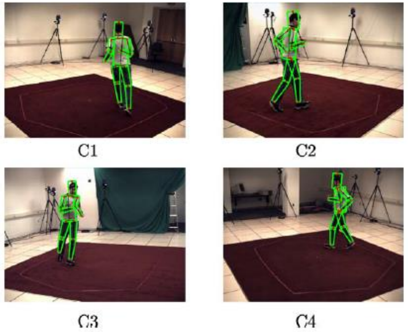
- Exploring alternative ways to recognize the imitate human gestures to perform complex and difficult tasks in various areas.

- Wearable computing trends allowed devices to be portable and smaller in size.

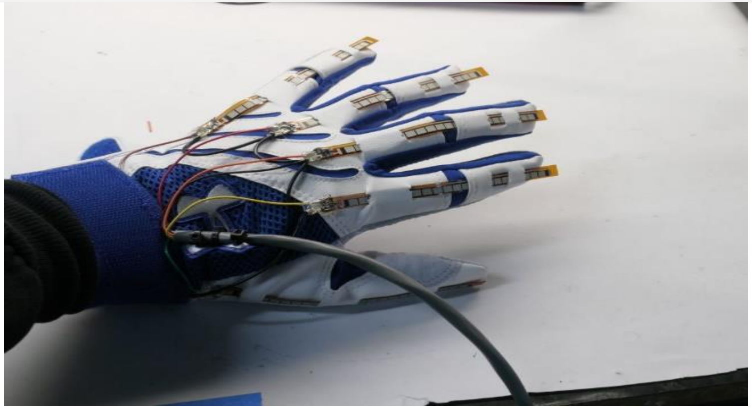


Literature Review

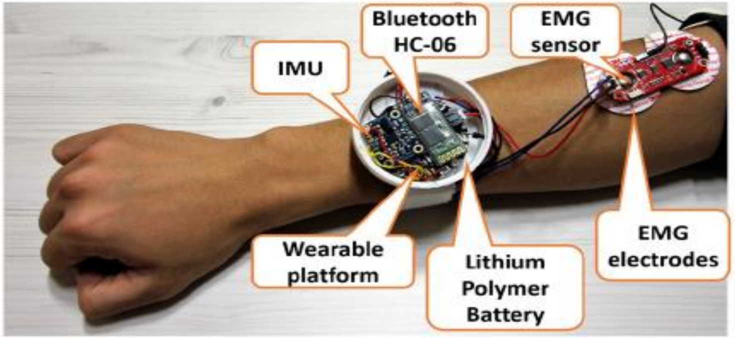




Vison system [1] captures the motions by using multiple high-speed infrared cameras



Pathk [2] presented a framework for hand gesture recognition



Gesture control armband using single EMG and IMU

Smart Wearable Controlling System

Tend to wearable computing trend and high accuracy rate:

