

Tracking the sedentary lifestyle using smartphone: A Pilot Study

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Abstract— Smartphone is most ubiquitous device and provides unique opportunity of continuous and automated tracking of sedentary lifestyle with the help of embedded sensors. In this paper, we present the evaluation of our pilot study results to track the sedentary lifestyle. The proposed model works well in real-time and inside the smartphone environment to process the sensory data. We compute the time and frequency domain features over the acceleration signals and classify the context with non-parametric nearest neighbor algorithm. To analyze the lifestyle patterns, information is transferred to the cloud server for archiving, further computation and its availability anywhere, anytime for visualization. It facilitates users to maintain and monitor their everyday lifestyle patterns and assists them to change their unhealthy sedentary behaviour identified by the proposed research. Furthermore, achieved results demonstrate the applicability of the proposed research in real-world scenarios.

Keywords— Lifestyle, Sedentary behaviour, Smartphone, k-NN

I. INTRODUCTION

Sedentary lifestyle is a way of life, in which physical activities and energy expenditure is very low. In both developed and developing countries, sedentary lifestyle is increasing due to societal changes. Sedentary activities include sitting while watching television, playing video or board games, computer or cellphone use, driving automobiles, reading books, and lying on the couch [1]. A person is considered sedentary if they spend large amount of their day with such activities. Sedentary lifestyle is associated with poor health outcomes, including the high risk of overweight and obesity [1], physiological and psychological problems [2], cardiovascular disease, diabetes [3] and morality independent from physical activity levels [4].

Different ways to monitor and track sedentary lifestyle are self-reporting, direct observation and accelerometer and inclinometer [5]. Self-reporting used time-series diaries, where user's report frequency and duration of sedentary activities. It is an easy and simple way to track the sedentary behaviour; however, it is difficult to manage it regularly. Direct observation is alternative way that could yield reliable estimates but at the cost of high level of intrusion. It is effective for children, and parents are requested to estimate it

through observations. Accelerometer and inclinometer are automated method to capture the total time spent in sedentary activities. Furthermore, inclinometer can quantify time spent in different postures. User need to wear these external devices to track their daily routines. However, it is an intrusive and uncomfortable way to track the sedentary behavior with limited information about user's daily routines.

In order to track sedentary lifestyle, there is a need to develop a ubiquitous system to track the sedentary elapsed time accurately with all its minor routines ranging from office work or home to watching television in leisure time. Current generation smartphones are an alternative solution to external devices due to their many diverse and powerful embedded sensors. Furthermore, it is one of the best choices due to its unobtrusive characteristics, high storage capacity and computation, low energy consumption and programmable capabilities. In order to track sedentary lifestyle in daily routines, we proposed a tracking application based on the accelerometer sensor of smartphone. It can help ordinary people to monitor their lifestyle in a proactive way. Based on the tracked behavior, users will be able to monitor and manage their daily activities that may help to adopt active lifestyle. For self-management, our application provide visualization of sedentary behaviour patterns and useful analytics to assess users' daily routines.

Rest of the research paper is organized as follows. Related work and limitations of existing systems are discussed in Section 2. In Section 3, the proposed architecture and its implementation inside the smartphone environment to track the sedentary lifestyle is presented. In Section 4, we explain our experimental setup and results with discussion on the results. Finally conclusions our finding in Section 5.

II. RELATED WORK

Several research studies and a large number of lifestyle tracking devices are available [2], [6], [7], and [8]. Burke *et al.* [7] addressed the self-monitoring system for lifestyle modification and showed that technology played an important role and superior to traditional paper-and-pencil diaries during the weight management. Matthews *et al.* [8] utilized actigraph instrument that records integrated acceleration information to estimate the bodily movement. The device was set to provide

information in 1-minute epochs and participants wear this on their right hip attached by an elastic belt during all walking hours. After collection of data, the device was attached with computer and data was analysed using their developed software. This mechanism is intrusive and user need to attach the device with their body.

Barwais *et al.* [2] presented a method to reduce sedentary behaviour. Their objective was to assess the effectiveness of a four week intervention in which an external device mounted with tri-axial accelerometer was used to reduce sedentary behavior among sedentary adults. In this device users needed to connect the device with USB port and send the data to computer where it was visualized using a developed software.

