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Physical Activity Recognition based on Rotated Acceleration Data using Orientation Filter

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Introduction

The purpose of the study was to examine the accuracy of physical activity (PA) classification algorithms using a rotational analysis.

Method

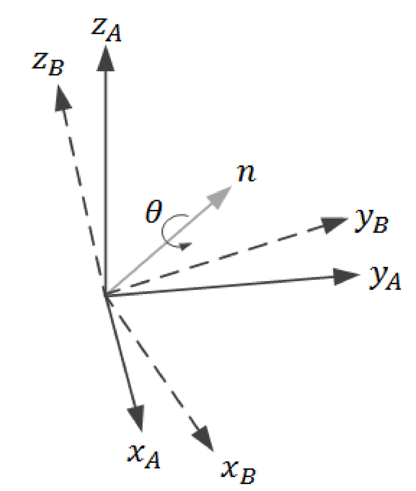
➤ Quaternion & Orientation filter

- A four-dimensional complex number that can be used to represent the orientation of coordinate frame in three-dimensional space as in equation **(1)**.
- An arbitrary orientation of frame B can be achieved through a rotation around an axis n with angle θ defined in frame A as represented in **Figure 1**.

$$q = [q_1\ q_2\ q_3\ q_4] = [s, \vec{v}] = \left[\cos\frac{\theta}{2}, \sin\frac{\theta}{2}\vec{n}\right] = \left[\cos\frac{\theta}{2}\ \ \sin\frac{\theta}{2}\vec{n}_x\ \ \sin\frac{\theta}{2}\vec{n}_y\ \ \sin\frac{\theta}{2}\vec{n}_z\right] \quad (1)$$

q_1 : scalar part of quaternion

q_2, q_3, q_4 : vector part of quaternion



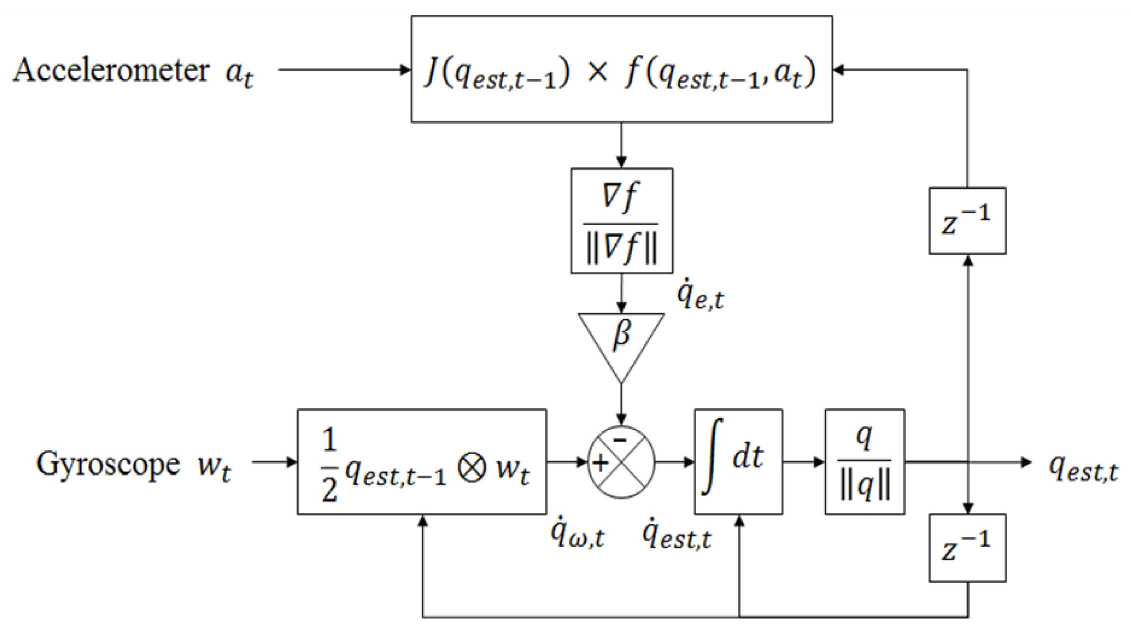
< **Figure 1**. Graphical representation of quaternion >

- A three dimensional vector $\boldsymbol{v_A}$ in frame A can be rotated by a quaternion to vector $\boldsymbol{v_B}$ in frame B using the relationship described in equation **(2)**.