- Utilizing only three IMUs
- Recognizing 22 gestures

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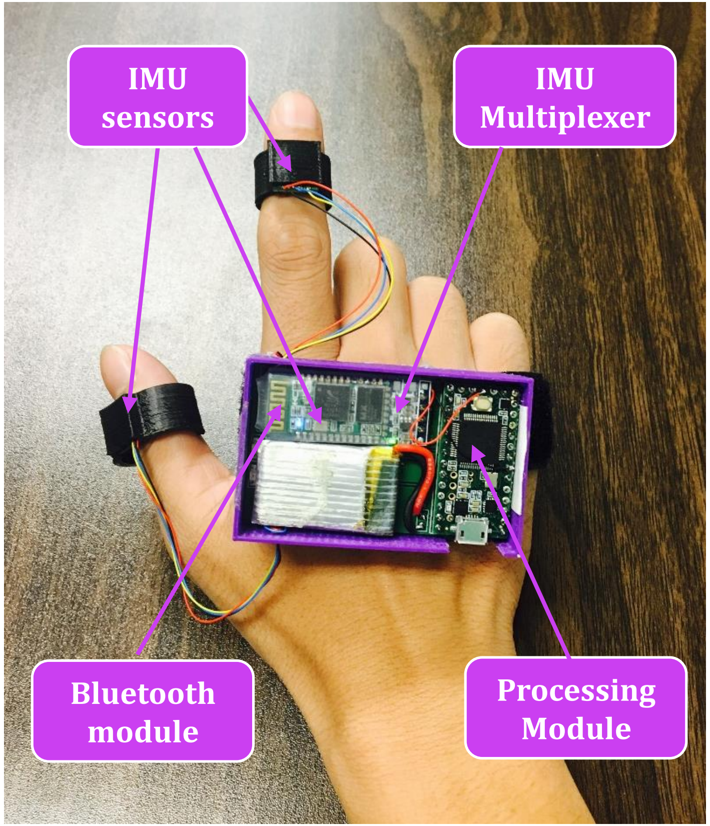
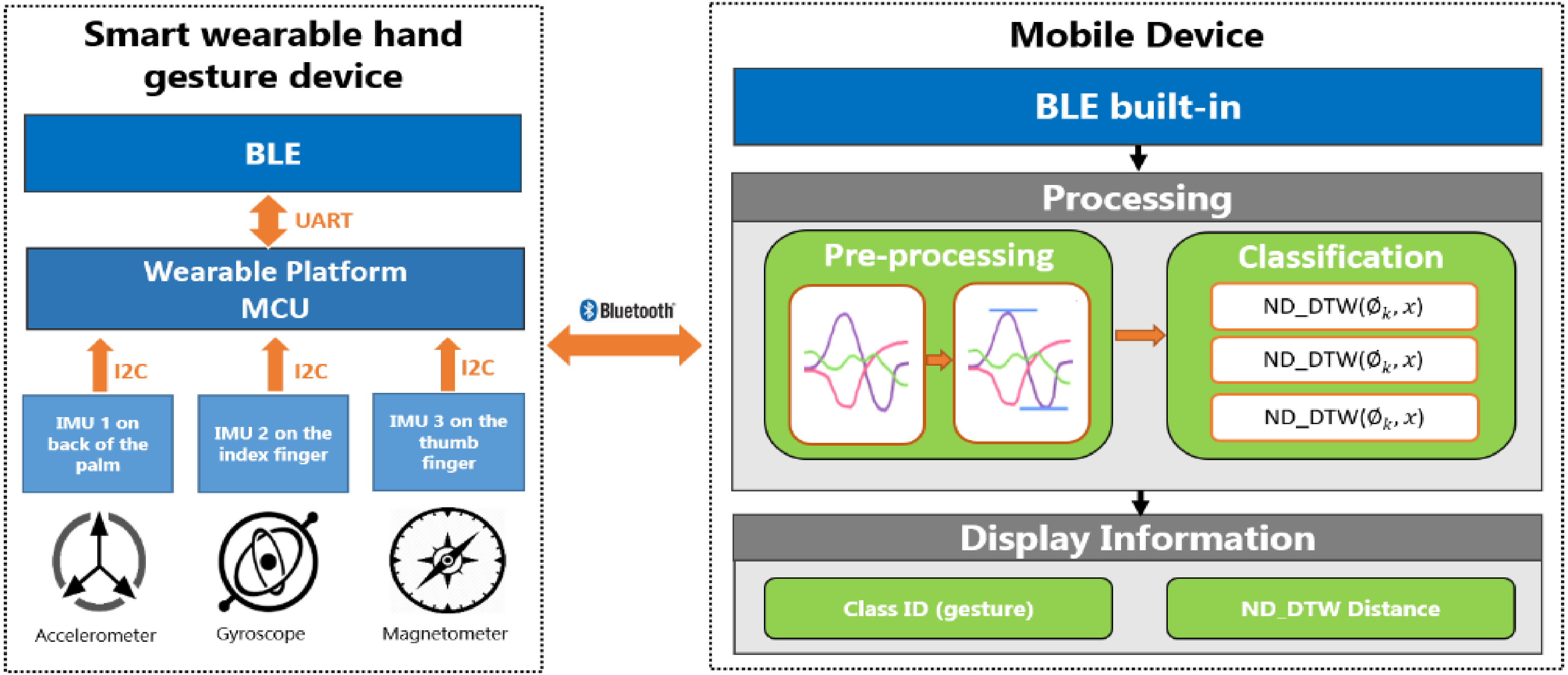
System Overview

The system includes:

- Sensor module
- Processing module
- Mobile device



System Overview

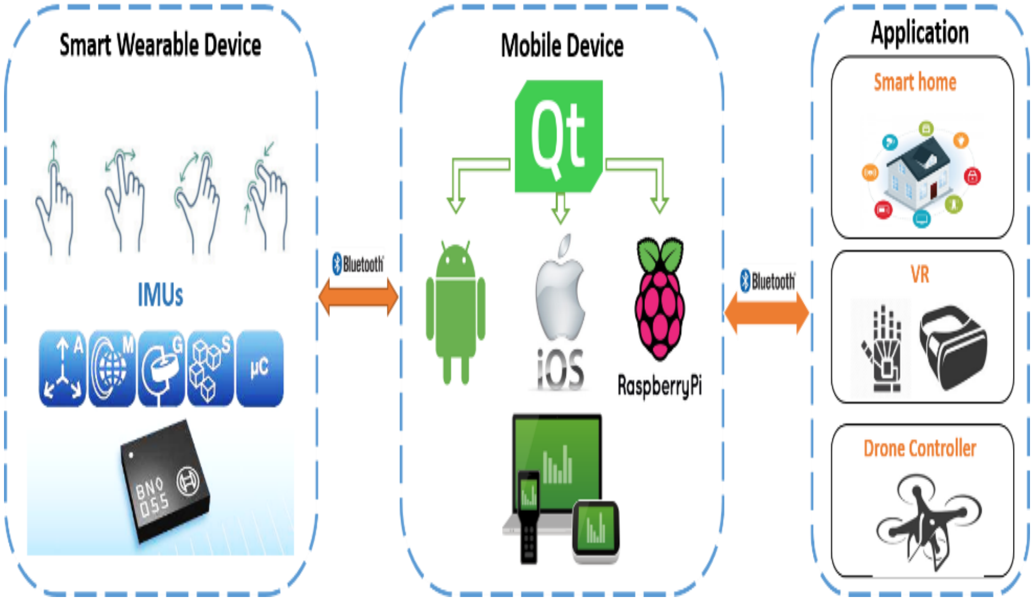


System design overview.

