ARTICLE IN PRESS

Pervasive and Mobile Computing ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Pervasive and Mobile Computing

journal homepage: www.elsevier.com/locate/pmc

A smart segmentation technique towards improved infrequent non-speech gestural activity recognition model

Mohammad Arif Ul Alam [a,*], Nirmalya Roy [a], Aryya Gangopadhyay [a], Elizabeth Galik [b]

[a] Department of Information Systems, University of Maryland Baltimore County, United States

[b] School of Nursing, University of Maryland Baltimore, United States

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Smart jewelry
Behavioral health
Change-point detection
Energy efficiency
Smart segmentation

ABSTRACT

Infrequent Non-Speech Gestural Activities (IGAs) such as coughing, deglutition and yawning help identify fine-grained physiological symptoms and chronic psychological conditions which are not directly observable from traditional daily activities. We propose a new wearable smart earring which is capable of differentiating IGAs in daily environment with single integrated accelerometer sensor signal processing. Our prior framework, GeSmart, shows significant improvement in IGAs recognition based on smart earring which necessitates users to replace the earring batteries frequently due to its energy hungry requirement (high sampling frequency) towards fine-grained IGAs recognition. In this improved work, we propose a new segmentation technique along with GeSmart which takes the advantages of change-point detection algorithm to segment sensor data streams, feature extraction and classification thus any machine learning technique can perform significantly well in low sampling rate. We also implement a baseline traditional graphical model based gesture recognition techniques and compare their performances with our model in terms of accuracy, energy consumption and degradation of sampling rate scenarios. Experimental results based on real data traces demonstrate that our approach improves the performances significantly compared to previously proposed solutions. We also apply our segmentation technique on two benchmark datasets to prove the superiority of our technique in low sampling rate scenario.

1. Introduction

Modeling and analyzing the physiological symptoms and psychological behaviors of older adults have a profound impact on future smart and connected older adults care. The fine-grained insights about the human health, wellness and independence obtained from the physiological and psychological data analysis if coupled with activities of daily living can help improve the mental health, stress disorders, ambulatory conditions, and social interactions of older adults. The wide availability of commodity smart healthcare appliances, stand-alone and integrated sensing devices make it increasingly easy to ubiquitously and continuously monitor an individual's health-related vital signals, activities, and behavior and to integrate such data into healthcare systems. We are witnessing early commercial activity, where a combination of *body-worn* medical and non-medical sensors (e.g., sensors to monitor blood oxygenation or accelerometers to monitor

* Corresponding author.
E-mail addresses: alam4@umbc.edu (M.A.U. Alam), nroy@umbc.edu (N. Roy), gangopad@umbc.edu (A. Gangopadhyay), galik@son.umaryland.edu (E. Galik).

http://dx.doi.org/10.1016/j.pmcj.2016.06.015
1574-1192/

movement) and *in situ* sensors (e.g., thermal and motion detectors) continuously monitor and automatically determine an individual's context. Broadly speaking, *context* in smart health refers to a variety of dynamically changing states, related to either an individual's activities (e.g., ambulatory vs. sleeping), biomedical conditions (e.g., fatigue vs. anxiety), or behavioral conditions (e.g., shouting vs. agitation). In many health and wellness applications, such context enables critical capabilities, such as alerting a first responder if the individual is shouting for an abnormal period of time or flagging a health risk by analyzing wellness data related to continuous burping or hiccup after every day eating. In this paper, we particularly investigate the recognition and discovery of infrequent non-speech gestural activities (henceforth defined as IGAs) which are observable and detected; provide significant insights about the long-term well-being of the older adults. Our approach enables efficient abstraction and finer correlation of the activities of daily living with the acute physiological symptoms and chronic psychological conditions.