$$v_B = q \otimes v_A \otimes q^* \quad (2)$$

q^*: conjugate of quaternion

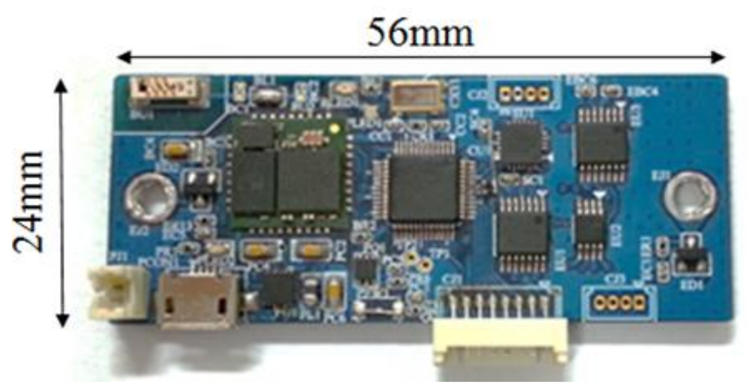
- The quaternion is calculated and calibrated by accelerometer and gyroscope data as represented in **Figure 2**.(Madgwick's orientation filter)



< **Figure 2**. Madgwick's orientation filter block diagram >

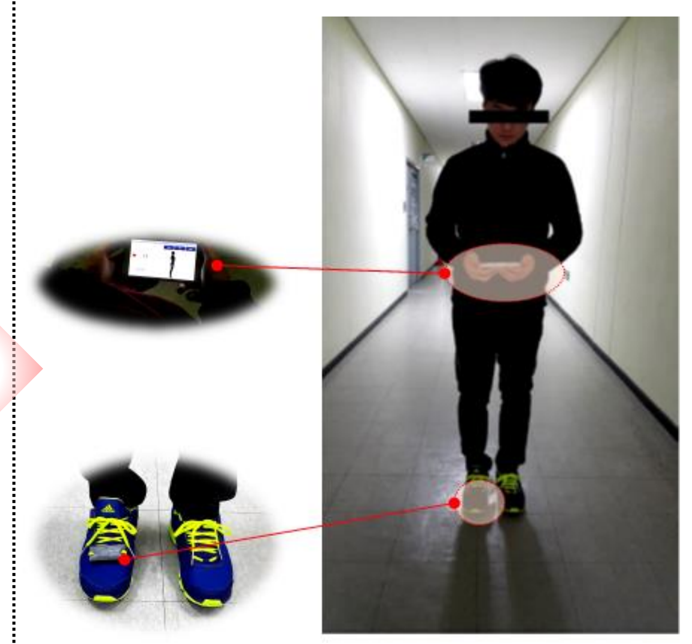
➤ Experimental process

- 17 healthy, untrained subjects (age: 25.8±2.4, range 21-33yrs) participated.
- Experimental protocol consisted of four stages: walking, running (horizontal movement: 75 meters), going up and down stairs (horizontal movement: 12 meters and vertical movement: 10 meters).
- A customized accelerometer and a gyroscope module were utilized to assess gait behaviors of participants.
- Acceleration (i.e., x, y, and z) and gyroscope (i.e., yaw, pitch, and roll) data were recorded at 100Hz and transmitted to the customized android smartphone application (Galaxy Note II, Samsung).