System Overview

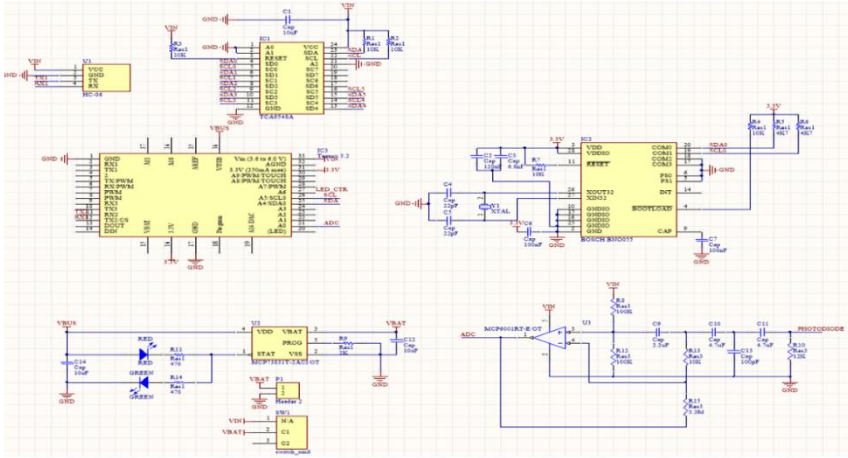
- Qt cross platform software

- Applying to various applications as home automation, games controller ...

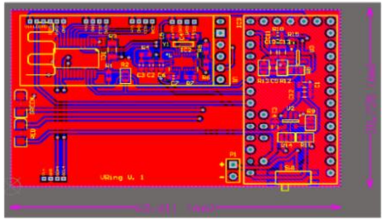


Proposed smart wearable controller system can be applied to various applications.

Hardware

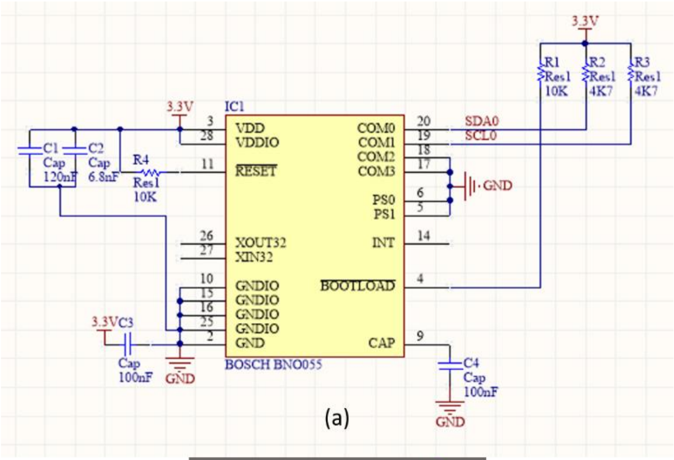


(a)

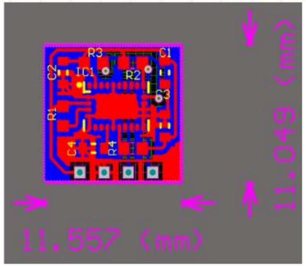


(b)

(a) Schematic and (b) PCB layer design of processing module.



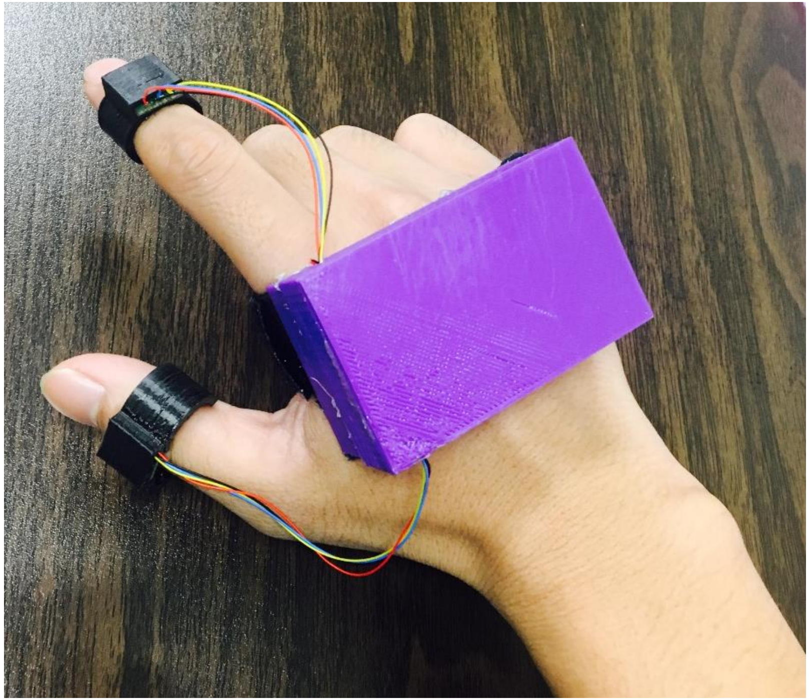
(a)