Shin *et al.* in [6] developed a mobile application to recognize user sedentary activity using mobile device. Their method was based on rotated acceleration using quaternion that classified sedentary behaviour with higher accuracy. However, there application required server side processing to classify user activities patterns.

It is visible that many systems and models were proposed to track the sedentary behaviour; however, they had their limitations. Our objective is to utilize the embedded sensors of smartphone and process data in real-time inside the smartphone environment, to provide more robust and accurate results for tracking and managing the sedentary lifestyle of a user.

III. THE PROPOSED APPROACH

The proposed approach consists of smartphone environment, cloud storage, and lifestyle visualization to make it an acceptable and usable solution. The proposed architecture of sedentary lifestyle tracking application is illustrated in Figure 1 and details of sub-components are as follow:

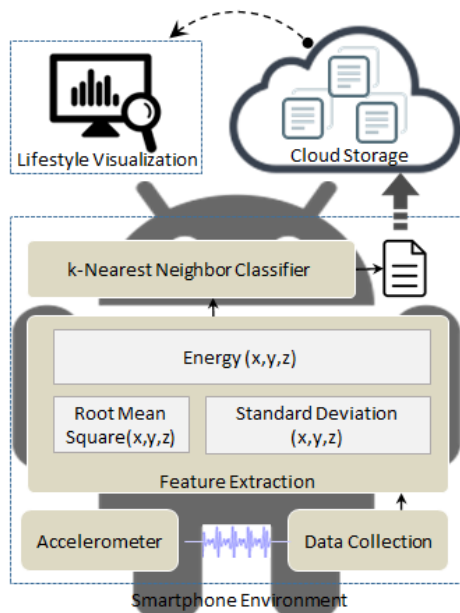


Figure 1. The Proposed Architecture

A. Smartphone Environment

An Android based smartphone application is developed to track user lifestyle. It activate accelerometer sensor and sense the sedentary and motion pattern of a user. We read sensor's readings at normal delay and process it inside the smartphone environment. After collection of the accelerometer data we apply feature extraction technique and classification algorithm to know the context of users (i.e., sedentary, short break, or active).

Feature Extraction: It is highly domain specific method to transfer raw signals into meaningful region. Firstly, we solve the orientation issue of accelerometer data suggested by Mizell [14] and then extract following time and frequency domain features.

$$\mu = \frac{1}{n} \sum_{i=1}^n x_i \quad (1)$$

$$\delta = \sqrt{\frac{1}{n} \sum_{i=1}^n x_i - \bar{x}} \quad (2)$$

$$E = \frac{1}{n} \sum_{i=1}^n |FFT_i|^2 \quad (3)$$

In eq. 1, the mean (μ) is a statistical time domain feature to measure the central tendency of varying quantity over the defined fifteen seconds window. Standard deviation (δ) is a dispersion metric to measure the data spread for different activities and is calculated by eq. 2 Similarly, in eq. 3, the energy feature is calculated by applying the Fast Fourier Transformation (FFT) to find the quantitative characteristics of the data over a defined time period. The extracted features are later passed to the classifier.

Classifier: We classify data from accelerometer sensor by non-parametric nearest neighbor algorithm. It is one the most used algorithm in many applications and proved itself light weight and easy to implement [9]. It has two stages; one, determination of nearest neighbors and second, assigning class label using those neighbors. In the proposed method, Euclidean distance metrics is applied to find the neighbors and four neighbors (i.e., $k = 4$) are considered to classify activities.

B. Cloud Computing Environment

Cloud computing provides ubiquitous computing model, where resources, such as computing power, storage, network and software are abstracted and provided as services over the internet [10]. For instance: Amazon S3, Microsoft Windows

Azure Blob Storage, OpenStack and Rackspace. We have deployment of open source OpenStack cloud environment in our *Machine Learning* laboratory [11] to provide the storage, computing and access services anywhere and anytime. Our mobile application classify user context inside the smartphone and send lifestyle logs to the cloud storage over the internet. Furthermore, these logs are processed and analyzed to infer useful information.