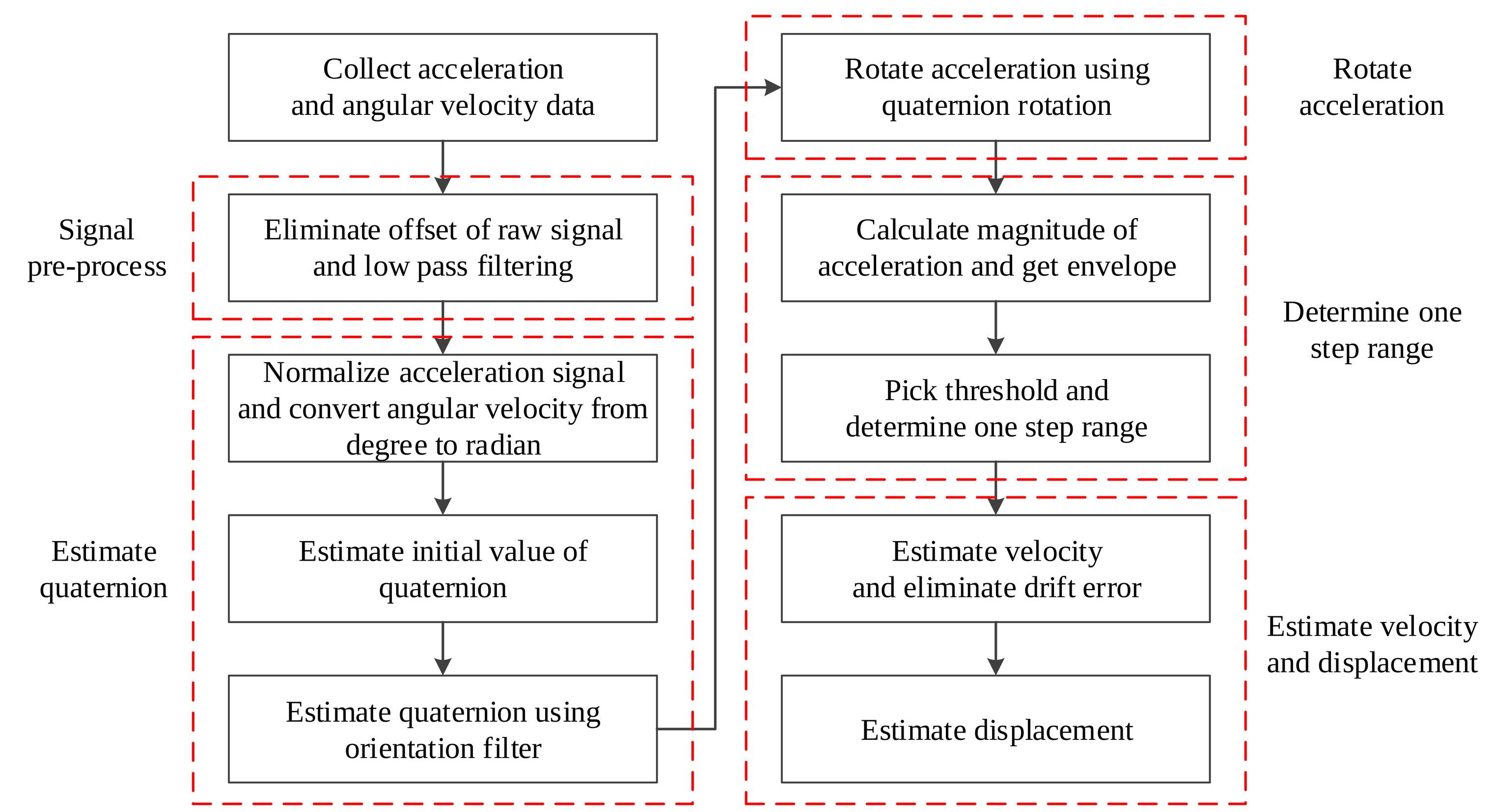


< **Figure 3**. Fabricated collector of tri-axial Acceleration and Angular

< **Figure 4**. Data acquisition device : Smartphone application >



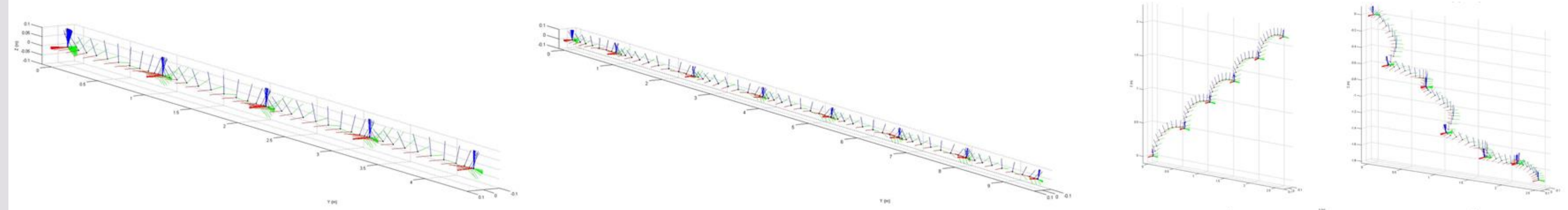
< **Figure 5**. Experimentation environment >



< **Figure 6**. Signal processing and data analysis sequence >

Results

➤ Signal processing results of each activity



< **Figure 7**. Signal processing results >

➤ PA classification

- 70% (5,686 steps) of the total data (8,099 steps) was applied to the machine-learning algorithm for training and 30% (2,413 steps) was applied to the test.
- The highest average accuracy of PA classification (100%) was observed using the Support Vector Machine (SVM) algorithm (Naïve Bayes: 95.4%, J48: 99.8%, and RBF Network: 98.8%).
- The confusion matrix showed over 97% accuracy about test data as represented in Table 1.

< **Table 1**. Confusion matrix >

Activity (state)	Classified as				Accuracy (%)
	Walk	Run	Going up stairs	Going down stairs	
Walking	1,099	0	12	0	98.9
Running	6	816	1	0	99.2
Going up stairs	0	0	236	2	99.2
Going down stairs	2	0	3	236	97.9

< **Table 2**. Movement distance >

Activity (state)		Actual movement distance(m)	Data set (subjects ×trials)	Estimation distance(m)		Accuracy(%)
				Mean	SD	
Walking		75	68	71.36	±2.02	95.15
Running		75	68	70.69	±3.11	94.25
Going up stairs	Horizontal	12	34	11.18	±1.30	93.21
	Vertical	10	34	9.86	±0.75	98.64
Going down stairs	Horizontal	12	34	12.57	±0.99	104.71
	Vertical	10	34	4.61	±1.04	46.10

Conclusion

➤ PA classification utilizing a rotational analysis provides an accurate prediction of PA patterns, including the average distance, speed, and direction of activities