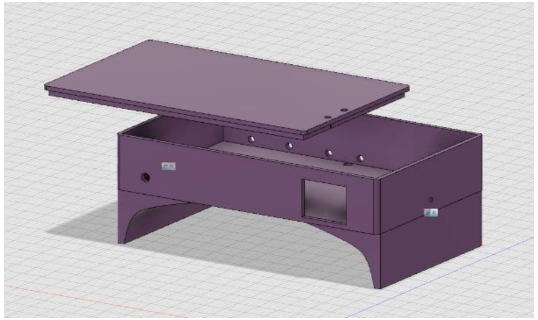


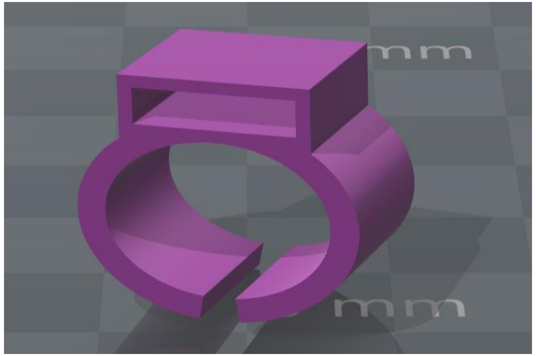
(b)

(a) Schematic and (b) PCB layer design of sensor module.

Hardware







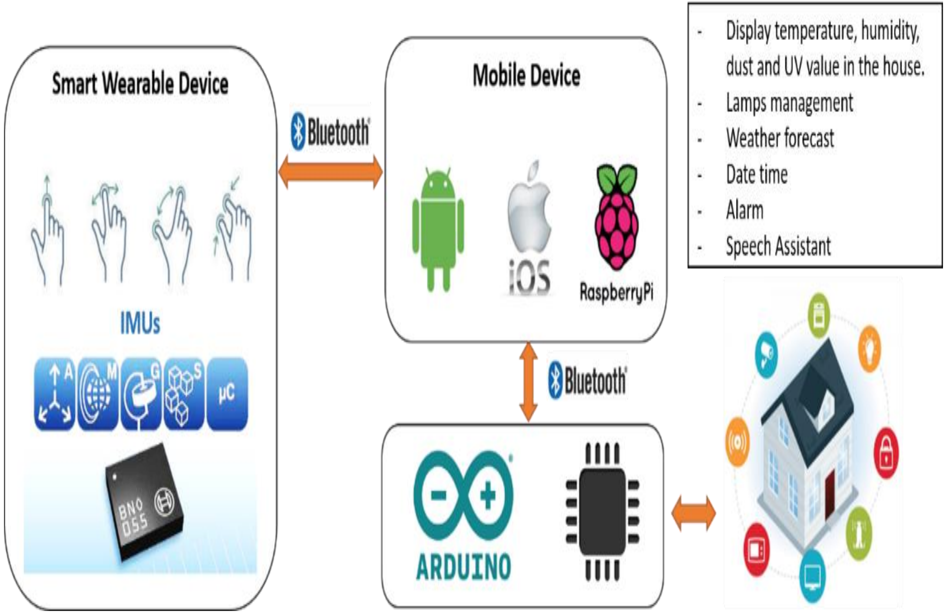
Appearance design using 3D Printer

Design of Software

- Cross-platform application framework (Linux, OS X, Windows, Android, iOS).
- Framework written in C++.
- GUI is written in QML instead of the whole application whereas the application's backend is written in C++.

Qt cross-platform application development framework.

Design of Software



System overview of smart home application.

Screenshot of the smart home application

Design of Software

Video Demo

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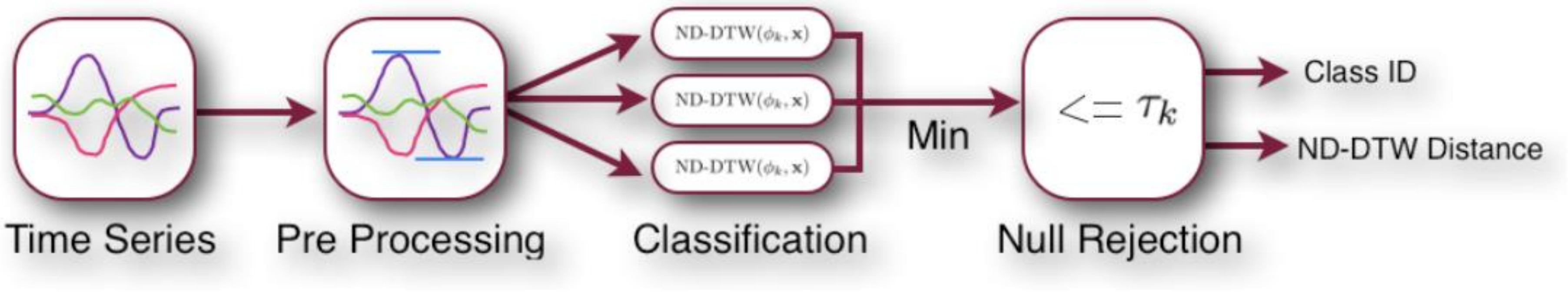
Method

