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Detecting abnormal behaviours of institutionalized older adults through a hybrid-inference approach

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ABSTRACT

Residences for geriatric patients are usually understaffed, with each caregiver being in charge of several residents. A caregiver must assess the well being of residents and report to the medical staff if there is something unusual with a resident. Deviations from the routine will trigger an alarm, and automatic tools can help in making timely decisions.

In this paper, we explore three visualization metaphors aiming at providing caregivers with an individualized overview of the activities carried out by residents in a given time frame. We postulate that this overview is sufficient to distinguish between normal and abnormal periods of time when visually compared in groups. We also present two automated approaches, data driven and knowledge driven respectively, to detect abnormalities. The visualization and the automated approaches are tested on a naturalistic dataset obtained from a long-term personalized sensing and annotation campaign in a residence for geriatric patients. Data is of two types, obtained from IoT infrastructure and wearables and from manual annotations made by the staff. Both approaches were empirically evaluated and validated in the paper. A side product of this research is a large repository of cleansed data from the sensing and annotation campaign for 45 older adults over a period of 39 months.

1. Introduction

Institutionalized older adults living in residences for geriatric patients [1], demand specialized and personalized care, depending on their mental and physical decline and other conditions exhibited [2]. The Internet of Things (IoT) enables the development of Assistive Technologies (AT) [3] to locally or remotely monitor patients through sensors [4], devices [5] and applications [6]. These AT have permeated to the domain of older adult healthcare. Sensors, devices and applications enable the generation of life-logging [7] and healthcare records from older adults. Diverse types of data from various sensor sources embedded in the environment are produced automatically. This structured data has an intrinsic value and can be supplemented with relevant and unstructured information about older adults (visits, food, showers, etc.) recorded manually by the caregiver. Taken together, data gathered from automatic and manual sources are diverse and vast. Moreover, after the data is processed and analysed correctly [8], its intrinsic value increases. The study and analysis of large amounts of data from mixed data sources pose certain challenges [9]. The challenge of *variety* is tackled in this work: it relies on the combining of old-fashioned and new forms of data, as well as the transformation of unstructured and semi-structured data through the use of effective processing platforms equipped with data mining, machine learning and semantic techniques.

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In this paper, we combine data-driven and knowledge driven approaches [10] in the analysis of personal data about older adults in a residence for geriatric patients. This combined approach was taken because the data obtained from the sensing and annotation campaigns are diverse and complementary. We observed that data-driven approaches (DDA) have a good performance [11], with the analysis of raw sensor data using machine learning techniques, although an important disadvantage of this approach is the generation of a *generic user model* from the data [12]. This suggests that sometimes the personalization may be compromised [13,14], and in health care domain, individualization is crucial to the provision of a better quality of attention [15–17]. On the other hand, knowledge-driven approaches (KDA) use a semantic schema where caregivers' annotations can be modelled easily. However, an exhaustive analytic process cannot be taken with this approach [18,19]. One further step in individualization addressed in this paper is the design of three different visualization tools allowing comparison of the behaviour of one resident over a given time frame. The proposed visualization metaphors allow a quick overview of the period of time, and based on comparisons of other periods of time of the same individual, the caregiver can quickly judge if the given time frame is normal or abnormal.

This paper is structured as follows. In Section 2, related work is presented. Section 3 describes the dataset and the main components of the proposal. The evaluation settings and experimental results are shown in Section 4. Section 5 includes the discussion and an explanation of the limitations. Finally, we present the conclusions in Section 6.

2. Related work

In this paper, we detect abnormal behaviour by analysing the daily activities of older adults to assist caregivers when providing personalized care. Hence, the literature review includes AT which provide supporting tools for older adults' care. Analysis of behaviours has been tackled from two perspectives (i.e. DDA and KDA) which are also presented in this section. One goal that this behaviour analysis pursues is to detect abnormalities and deviations in behaviour; therefore, the various techniques and methods to achieve this goal are discussed here, too.

2.1. Assistive technologies

The literature reports a vast number of research efforts with a focus on AT used to support independent older adults living at home, such as monitoring systems to provide care without any need to visit hospitals [20]. There is also research into AT used to support physicians in providing timely diagnosis [21]. The AT designed for informal caregivers aims at reducing their burden at home. There is, however, a lack of tools to support formal caregivers in the performance of their daily task and the easing of their burden in residences for geriatric patients [22]. Our approach is intended to be used by formal caregivers keeping a personal log of institutionalized older adults.

2.2. Behaviour analysis

Although human behaviour is convoluted and not easily defined, humans tend to execute sequences of actions in specific spaces and within the same time frames during periods of time. Think, for example, of the actions involved in taking a shower, having breakfast, driving to work, etc., in a daily cycle. Over longer cycles, e.g. a year or a season, there is also a pattern, and so on. Older adults may tend to have a highly periodic set of daily routines performed every day [23].

There is no consensus on the definition of behaviour [24–27], but from the point of view of computer science literature, behaviour has been tackled as the analysis of activities [28–30]. For the purpose of this work, behaviour is defined as a repetitive sequence of activities, taking into consideration the frequency of the sequence of activities over a period of time. DDA and KDA address this behaviour analysis [10]. In the former, machine learning [31] and data mining [32] techniques are implemented, but there is a need for plentiful data if they are to work sufficiently well. Moreover, the creation of a personalized model is not always possible, nor its re-use in other domains. The latter uses formalisms to capture the semantics of complex contexts into a semantic model, but it is not flexible enough for the model's changes in real time [19]. In this sense, in [33] a ''big data'' analysis of activities is proposed, where the authors detect behavioural changes in routines based on a sequence of activities; the activity duration time is used to compare activity curves. This approach is very useful when daily activities are recognized automatically from raw data, using activity recognition algorithms. However, executing an analysis based on duration time is a disadvantage when the activities are annotated by caregivers, because they indicate only the time when the activity occurred. The authors of [34] propose a behaviour analysis taking into account data collected from a sensor network based on the occupancy of areas of the home. Instead of performing only a quantitative analysis, the authors also execute a qualitative analysis to compare the results with the original data annotations. This suggests that more information is needed than only that originating from sensors, to incorporate more semantics into the context and enrich the results of the quantitative process. Once the analysis of activities is performed, the detection of abnormalities is a natural next step.

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