Faculty of Engineering

Lower Limb Gait Activity Recognition

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By

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Statement

This thesis is submitted in the requirement for master degree in Mechanical Engineering to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

Signature

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Abstract

Lower limb activity recognition, recently, has shown large demand in health care and rehabilitation fields. Wearable activity recognition system has the ability to monitor patients' activities, especially those need to be followed up such as people suffering from traumatic brain injuries. Furthermore, home-based self rehabilitation can be provided for disabled people using assistive systems where activity recognition plays an essential role.

However, sensor data acquisition and preprocessing, data segmentation, feature extraction and selection, training and classification are considered as the research challenges that face any lower limb recognition system. Although the sensor data acquisition step affects the prediction performance, only few studies dealt with the sensors positioning challenge. In this research work, the author targets to determine the lower limb segments with the highest contribution to the activity recognition process.

The 3-D kinematics and orientation profile of the lower limb segments are acquired using a sensor network of four Inertial Measurement Units (IMU) spread over the lower limb segments of one leg. Time (statistical) and time-frequency (wavelet components) features are extracted from the segments motion profile (kinematics and orientation). Those features are used in the proposed algorithm for sensor localization, which depends on determining the sensors of the most discriminative features selected by a filter type feature selector. Most of the discriminative features are found to be extracted from the sensors fixed on the thigh segment followed by the foot sensors.

The results are validated by using random forest classifier for lower limb activity recognition. The validation process supported the results that the thigh kinematics and orientation data are sufficient to recognize the lower limb activities. The overall recognition accuracy using thigh sensor only is 95.7%, while 97% if both thigh and foot sensors are used, in other words the accuracy decreased by 2.3% and 1%, respectively, compared to the accuracy using the four IMU sensors. To overcome the reduction in the accuracy rate several amendments to the extracted features and classification techniques are suggested.

Keywords

Motion Capturing system, IMU sensor network, Mutual Information Features selector, Random forest, Multi-layer classifier

Summary

The number and location of the Inertial Measurement Units (IMU) used in the motion capturing system for the lower limb activity recognition plays a vital role in the recognition performance and the computational time. Searching for the lower limb segments that contains the most discriminable information about the different activities (walking, stair ascending, stairs descending, ramp ascending, ramp descending) helps in increasing the sampling frequency and reducing the time needed for signal conditioning and processing due to the reduction in the gathered data by eliminating the redundant and non relevant signals before proceeding to the feature stage. Consequently, removing the non-relevant data reduces the over fitting problem that may affect the classifiers, while training, which is a main reason for accuracy reduction. However, this shows the importance of localizing the IMU sensors. Finally, at the end of the thesis, Physical features are suggested to improve the recognition system accuracy, in addition to, presenting multi layer classifier technique.

Chapter 1 introduces the thesis objectives and layout, which could be concluded in optimizing the IMU sensor network for motion capturing by eliminating the sensors that captures non-relevant or redundant data without affecting the activity recognition process. This objective has been successfully achieved in the following six chapters.

Chapter 2 presents an overview of the lower limb activity recognition stages and the previous research efforts done within each stage in order to improve the prediction accuracy for the activities, by emphasizing on the motion capture techniques used for these systems and specially the design of the systems depending on inertial sensors.

Chapter 3 illustrates the implementation details of the full set of the IMU sensor network (motion capture system), that will be modified in the following chapter, reaching to the most important sensors and locations in this system.

Chapter 4 shows the procedure followed in this work in order to elect the best sensor location for lower limb activity recognition systems.

Chapter 5 presents the recognition system that validates the election hypothesis resulted from the procedure shown in the previous chapter. Furthermore, this chapter

discusses the modification that could be done on the same recognition system in order to recover the decrement in the recognition accuracy due to the reduction in the number of the sensors in the IMU sensor network.

Chapter 6 is the results and discussion chapter, which shows the output of the chapter 4 procedure that results the best sensor's location hypothesis. Moreover, it illustrates the effect of using the hypothesis on the validation recognition system presented in chapter 5.

Based on this work, some recommendations and future research have been introduced in chapter 7.

Table of content

List of Figures

List of Tables