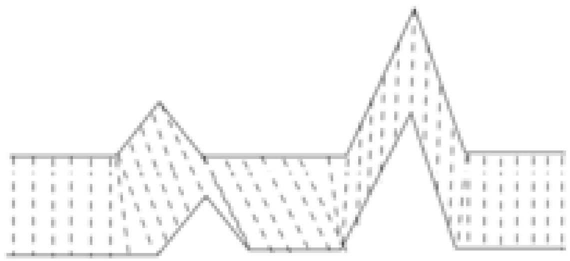


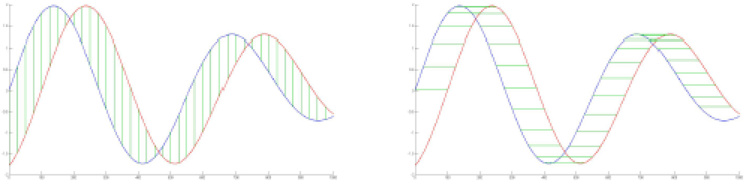
Flowchart of method

Dynamic Time Warping (DTW)

DTW is an algorithm that can compute the similarity between two time-series, even if the lengths of the time-series do not match.

DTW has been applied to temporal sequences of video, audio, graphics data and gesture recognition.





(a) Euclidean Distance (b) Dynamic Time Warping

Two identical time-series signals, with phase differences measured with (a) Euclidean distance and (b) Dynamic Time Warping.

Dynamic Time Warping (DTW)

- Given two, one-dimensional, time-series:

$$x = \{x_1, x_2, \dots, x_{|x|}\}^T$$
$$y = \{y_1, y_2, \dots, y_{|y|}\}^T$$

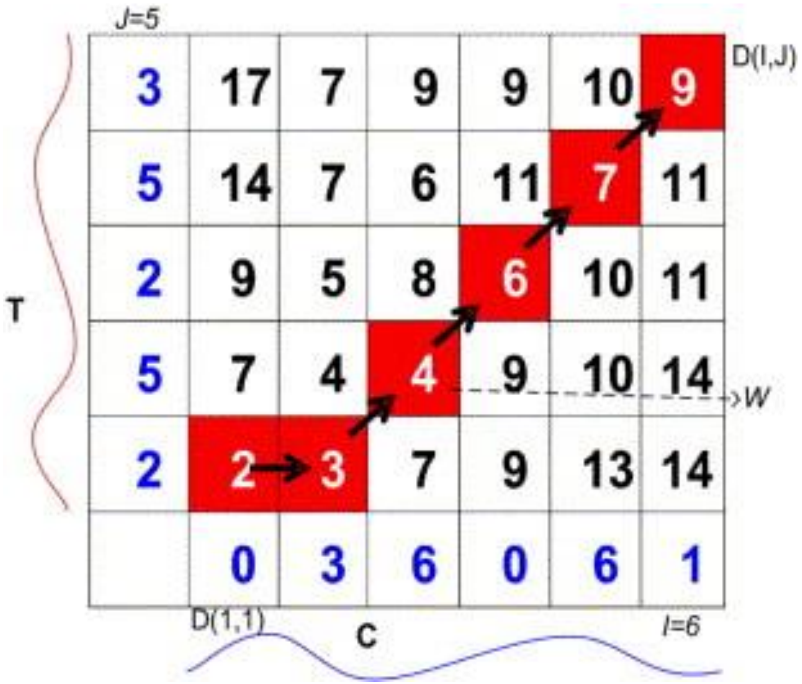
- Construct a warping path $w = \{w_1, w_2, \dots, w_{|w|}\}^T$
- A number of constraints are placed on the warping path which are as follows:

- start at: $w_1 = (1, 1)$
- end at: $w_{|w|} = (|x|, |y|)$
- Continuous
- cannot move backwards.

- The warping cost given by:

$$\min \frac{1}{|w|} \sum_{k=1}^{|w|} DIST(w_{k_i}, w_{k_j})$$

where $DIST(w_{k_i}, w_{k_j})$ is the distance function (Euclidean)

