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An automatic data mining method to detect abnormal human behaviour using physical activity measurements

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ABSTRACT

Abnormal human behaviour detection under free-living conditions is a reliable method to detect disorders and diseases in healthcare applications. The problem with current methods to detect human behaviour changes is the use of supervised techniques that require human intervention. This work proposes an automatic data mining method based on physical activity measurements. Abnormal human behaviour is detected as an increase or decrease of the physical activity according to the historical data. Human behaviour is evaluated in real time grading its abnormality. The method has been validated involving users with a precision of 100% and a recall of 92%.

1. Introduction

In recent years, several human behaviour studies have been carried out [1]. These studies are related to the early diagnosis of diseases such as insomnia or dementia and the monitoring of other diseases such as COPD (Chronic obstructive pulmonary disease) [2,3] or CF (cystic fibrosis) [4]. Early symptoms of these diseases can be detected by analysing human behaviour and identifying abnormal behaviour as changes in routines. Physical activity, defined as any body movement produced by skeletal muscles resulting in energy expenditure [5], is a good indicator of the health status of a person [6] and can be used to sense changes of behaviour.

Abnormal detection refers to finding patterns in data which do not conform to normal or expected behaviour [7]. Abnormalities in data can be translated to significant and critical actionable information. In the human behaviour field abnormalities are defined as significant changes in the activity level of a user not expected according to his usual activity level [8,9]. They are useful to detect and monitor health diseases such as Alzheimer or dementia. Fig. 1 describes the three main stages of an abnormal human behaviour detection method according to the guidelines given in [10]:

- Human behaviour measurement: In this stage two main fields should be studied: sensors and measurement. Several sensors and magnitudes can be used to measure human behaviour. The reliability of a human behaviour measurement method is related to the reliability of the sensors and magnitudes selected. Ambient and wearable sensors are the two main alternatives used to measure human behaviour [1]. The magnitude used for the measurement depends on the kind of sensor selected.

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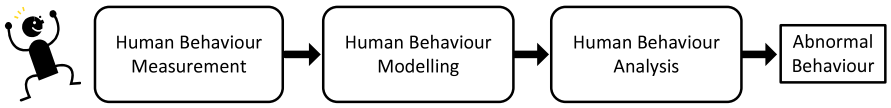

Fig. 1. Stages of an abnormal human behaviour detection method.

- Human behaviour modelling: Human behaviour measurements are used to model human behaviour. In this stage, a human behaviour modelling algorithm is used to determine the reference behaviour. This algorithm must be dynamic and easily adjustable to human behaviour changes according to different circumstances. One of the main applications of human behaviour modelling is related to context-aware applications. Two main approaches to human behaviour modelling can be found in scientific literature [1]: activity recognition and discrimination.
- Human behaviour analysis: This is the main stage of the method and its output determines when human behaviour is abnormal. The human behaviour model built in the previous stage is used to perform the analysis in this stage. An algorithm for abnormal detection must be implemented to detect significant abnormal human behaviour while minimizing error in the detection.

The main challenge in the state-of-the-art methods to detect abnormal human behaviour is related to human behaviour measuring and modelling. Sensors and magnitudes used to measure human behaviour in pervasive environments should be objective [11] and should minimize users' reluctance and invasiveness [12]. In [1] several supervised methods to model human behaviour are reported highlighting their challenges in real-world scenarios. Human bias introduced during model enunciation [13] (labelling and training stages) and the lack of standard datasets complicate the enunciation and validation of a standard human behaviour model. Therefore, research into a non-invasive and autonomous system to measure human behaviour in real time while improving long-term performance is required.

To this end, an abnormal human behaviour detection method based on an automatic data mining approach is proposed in this work. The method is based on physical activity measurements and provides a holistic solution to identify changes in routines (abnormal human behaviour) for healthcare purposes. The solution works in real time using human behaviour measurements based on physical activity. Historical data is used to model human behaviour without assuming theoretical models, only but rather information about the last physical activity levels of the user. Detection of abnormal human behaviour relies on this model, using data mining techniques based on statistical parameters to determine when user behaviour is abnormal.

The paper is organized as follows. Section 2 introduces work about abnormal human detection focusing on the three stages shown in Fig. 1. Section 3 describes the stages of the proposed method and in Section 4 the experiment to validate it is presented. The results of two experiments with users under free-living conditions are detailed and discussed in Section 5 and the results are summarized in Section 6.

2. Related work

2.1. Human behaviour measurement

Two main alternatives to measure human behaviour can be found in scientific literature: ambient sensors and wearable sensors.

Ambient sensors are embedded in user environments. They are usually integrated in common objects or in common locations providing pervasive sensing in free-living environments. The integration of ambient sensors in smart homes is a widely used approach to measure human behaviour.

Several works have researched the use of smart homes with different kinds of sensors embedded in the environment [14]. Cameras [15], electricity usage detectors [16], RFID (radio-frequency identification) sensors placed on furniture [17] and motion sensors [18] are examples of ambient sensors used to measure human behaviour and to detect abnormalities in a smart home environment.

Information gathered by multi-modal and ambient sensors can be used to predict and to prevent health risks by healthcare platforms or alarm-triggering systems [19]. However ambient sensors like cameras can be intrusive in some scenarios and can be seen as a privacy issue by users.

Wearable sensors refer to sensors that can be worn by users. Although they are more accurate than ambient sensors to measure the human body, some works report their invasiveness [14] and the reluctance of some users to wear them [4]. The solution is to integrate sensors in clothes or clothing accessories to achieve an accurate wearable measurement method without invading user privacy. Commercial wearable sensors (Fitbit, JawBone Up, Nike+ Fuelband) are available in the market as an example of this strategy. They are mainly integrated in wrist accessories with sport-tracking purposes.

Accelerometers are the most common wearable sensor used to measure human behaviour through physical activity. They are small, lightweight and portable, and motion can be recorded to provide an indication of the frequency, duration, and intensity of activities [20]. Their drawback is the lack of standards for conversion of the raw output of an accelerometer