Single Inertial Sensor for Local Muscular Endurance (LME) Exercise Detection

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1. Introduction

An activity recognition framework based on machine learning to automatically recognize LME exercises and to count the repetitions using a wrist-worn inertial sensor is proposed. Fourteen binary classifiers are trained using optimized SVM models [1, 3] to recognize individual LME exercises, achieving overall accuracy of more than 98%.

2. Methodology

2.1. Sensor Calibration and Data Capture

The sensors are calibrated (accelerometer $\pm$2g and gyroscopes $\pm$2000 deg/sec) to obtain consistent and accurate data. Data for fourteen LME exercises (refer Table 1) from six participants is collected at 512 Hz. The raw data captured from all participants using the designed experimental protocol is shown in Figure 1.

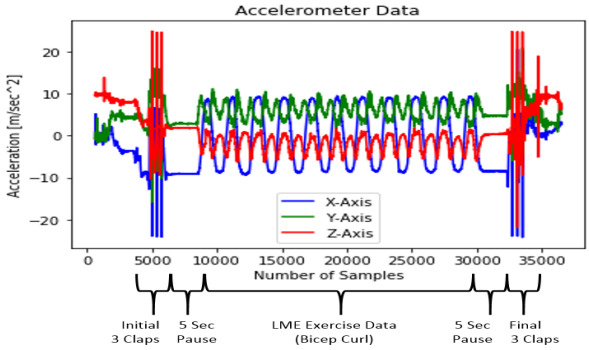

Figure 1: (a) Accelerometer data captured using the protocol for Bicep curls

Table 1: List of LME Exercises

Upper Body LME Exercises			
Ex 1	Bicep Curls	Ex 6	Pec Dec
Ex 2	Triceps extension (right)	Ex 7	Trunk twist
Ex 3	Upright row	Ex 8	Side Bends - alternating sides
Ex 4	Lateral raise (arms up)	Ex 9	Bent Over Row (right arm)
Ex 5	Frontal raise (arms up)	Ex 10	Press up against wall
Lower Body LME Exercises			
Ex 11	Squats	Ex 13	Standing bicycle
Ex 12	Lunges - alternating sides	Ex 14	Leg lateral raise (right)

2.2. Segmentation of Data

The 30 second data between initial and final pause period is segmented and annotated as **Class1** for each experiment. Segmentation of non-activity (random movement) is annotated as **Class0**. Annotated training data (**Class1** and **Class0**) from 4 participants were concatenated for each exercise and used for feature reduction.

2.3. Feature Extraction

A total of 24 features over a single 4 second sliding window with 2 seconds overlap are extracted. Features used are mean, std dev, min, max, & RMS values, correlation coefficients, FFT coefficients and entropy values.

2.4. Feature reduction using PCA

PCA is performed on the feature data set and components that explain the variance of 98% are retained. Feature space is reduced to 10 components instead of 24 features.

2.5 Activity Recognition and Repetition Counting

Fourteen SVM classifiers (one for each activity) with optimum hyperplane parameters are used to recognize each LME exercise from that of random movement. Data from best suitable axis (either accelerometer or gyroscope) is filtered using Savitzky-Golay filter (order 4) [2] and used for repetition counting using Peak-to-peak (PP) detection and/or threshold crossing (ThC) methods.

3. Results and Conclusion

Performance measures of each SVM model recognizing the activity are listed in Table 2. The Sensor and axis that correctly identifies the repetition count and the method used are indicated in the last two columns of Table 2. The LME exercises are recognized with an overall accuracy $\geq$ 98%.

Table 2: Performance Measures & Repetition Counting

Exercise	Precision	Recall	F1 score	Senosor & Axis	Method
Ex 1	1.000	1.000	1.000	Acc - X, Gy - Z	Acc - PP, ThC Gy - ThC
Ex 2	1.000	1.000	1.000	Acc - X	Acc - PP, ThC
Ex 3	1.000	1.000	1.000	Acc - X	Acc - PP, ThC
Ex 4	1.000	1.000	1.000	Acc - X	Acc - PP, ThC
Ex 5	1.000	1.000	1.000	Acc - X, Gy - Y	Acc - PP, ThC Gy - PP, ThC
Ex 6	1.000	1.000	1.000	Gy - X	Gy - PP, ThC
Ex 7	1.000	1.000	1.000	Gy - Y	Gy - PP
Ex 8	1.000	0.963	0.981	Acc - Z	Acc - PP
Ex 9	1.000	1.000	1.000	Acc - X	Acc - PP
Ex 10	1.000	1.000	1.000	Acc - X	Acc - PP, ThC
Ex 11	1.000	1.000	1.000	Acc - X, Gy - Z	Acc - PP, ThC Gy - PP, ThC
Ex 12	0.963	0.963	0.963	Acc - X	Acc - PP
Ex 13	1.000	1.000	1.000	Gy - X	Gy - PP, ThC
Ex 14	1.000	0.963	0.981	Acc - Y, Gy - Z	Acc - PP,ThC Gy - PP

Acknowledgement

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References

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