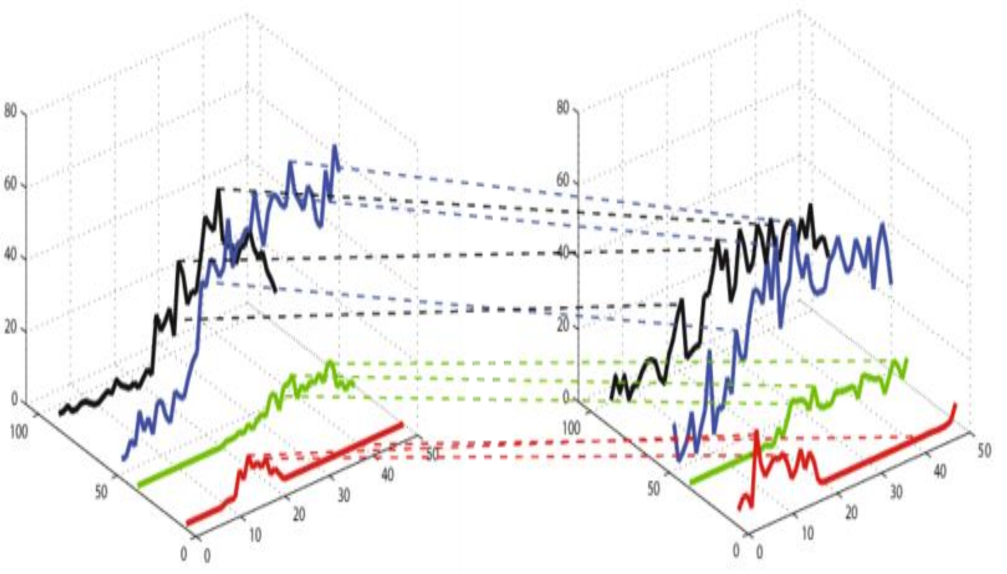


Example of warping path in a distance table. Length of class sequence, x = 6 and length of test sequence, y = 5.

N Dimension DTW

- Computing the distance between 2 given time-series.
- The total distance across all N dimensions is used to construct the warping matrix with the Euclidean distance:

$$DIST(i,j) = \sqrt{\sum_{n=1}^{N} (i_n - j_n)^2}$$

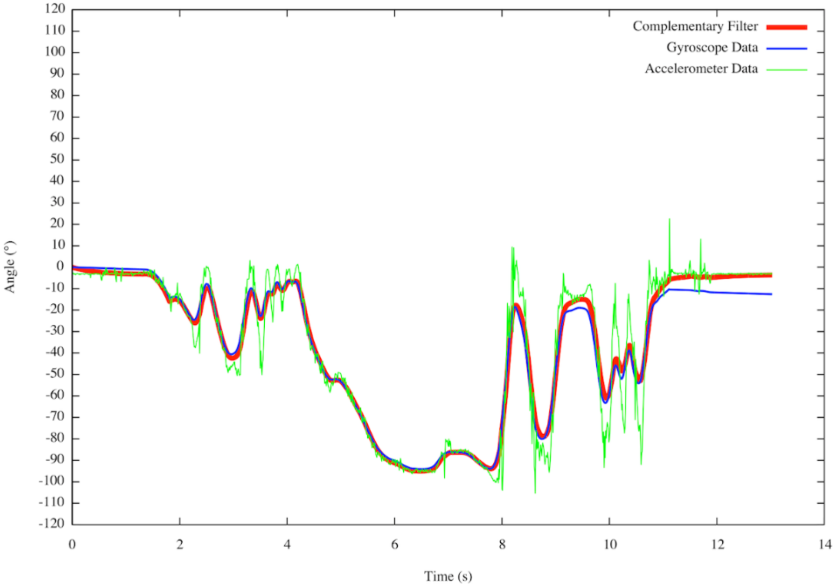


Multiple dimension DTW

Pre-processing

- Accelerometer is reliable only in the long run, but so noise in the short run.
- Gyroscope is reliable only in the short run, but is drifted in the long run
- Using measurement by the fusion of accelerometer and gyroscope data with Complementary filter:

$$\text{angle} = \underbrace{(0.98)*\underbrace{(\text{angle} + \text{gyro}*\text{dt})}_{\text{Integration.}}}_{\substack{\text{Something resembling a high-pass filter}\\ \text{on the integrated gyro angle estimate. It}\\ \text{will have approximately the same time}\\ \text{constant as the low-pass filter.}}} + \underbrace{(0.02)*(\text{x\_acc})}_{\substack{\text{Low-pass portion acting on the}\\ \text{accelerometer.}}};$$



Training

- Template is required to store all the intended gestures in database by recording M_g training samples for each of the G gestures
- Each of G template can be found by computing distance each of M_g training samples
- Searching for the training samples that provide the minimum warping distances when compare the other training samples in that class

Classification Threshold

- The N-dimensional input time-series X is not matched with any of the gestures in the template
- Thus this false classification issue can be resolved by defining a classification threshold for each gesture in the template during the training phase.
- The algorithm will indicate the particular gesture as no match:

$$c = \begin{cases} c \; if \; (d \leq \tau_g) \\ 0 \quad otherwise \end{cases}$$

where d is the total normalized warping distance

$$\tau_g = \mu_g + (\sigma_g \gamma)$$

$$\mu_g = \frac{1}{M_g - 1} \sum_{i=1}^{M_g} 1\{ND - DWT(\emptyset_g, X_i)\} \qquad \sigma_g = \sqrt{\frac{1}{M_g - 1} \sum_{i=1}^{M_g} 1\left\{\left(ND - DWT(\emptyset_g, X_i) - \mu_g\right)^2\right\}}$$