C. Lifestyle Visualization

Visualization is concerned with exploring data and information [12]. The proposed architecture provide visualization of user daily patterns in terms of sedentary time, active time, breaks during sedentary time, and total time spent during the sedentary and being active. It may help users for self-management and being active. We are using Google charting [13] for visualization over the internet. We create the limited number of credentials that is equal to number of participants to interact with the system and visualize the lifestyle patterns.

IV. EXPERIMENTS AND EVALUATION

This pilot study was conducted on sensory data collected from four healthy adults (four university students) with age 21 to 25 for one week. The participants installed our developed lifestyle application on their smartphones to analyze and visualize their sedentary patterns. Smartphones used in this study are Samsung Galaxy S3, and Asus Zen 5. The application has been used for 24 hours a day on smartphone and it has shown very low power consumption. In order to get the training data for classification, four subjects are request to performed five trails of body movement in a natural and comfortable way. Our application is trained over the “still” patterns and rest of the activities are considered active. In real time, we collect the accelerometer sensor data and is processed inside the smartphone by extracting the features and applying classification algorithm as discussed in Section II and III. Time scale for inferencing is set to one minute epoch that is sufficient to distinguish among sedentary state, active state and break times. For discussion, we are presenting one subject’s 24 hours data of a working day. Table 1 shows one day activities for the subject with total hours spent in sedentary, short breaks and active time.

Table 1 One Day Routine of Time Spent Duration

Time Spent	Duration (Hours)
Sedentary	16.2
Short Break	0.15
Active	8.1

In Figure 2, the subject day start from 7:00 AM in the morning and time spent graph shows how the pattern is observed in 24 hours. The subject is quite active with balance short breaks that will may help him to remain healthy lifestyle; however, this is activity routine for a day. The subject usually prefer

stairs instead of lifts, after lunch short walk and sports time as well. In Figure 3, we have presented 120 minutes of subject’s activities where activity pattern consist of 4 short breaks and one active time.

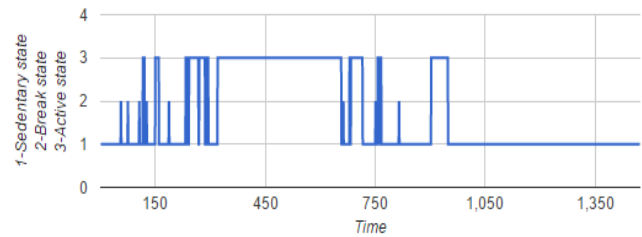


Figure 1. Daly routine with time spent of activity pattern

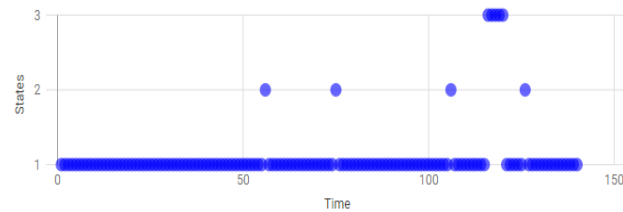


Figure 2. Two hours activity patterns with three recongized states (Sednetary, Short Break and Active)

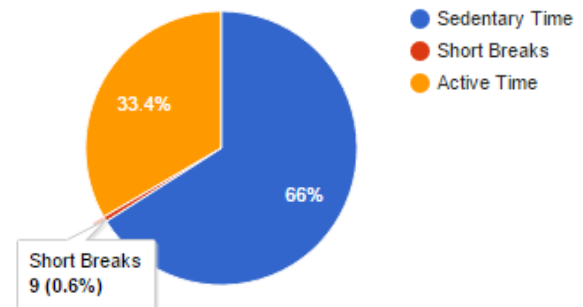


Figure 3. Daily routine pattern visualization

In Figure 4, daily routine pattern is visualized and provide us information on percentage of time in 24 hours spent in different predefined activities. We also extract the information about the number of short breaks (i.e., 9 short breaks) that help subject to avoid longer sedentary activity.

