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Evaluation of Human Activity Recognition System using Wearable Sensors: A Review

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ABSTRACT

Human Activity Recognition is an important area of computer vision research today. The goal of human activity recognition is to automatically analyze ongoing activities from an unknown video (i.e. sequence of image frames). In a simple case where a video is segmented to contain only one execution of human activity, the objective of the system is to correctly classify the video into its activity category. This paper surveys the state of the art in Human Activity Recognition using wearable sensors. In this survey, we have categorized Human Activity Recognition Systems in two levels. The first one has to do with learning approach, which can be either supervised or semi-supervised and the second has to do with the response time. Twenty Eight systems are evaluated in terms of performance, energy consumption, obtrusiveness and flexibility. Finally, future considerations are addressed.

Keywords: Human Activity Recognition, Wearable Sensors, PDA, Mobile, GPS, Laptop and machine learning.

I. Introduction

Human Activity Recognition is an important area of computer vision research today. The goal of human activity recognition is to automatically analyze ongoing activities from an unknown video (i.e. sequence of image frames). In a simple case where a video is segmented to contain only one execution of human activity, the objective of the system is to correctly classify the video into its activity category.

The ability to recognize complex human activities from videos enables the construction of several important applications.

1. Automated Surveillance systems in public places like airports and subway stations require detection of abnormal and suspicious activities as opposed to normal activities. For instances an airport surveillance system must be able to automatically recognize suspicious activities like person leaving a bag or 'a person placing his/her bag in a trash bin'.
2. Recognition of human activities also enables the real-time monitoring of patients, children and elderly person.
3. The construction of gesture-based human computer interfaces and vision based intelligent environments becomes possible as well with an activity recognition system.

There are various types of human activities. Depending on their complexity, we conceptually categorize human activities into four different levels.

a.) Gestures
b.) Actions
c.) Interactions
d.) Group Activity

a.) Gestures: Gestures are elementary movements of a person's body part and are the atomic components describing meaningful motion of a person.

For Example: Stretching an arm and raising a leg are good examples of gestures.

b.) Actions: Actions are single person activities that may be composed of multiple gestures organized temporally such as 'walking', 'waving' and 'punching'.

c.) Interactions: Interactions are human activities that involve two or more person and/or objects.

For Example: Two persons fighting is an interaction between two humans and a person stealing a suitcase from another is a human object interaction involving two humans and one object.

d.) Group Activities: Group Activities are the activities performed by conceptual groups composed of multiple persons and/or objects.

For Example: A group of person marching, a group having a meeting and two groups fighting are typical example of group activities.

The overview of the activity recognition taxonomy based on hierarchical approach classified activity recognition system into various categories [1].

The first work on human activity recognition was done at the end of 90's [5][6]. However, there are still many issues that motivate the development of new techniques to improve the accuracy under more realistic conditions.

Some challenges with this system includes:

a.) the selection of attributes to be measured.
b.) the construction of a portable, unobtrusive and inexpensive data acquisition system.
c.) the design of feature extraction and inference methods.
d.) the collection of data under realistic conditions.
e.) the flexibility to support new users without the need of re-training the system.
f.) the implementation in mobile devices meeting energy and processing requirement [7]

The different types of human activities are recognized in two different ways as shown below:-

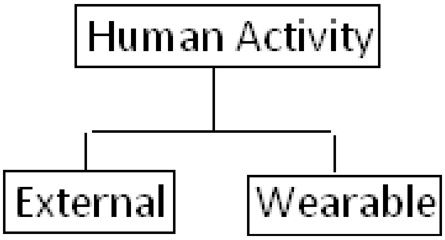

Figure 1: Human Activity Recognition Approaches

In the external approach, the devices are fixed in predetermined points of interest, so the inferences of activities entirely depend on the voluntary interaction of the users with the sensors.

Intelligent homes [8]-[11] are typical example of external sensing. These systems are able to recognize fairly complex activities. For example, eating, cleaning of house and washing of dishes. Since they rely on data from a various sensor placed in target objects which peoples are supposed to interact with. The drawback with this system is that, nothing can be done if the user is out of the reach of the sensor or they perform activities that do not require interaction with them and the installation and maintenance cost of the sensor usually entails high costs.

Camera is also considered as an external sensor for Human Activity Recognition. In fact, the recognition activities and gesture from video sequences has been the focus of extensive research [12]-[14]. This is suitable for security, and interactive applications. Another memorable example, is the kinect game console [16] developed by Microsoft. The users are allowed to interact with the game by means of gestures, without any controller devices. Nevertheless, video sequence certainly has some issues in Human Activity Recognition. Privacy, Pervasiveness and Complexity [95] are some of them.

II. General Structure

The activity recognition process is made up of two stages known as Evaluation Process. The Evaluation process consists of :

a.) Training
b.) Testing

The training stage initially requires a time series dataset of measured attributes from individuals performing each activity. The dime series are split into time windows to apply feature extraction by filtering relevant information in the raw signals. Later, Learning methodologies are used to generate an activity recognition model from the dataset of extracted features.