γ could be initially set to any number during the training phase and later be adjusted by the user

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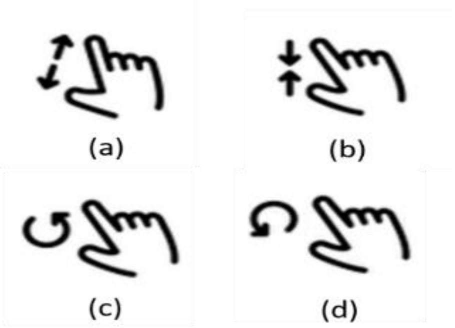
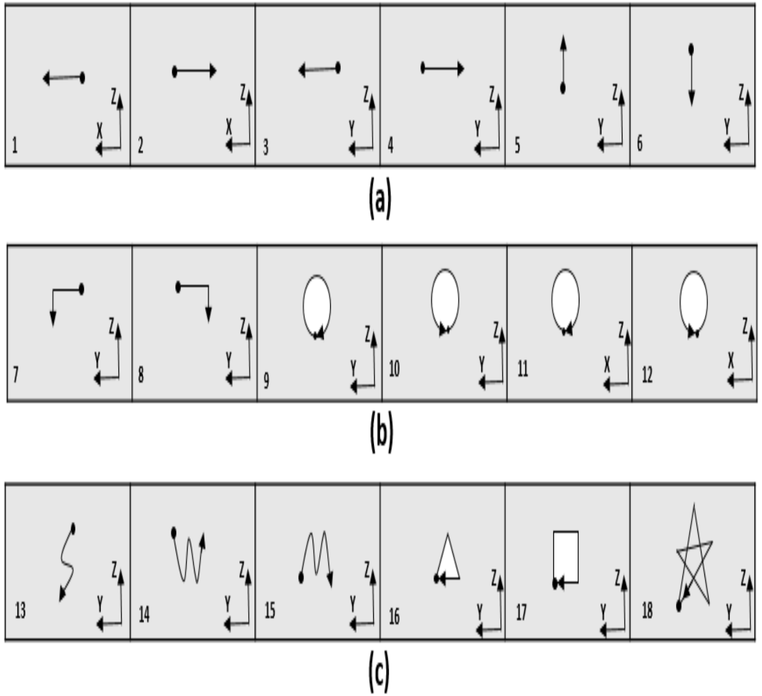
Experiment Setup

- Six right handed subjects are voluntarily participated in the experiments.
- Subjects are requested to perform 25 repetitions of 22 gestures.
- The gestures consisted of 18 hand gesture and 4 fingers gestures.

