METHODS AND TECHNIQUES FOR HUMAN ACTIVITY RECOGNITION USING INERTIAL MOTION PRIMITIVES

By

Ayman Mohamed AboElMaaty Mohamed AboElHassan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Computer Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

METHODS AND TECHNIQUES FOR HUMAN ACTIVITY RECOGNITION USING INERTIAL MOTION PRIMITIVES

By

Ayman Mohamed AboElMaaty Mohamed AboElHassan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Computer Engineering

Under the Supervision of

Assoc. Prof. Dr. **Amr Wassal**

Associate Professor
Computer Engineering
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

METHODS AND TECHNIQUES FOR HUMAN ACTIVITY RECOGNITION USING INERTIAL MOTION PRIMITIVES

By

Ayman Mohamed AboElMaaty Mohamed AboElHassan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Computer Engineering

Approved by the Examining Committee:

Assoc. Prof. Dr. **Amr Wassal**, Thesis Main Advisor

Prof. Dr. **ElSayed Hemayed**, Internal Examiner

Prof. Dr. **Mohamed Zaki Abdelmaged**, External Examiner
- Faculty of Engineering, Al-Azhar University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

Engineer's Name: Ayman Mohamed AboElMaaty Mohamed AboElHassan
Date of Birth: 17/2/1992
Nationality: Egyptian
E-mail: Ayman.abo.elmaaty@eng.cu.edu.eg
Phone: +201091222727
Address: 108 El-Shaheed Ahmed Hamdy St., Madkoor, Faisal, Bolak Ad-Dakror, Gizah, Egypt
Registration Date: 1 / 10 / 2014
Awarding Date: 2017
Degree: Master of Science
Department: Computer Engineering

Supervisors:

Assoc. Prof. Dr. **Amr Wassal**

Examiners:

Prof. **Mohamed Zaki Abdelmaged** (External Examiner)
- Faculty of Engineering, Al-Azhar University

Prof. **ElSayed Hemayed** (Internal Examiner)
Assoc. Prof. Dr. **Amr Wassal** (Thesis main advisor)

Title of Thesis:

Methods and Techniques for Human Activity Recognition Using Inertial Motion Primitives

Key Words:
Learning by Demonstration; Human Activity Recognition; Online Classification; Time-series Clustering; Hidden Markov Model

Summary:
In this thesis, we propose an inertial HAR system to recognize complex human activities using motion primitives. Inertial sensor readings are segmented into set of finite motion primitives, then recognized motion primitives are used to classify the complex activity. Complex activities are classified using 2-level hierarchical HMM classifier. We introduce a motion primitive generation algorithm that extracts most distinct time-series segments from a set of complex activities. We also apply three different features selection approaches to reduce the processing time. SBHAR and PAMAP2 public datasets are used to evaluate the system's performance, where we show that our approach achieves 93.77% and 86.84% accuracies respectively. A comparison with related researches which used the same datasets is conducted to compare our results regarding methodology, features, accuracy, time complexity and classification rate.

Acknowledgements

Firstly, I would like to thank my supervisor Dr. Amr G. Wassal for his continuous support through the course of my academic career. Our discussions have been really helpful and generated lots of creative ideas in order to achieve the research objectives.

Secondly, I want to thank Asmaa Rabie for her help and insights. Despite that we were a small research group, I couldn't have reached this level without her help. Moreover, I would like to thank my department and all its members whom have been very supportive and welcoming. They made me feel like they are my second family.

I also want to express my gratitude to my close friends: A. Ahmed, A. Nasr, Islam, M. Azab, M. Badry, M. Daif, M. Kamhawy, M. Sadek, M. Sedik, M. Shokr and Tarek whom have been always backing me up. Finally and most importantly, I want to thank my family: my father, my mother, and my brother. They have overwhelmed me with their unconditional love and support that gave me the strength and will to continue in my career.

Table of Contents

List of Tables

List of Figures

List of Symbols and Abbreviations

AdaBoost	Adaptive Boosting
AdaGrad	Adaptive Gradient
ANN	Artificial Neural Network
APG	Automatic Primitive Generation
B-BLSTM-RNN	binarized bidirectional Long Short-Term Memory RNN (LSTM-RNN)
CHMM	Continuous Hidden Markov Model
CQP	Constrained Quadratic Programming
DCNN	Deep Convolutional Neural Networks
DFT	Discrete Fourier Transform
DHMM	Discrete Hidden Markov Model
DNN	Deep Feed-Forward Neural Networks
DT	Decision Tree
DTW	Dynamic Time Warping
ECG	Electrocardiogram Sensor
EM	Expectation Maximization
EX-SMO	Extended Sequential Minimal Optimization
FFP	Feed-Forward Phase
FFT	Fast Fourier Transform
GA	Genetic Algorithms
GMM	Gaussian Mixture Model
GPS	Global Positioning System
HAR	Human Activity Recognition
HMM	Hidden Markov Model
IMU	Inertial-Measurement Unit
k-NN	K-Nearest Neighbors
L1-Norm	Manhattan Distance Norm

L2-Norm	Euclidean Norm
LbD	Learning by Demonstration
LbE	Learning by Example
LSTM-RNN	Long Short-Term Memory RNN
MC-LSVM	Multi-Class Linear Support Vector Machine (SVM)
ML	Machine Learning
MLP-NN	Multi-Layer Perceptron Neural Network
PAMAP2	Physical Activity Monitoring for Aging People
PCA	Principal Components Analysis
PDF	Probability Density Function
ReLU	Rectified-Linear Unit
RF	Random Forest
RMSprop	Root Mean Square Propagation
RNN	Recurrent Neural Network
SBHAR	Smartphone-based HAR
SGD	Stochastic Gradient Descent
SRC	Sparse Representation Classifier
SVD	Singular Value Decomposition
SVM	Support Vector Machine

Abstract

Learning by Demonstration (LbD) first appeared in computer engineering in 1980s. LbD gained much of interest in robotics, due to the complexity of designing and developing a robot program to perform a specific task. LbD paradigm is to create robotic framework that is capable of learning to perform a specific behavior by recording an instructors performance and repeating it. In this thesis, we propose the implementation of motion recognition, the first part of LbD paradigm. Where we build an inertial Human Activity Recognition (HAR) system to recognize complex human activities using motion primitives.

HAR goal is to recognize the activities and behaviors performed by the user given the environment and user's sensed attributes. HAR applications increased in the past decades, in order to improve the human's quality of life. However, inertial research flourished in the last few years due to the technological improvement in sensors industry. Inertial HAR approaches use IMU to capture linear and angular accelerations at certain points as chest, waist, hand and foot.

In this thesis, we investigate the capabilities of Hidden Markov Model (HMM) as a learning model to capture inertial motion sequences with high accuracy. HMM has the capability to capture time series data as in speech recognition, and has a low cost in terms of time and memory complexity. In our approach, 2-level hierarchical HMM classifier is developed to recognize the required complex activities. Inertial sensor readings are segmented into set of finite motion primitives, then recognized motion primitives are used to classify the complex activity.

We also introduce a motion primitive generation algorithm that extracts most distinct time-series segments from a set of complex activities using Pearson correlation. Where, primitive set should be unique and atomic to be differentiable from each other. Additionally, they should represent almost all atomic motions that defines the complex motion set.

We applied three different features selection approaches to reduce the processing time. SBHAR and PAMAP2 public datasets are used to evaluate the system's performance, where we show that our approach achieves 93.77% and 86.84% accuracies respectively. A comparison with related researches which used the same datasets is conducted to compare our results regarding methodology, features, accuracy, time complexity and classification rate.