Similarly for testing data are collected during time window, which is used to extract features. Such feature set is evaluated in the earlier trained learning model, generating a predicted activity model.

The generic data acquisition architecture for Human Activity Recognition System using wearable sensor is shown below in Figure 2.

Here, First Wearable sensors are attached to the person's body to measure attributes of interest such as motion [17], location [18], temperature [19], ECG [20] and lots more. These sensors should communicate with a device known as integration device which can be mobile phone [21], [22], a PDA [19], a laptop [20], [23] or a customized embedded system [24]. The main purpose of this integration device is to preprocess the data received from the sensors and transmit them to an application server for real time monitoring, visualization and or analysis [20],[25].

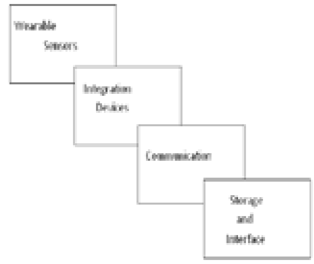

Figure 2: Generic Data acquisition architecture

III. Evaluation of System

The evaluations of Human Activity Recognition System that rely on wearable sensors are categorized in two levels [95].

a.) Supervised or Semi Supervised
b.) Online or Offline.
The semi supervised approaches are also implemented and evaluated offline.

Online schemes provide immediate feedback on the performed activities. On the other hand, offline approaches either need more time to recognize activities due to high computational demands or are intended for applications that do not require real-time feedbacks. These classes of activity recognition systems have very different purposes and associated challenges so they are evaluated separately. The evaluation process encompasses the mentioned aspects as:

a.) Recognized activities
b.) Type of sensors and the measured attributes
c.) Integration device
d.) Level of obtrusiveness which could be low, medium or high
e.) Type of data collection protocol, which could be low, medium or high.
f.) Classifier flexibility level, which could be either use specific or monolithic
g.) Feature extraction methods.
h.) Learning Algorithm
i.) Overall accuracy for all activities.

A.) Online Human Activity Recognition Systems: The applications of these systems can be easily visualized. In Medical sciences, continuous monitoring patients with physical and mental pathologies become crucial for their protection, safety and recovery. Likewise games for children may rise experience by considering activities and gestures. The most important works on online human activity recognition systems are describe as:

a.) Maurer et al.: Maurer et al. [25] introduced eWatch as an online activity recognition system which embeds sensors and a microcontroller within a device that can be worn as sport watch. Four sensors were involved, namely an accelerometer, a light sensor, a thermometer and a microphone. These were passive sensors and as they are embedded in the device, no wireless communication is needed. Hence, eWatch is considered as most energy efficient device. Using a C4.5 decision tree and time-domain feature extraction, the overall accuracy was up to 92.5% for six ambulation activities, although they achieved less than 70% for activities such as descending and ascending. The execution time for feature extraction and classification is less than 0.3 ms, which makes the system very responsive. However, in eWatch, data were collected under controlled conditions, i.e. a lead experimenter supervised and gave specific guidelines to the subjects on how to perform the activities [25].

b.) Vigilante: The authors proposed Vigilante [47], a mobile application for real time human activity recognition under the Android platform. The Zephyr's BioHarness BT [78] chest sensor strap was used to measure acceleration and physiological signals such as heart rate, respiration rate, breath waveform, amplitude and skin temperature, among others. The C4.5 decision tree classifier recognized three ambulation activities with an overall accuracy of 92.6%. The application can run for up to 12.5 continuous hours with diverse characteristics participated in training and testing phases, ensuring flexibility to support new users without the need to re-train the system. Unlike other approaches, Vigilante was evaluated completely online to provide more realistic results. Vigilante is moderately energy efficient because it requires permanent Bluetooth communication between the sensor strap and the phone.

c.) Tapia et al.: This system recognizes 17 ambulation and gymnasium activities such as lifting weights, rowing, doing pushups etc, with different intensities. A comprehensive study was carried out, including 21 participants and both subject-dependent and subject-independent studies. The average classification accuracy was reported to be 94.6% for subject-dependent analysis whereas a 56% of accuracy was reached in the subject-independent accuracy is 80.6%. This system works with very obtrusive hardware i.e. five accelerometers were placed on the user's dominant arm and wrist, hip, thigh and ankle, as well as a heart rate monitor on the chest. Besides, all these sensors require wireless communication, involving high energy consumption. Finally, the integration device is a laptop, which allows for better processing capabilities, but prevents portability and pervasiveness.

IV Future Research Consideration

The future research considerations with Human Activity Recognition system includes:

a.) Multiattribute Classification.
b.) Concurrent and Overlapping Activities.
c.) Composite Activities.
d.) Activity Recognition Dataset
e.) Cost-Sensitive classification.
f.) Crowd Human Activity Recognition etc.

V. Conclusion

This paper surveys the state of the art in Human Activity Recognition based on wearable sensors. The whole survey was based on two level taxonomy which is based on response time and learning scheme. Twenty eight systems are qualitatively compared in regards to response time, learning approach, obtrusiveness, flexibility, recognition accuracy and lots of design issues. Finally, various ideas are proposed for future research to extend this field more realistic and pervasive scenarios.

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