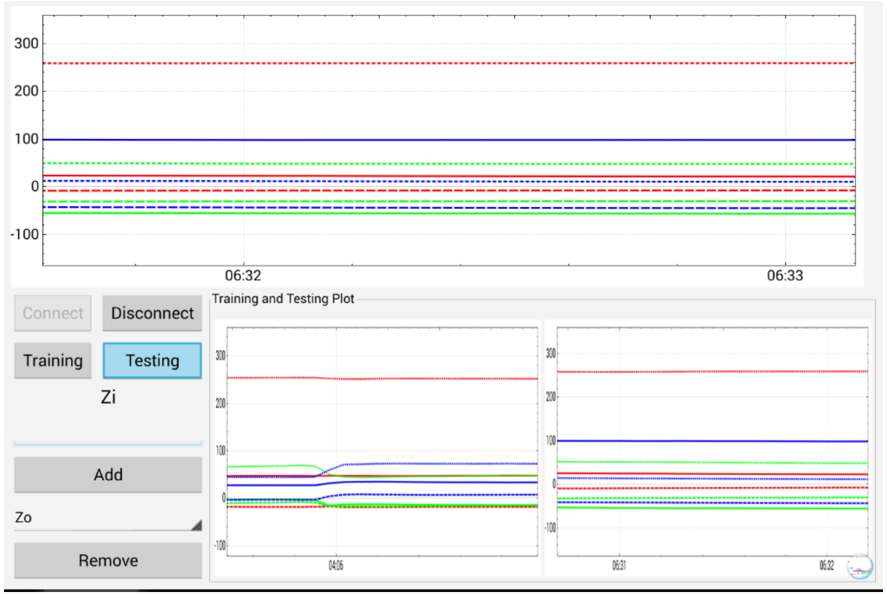


Four finger gestures

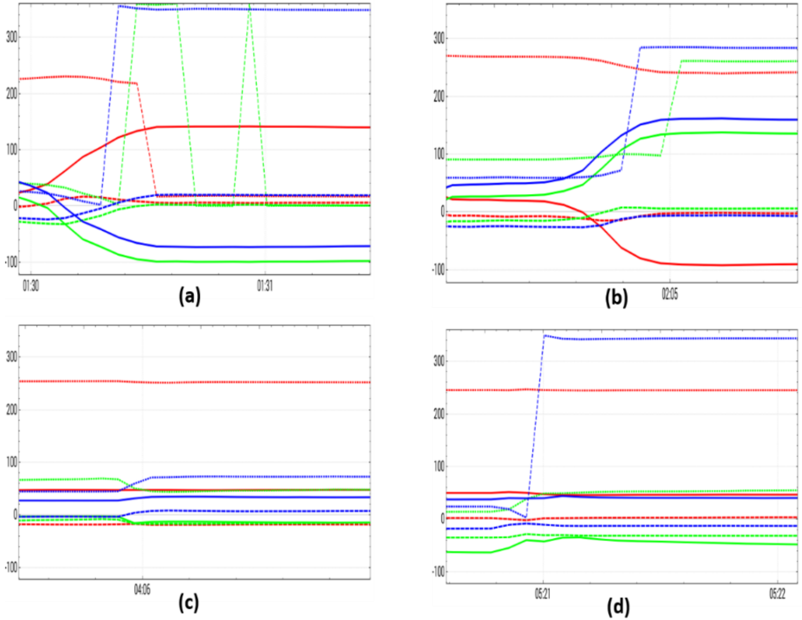


The predefined 18 gestures

Experiment Setup



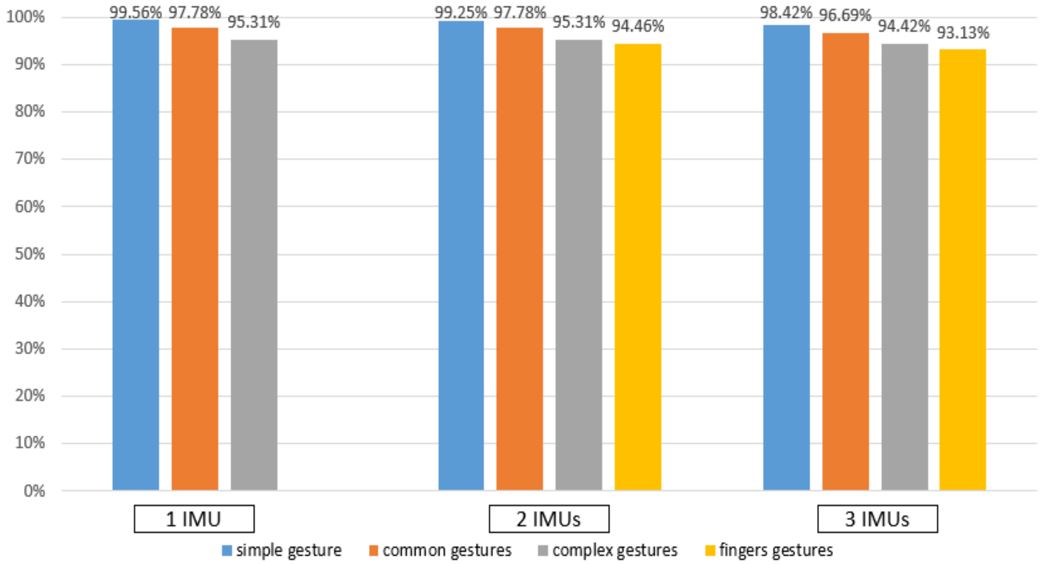
Self-development application for the purposes of training phase and testing phase.



Orientation samples obtained from 3 IMUs to the gestures including (a) rotate right, (b) rotate left, (c) zoom in and (d) zoom out.

Result and Discussion

- Experiments are conducted to validate the gesture recognition accuracy rate utilizing the ND-DTW algorithm.
- The impact to accuracy rate based on the quantity of IMUs used are also taken into consideration.
- The ND-DTW model was trained using 6-fold cross validation method



Result and Discussion

Table 4-4 Comparison of related systems.

Author	Type of sensors	Quantity of sensors	Number of gesture	Accuracy rate	Paper
Chang	IMU EMG	3	6	95.6%	[39]
Georgi	IMU EMG	17	12	97.8%	[40]
Khezri	EMG	4	6	92%	[41]
Englehart	EMG	4	6	98%	[42]
Liu	IMU	1	8	98.6%	[13]
Proposed study	IMU	1	18	97.55%	
Proposed study	IMU	2	22	96.90%	
Proposed study	IMU	3	22	95.89%	

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Conclusion

- Focused on the design and implementation of smart wearable controller system using hand and fingers for gesture recognition.
- The system utilized 3 IMUs sensors, to recognize total of 22 pre-defined gestures with DTW algorithm with low cost implementation and high accuracy rate.
- The study evaluated the IMUs quality impacted to the accuracy rate of system.
- System performed well with low energy consumption of 10 hours with 3.7V 240mA battery

Future Work

- Optimization of PCB design in term of size and dimensionality to reduce power consumption and its wearable comfortability.
- Implementation of recognition algorithm in embedded hardware as standalone system which is compatible to different software platforms.
- Recognition of more complex gestures that involved three dimensional gestures by utilizing hand and fingers motion.
- Inclusion of more functionalities for various applications and allow gestures self-customization by users.

THANK YOU!

Q&A

Reference