Providing both behavioral and physical health status in a unified setting is of utmost need for proactive healthcare. Mental disorders and cognitive impairments oftentimes evolve from chronic physiological symptoms and abnormal psychological behaviors. Suffering from different sort of mood disorders inhibits different patterns of infrequent gestures such as depression, sadness, crying, shouting etc. Likewise for different kinds of physiological health issues, the patient shows irregular gestures such as frequent coughing, burping, breathing problem etc. Therefore mental and physical health of older adults are correlated and if harnessed appropriately may provide meaningful microscopic physiological and psychological contexts. For example, a person feeling a headache from anxiety or anger might shout loudly or show irregular interpersonal traits. Thus the mental hygiene or physical wellness of a particular person can be inferred by monitoring the IGAs which reflect the emotional or behavioral state of the individual. On the other hand when a person shows infrequent gestures while being engaged in other activities, his or her body produces different kinds of movements. The differences between these subtle movements, if captured and detected naturally could help infer the infrequent gestural activities.

Previous works have focused on human speech processing extracting features from acoustic signal to detect human voice and non-speech human sounds. While acoustic sensor can certainly help determine the sound gesture of human but undermine significantly the operational cost and life longevity of wearable devices due to its energy hungry operations. Acoustic signal recording, pre-processing, ambient noise reduction, features extraction and classification process cause huge computational overhead which rapidly drains out the battery power of source devices. Sound signals generating from other individuals, surrounding the target user may cause severe misclassification problem creating unavoidable false positive results. Moreover, continuous sensing of sound signals may cause serious privacy violations. On the other hand embedding sensors on myriad objects of daily living, such as microwaves and kitchen cabinets [1] or mounting them on the ceiling has challenging operational costs and battery-life issues. Individuals, particularly, older adults appear reluctant to continually wear multiple sensors on the body [2].

Activity recognition generally assumes that sensor data is indiscriminately represented as a time series, and that at any given moment in the time series the subject involves with single activity. Thus the time series is thought of as being partitioned into a number of non-overlapping intervals (windows), which are delimited by moments in time when the subject stopped performing one activity and started performing another. Previous work has treated activity detection as an online problem, and has rarely considered performance metrics other than accuracy. In this paper we consider accuracy as well as detection as performance metrics to provide more fine-grained granularity of our model prediction. We propose to use an energy efficient and computationally inexpensive accelerometer sensor in the form of a smart earring for detecting fine-grained gestural activities of the user. We are also interested in the feasibility of partitioning and classifying a time series data in real time. More specifically we aim to facilitate the following **critical requirements**:

- **Long battery life**: Earring has become very common for men and women to have both ears pierced, and it is becoming more acceptable for teenage and pre-teen boys to have both ears pierced as well. The advantage of smart earring based physical/gestural activity recognition is its ubiquitous usage of all time even during sleep. However, the most advantageous fact also creates the most disadvantageous charge. Since users keep it worn for long time, it is obvious that they are reluctant of changing batteries frequently. Moreover, if the batteries must be replaced often (every day or every week), not only will the primary benefit (freedom from wiring constraints and costs) of wireless networks be lost, but also many remote sensing applications may become impractical. Therefore, long battery life is essential in earring sensor networks.
- **Small form factor**: It is obvious that devices must be small enough to be embedded in their operating environment. This requirement affects the choice of batteries—even AA batteries are too bulky to power the sensor node, so using coin cell batteries is the only option in many situations.
- **Low-sampling rate**: In our framework, sensor data is captured in the earring but transmitted, stored and processed by a remote node before it is transmitted to the central base station. The entire data streaming, transmission, storage and local processing are exhilarated with low sampling rate. However, low sampling rate costs the accuracy of the recognition process which also needs to be handled.

Research questions: Our investigations in this paper pursue the following research questions:

- Given the adaptation of activity recognition algorithms to help older adults in healthy independent living what sort of gestural activities may shed light on long-term physiological health and psychological behavior of older adults?

Please cite this article in press as: M.A.U. Alam, et al., A smart segmentation technique towards improved infrequent non-speech gestural activity recognition model, Pervasive and Mobile Computing (2016), http://dx.doi.org/10.1016/j.pmcj.2016.06.015