V. CONCLUSION

In this study, we have designed and developed a sedentary lifestyle tracking application that work well in real-time and process sensor’s signals inside the smartphone. We have extracted time and frequency domain features and classified them using k-NN algorithm while keeping the timestamps. Overall lifestyle analytics like total time spent in sedentary state, breaks between them and active state are provided in the proposed system to the user. Our application facilitates

healthy individuals to monitor their lifestyle and provide a proactive platform for self-management. Currently, our application is limited to the small group of participants. We have plan to implement the proposed model for a larger community and provide with recommendations for self-management.

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REFERENCES

- [1] M. S. Tremblay, R. C. Colley, T. J. Saunders, G. N. Healy, and N. Owen, "Physiological and health implications of a sedentary lifestyle," *Applied Physiology, Nutrition, and Metabolism*, vol. 35, no. 6, pp. 725–740, 2010.
- [2] F. A. Barwais and T. F. Cuddihy, "Empowering sedentary adults to reduce sedentary behavior and increase physical activity levels and energy expenditure: A pilot study," *International journal of environmental research and public health*, vol. 12, no. 1, pp. 414–427, 2015.
- [3] C. Vandelanotte, M. J. Duncan, C. Short, M. Rockloff, K. Ronan, B. Happell, and L. Di Milia, "Associations between occupational indicators and total, work-based and leisure-time sitting: a cross-sectional study," *BMC public health*, vol. 13, no. 1, p. 1110, 2013.
- [4] L. M. Leon-Munoz, D. Martinez-Gomez, T. Balboa-Castillo, E. Lopez-Garcia, P. Guallar-Castillon, and F. Rodriguez-Artalejo, "Continued sedentariness, change in sitting time, and mortality in older adults," *Medicine and science in sports and exercise*, vol. 45, no. 8, pp. 1501–1507, 2013.
- [5] S. Biddle, N. Cavill, U. Ekelund, T. Gorely, M. Griffiths, R. Jago, J. Oppert, M. Raats, J. Salmon, G. Stratton et al., "Sedentary behavior and obesity: review of the current scientific evidence," *United Kingdom-Department of Health: Department for Children SaF*, 2010.
- [6] Y. Shin, W. Choi, and T. Shin, "Physical activity recognition based on rotated acceleration data using quaternion in sedentary behavior: A preliminary study," in *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE*. IEEE, 2014, pp. 4976–4978.
- [7] L. E. Burke, M. A. Styn, S. M. Sereika, M. B. Conroy, L. Ye, K. Glanz, M. A. Sevvick, and L. J. Ewing, "Using mhealth technology to enhance self-monitoring for weight loss: a randomized trial," *American journal of preventive medicine*, vol. 43, no. 1, pp. 20–26, 2012.
- [8] C. E. Matthews, K. Y. Chen, P. S. Freedson, M. S. Buchowski, B. M. Beech, R. R. Pate, and R. P. Troiano, "Amount of time spent in sedentary behaviors in the united states, 2003–2004," *American journal of epidemiology*, vol. 167, no. 7, pp. 875–881, 2008.
- [9] X. Wu, V. Kumar, J. R. Quinlan, J. Ghosh, Q. Yang, H. Motoda, G. J. McLachlan, A. Ng, B. Liu, S. Y. Philip et al., "Top 10 algorithms in

data mining," *Knowledge and Information Systems*, vol. 14, no. 1, pp. 1–37, 2008.

- [10] J. Atul, D. Johnson, M. Kiran, R. Murthy, C. Vivek, G. Yogesh, "OpenStack Beginner's Guide (for Ubuntu - Precise)" v3.0, 7 May 2012
- [11] Machine Learning Research Laboratory, <http://ml.ce.izu.edu.tr/> [Visited: December 7, 2015]
- [12] M. Chen, D. Ebert, H. Hagen, R. S. Laramée, R. Van Liere, K.-L. Ma, W. Ribarsky, G. Scheuermann, and D. Silver, "Data, information, and knowledge in visualization," *Computer Graphics and Applications*, IEEE, vol. 29, no. 1, pp. 12–19, 2009.
- [13] Google Charting, <https://developers.google.com/chart/> [Visited: December 7, 2015]
- [14] D. Mizell, "Using gravity to estimate accelerometer orientation," pp 252 – 253, *Computer Society*, IEEE, 2003.



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