BoxerSense: Punch Detection and Classification Using an IMU

Yoshinori Hanada (15817073)
Lopez Laboratory

1. Introduction

Encouraging people to perform physical exercise regularly plays a key role in maintaining our health and quality of life. In fact, Hammer et al. found out that frequent physical exercise in a week reduce the risk of psychological distress [1] However, in practice, maintaining a regular physical exercise a lifelong habit is challenging. As a result, many people failed to maintain the recommended levels of exercise [2]. To solve these issues, many exercise tracking applications on wearable device such as smartwatches and smartphones are now being developed. In this paper, we specifically focus on an exercise called boxercise which is a training concepts aimed at all ages, fitness standards, all classes of shadow-boxing. We proposed machine learning and correlation-based methods for detecting and classifying shadow-boxing punches using an IMU sensor embedded in a smartwatch. In addition, to develop our research into a boxercise personal training system in the future work, we estimated the real-time performance of classification methods.

2. Related Work

Ovalle et al. classified 4 different taekwondo punches performed by 3 participants from IMU sensors attached to a right-hand wrist and a microphone using machine learning approach [3]. They investigated if it is possible to classify punches with bare hands and increase the classification accuracy by adding audio input that is produced by hitting mitt. As a result, they achieved 94.4% accuracy, but the audio input did not improve its accuracy. Their research lacks credibility of punch classification accuracy because they only used 3 participants and did not evaluate in person independent case.

Tobias et al. classified 4 different boxing punches by using machine learning approach [4]. They conducted experiment with 8 participant and gather 7600 punches. As a result, they achieved accuracy of 98.68% for the punch type classification. Their research also lacks credibility of punch classification accuracy because they did not evaluate in person independent case. Also, they did not propose any methods to automatically detect a punch.

3. Proposed Methods to Detect and Classify Punches

First, we used a single IMU sensor embedded in smartwatch worn on right hand wrist and targeted 3 types of shadow-boxing punches, rear straight, rear hook, and rear uppercut to collect data of acceleration and angular velocity for detection and classification. We developed an application shown in Figure 1 that sends sensor data as a CSV file to an external computer via Bluetooth connection.

Second, to automatically detect a single punch, we calculated filtered synthetic acceleration and set two thresholds to segment a punch.

Third, after detecting a punch automatically, we proposed methods to classify targeted punches using correlation-based approach and machine learning approach. For correlation-based approach, we used The Dynamic Time Warping algorithm which can calculate two time-series data that have different length. For machine learning approach, we compared three types of classifiers, multi-class Support Vector Machine (SVM), Random Forest (RF), K Nearest Neighbors (KNN) from scikit-learn a machine learning library for Python.

Finally, to develop boxercise supporting system in the future work which requires providing feedback in real-time, we estimated the time needs to classify a single punch with each classification methods by calculating the average of the time required to classify a single punch for each of the classification methods.

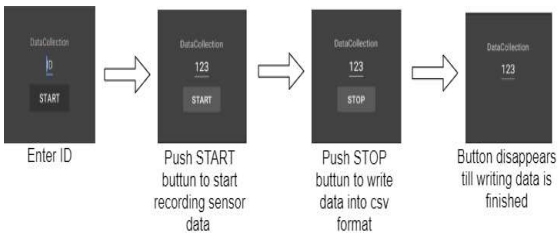

Figure 1: The displays of the smartwatch application for data collection

4. Validation of Proposed Methods

First, we conducted experiment on 10 participants using Polar M600 smartwatch which has a gyroscope and accelerometer with 100Hz sampling frequency embedded inside the watch. In the experiment, participants are asked to perform same type of punch 30 times with 4 seconds interval. They are also asked to perform all types of punch. As a result, we aimed to collect 900 punches in the experiment.

Second, we evaluated how accurate our detection method can correctly detect the actual punches in the experiment. As a result, we achieved the detection accuracy of 98.8% with 1 false negative and 11 false positive. The detection result for each punch is shown in Table 1.

Third, we evaluated the classification methods we proposed. As a result of a correlation-based method (DTW), we achieved 72.8% of accuracy (71.2% f1-score) with z-axis acceleration signal. As a result of machine learning methods, we achieved 99.0% accuracy (99.0% f1-score) with SVM as our best score for person dependent case, and 91.1% accuracy (90.6% f1-score) with SVM as our best score for person independent case.

Finally, as result of estimated real-time classification performance, we found out all our methods could classify a single punch in less than 0.01 seconds and SVM was fastest method to classify with the record of 0.0107 seconds. The result of estimated real-time classification speed is shown in Table 2.

Table 1: The detection result for each punch

	Straight	Hook	Uppercut	Total
Accuracy	99.0%	98.7%	98.7%	98.8%
Precsion	100.0%	100.0%	98.4%	98.8%
Recall	99.0%	99.0%	99.7%	99.9%

Table 2: Estimated real-time classification speed

Rank	Methods	Classification time
1	SVM	0.0107 seconds
2	RF	0.0114 seconds
3	KNN	0.0120 seconds
4	DTW	0.0992 seconds

6. Conclusion

In this thesis, we focused on boxercise, a fitness standard exercise, and proposed punch detection and classification methods using acceleration and angular velocity signal obtained by a single smartwatch on participant rear hand wrist. In addition, we estimated the real-time performance of classification methods to develop our research into a boxercise personal training system in the future.

Reference

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