Monitoring and Modeling the Every-Day Behavior of People with Special Needs

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***Abstract*— We present preliminary work on a sensor-based system that we are currently implementing with the aim of monitoring the health of the elderly and people with special needs. The system functions both inside and outside the home of the monitored individuals, using sensors and GPS-enabled cellular phones. Its objective is to first learn the daily behavior of the monitored individuals, and then detect changes in their routines and health status, providing alerts and a preliminary diagnosis as quickly as possible when something out of the ordinary occurs.**

I. Introduction

This short paper serves as an introduction and a presentation of our preliminary work on ARCHANGEL, a sensor-based system we are currently implementing, that focuses on monitoring the health of the elderly and people with special needs. The system relies not only on location sensors, but also on GPS-based location tracking. Its main objective is to detect changes in the health status of the individuals that it monitors, and to provide alerts and a preliminary diagnosis as quickly as possible whenever something out of the ordinary occurs. This takes place both inside (using sensors) and outside the home (using positioning-enabled cellular phones) of the monitored individuals. A secondary function of the system will be the actuator-based automation of certain tasks inside an individuals home, exploiting the history of an individuals actions to build a profile of its “standard” behavior. This will simplify certain aspects of the individuals life inside their home because common tasks will be automated (such as, for example, automatically switching on the TV when a certain pattern of movement is detected in the living room). Finally, using location tracking (based on GPS-enabled cellular phones), the system will be able to detect an individuals location when outside their home; if something out of the ordinary occurs (such as a change in the usual pattern of everyday walking), an alert can be issued. These alerts will be propagated over the cellular network and the Internet to the appropriate location, where filtering software will decide whether to forward the alert to qualified human caretakers.

Our aim for the prototype is to build it using off-the-shelf sensors and GPS-enabled cellular phones, and to use standard software platforms both for the mobile side (Windows Mobile) and the server side (Windows, Linux). Finally, we will provide a user-friendly interface to the human caretakers. In addition to a fully functional prototype that will showcase all the components and interfaces of our architecture, the system will be evaluated using simulations that will show how our architecture scales, and at what cost. It is perhaps obvious that, in addition to alerts that are triggered when something out of the ordinary occurs at home, the GPS-based location tracking component is also crucial because, if, for example, an individual has not returned home within a reasonable timeframe (based on earlier behavior which the system learns and adapts to), an alert can be issued, and hopefully, the individuals location can be pinpointed with sufficient precision. This would allow people suffering from memory and orientation problems to be traced by caretakers.

The general research aim of our project is to realize a holistic framework that will support all these functions, and to test its performance in a controlled trial setting. In this context, the project aims to design, implement, and validate a cost-effective, secure (not compromising the monitored persons privacy), adaptable and interoperable framework for learning and monitoring the daily behavior and personal routines of the monitored individuals using advanced sensor networking, machine learning, and controlled interaction with caretakers. While in this paper we do not concern ourselves with the privacy implications of the above scenario, these will be addressed in the final version of our prototype.

II. System Models, Functions and Evaluation

According to [1], a persons actions can be characterized and grouped in certain categories based on everyday habits. Based on a data sample that was acquired by recording everyday activities using “tape on and forget” sensors in private spaces [2], we know that we can detect and identify certain actions of the monitored individuals with an accuracy of up to 89%. These identified actions can be processed to produce a useful outline of the everyday habits of persons being monitored. The research presented in [2] was based on available data obtained from the everyday life of two individuals, 30- and 80-year-old respectively. The set of actions recorded in their private spaces was obtained by sensors that were positioned in nearly 80 different locations inside their appartments. These actions were then grouped in categories, which helped make the processing of the samples easier, with the final aim always being the

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extraction of in-home patterns of common behavior. The data set, made public by the researchers, can be used in our system as input for the custom in-home mobility models that we will produce to test the systems sensor-based algorithms.

We will then attempt to statistically evaluate a persons habits in confined spaces in order to create rules that will help to identify common behavior [3], [4]. Specifically, we will annotate the in-home actions depending on where exactly each one occurs (such as, the bedroom, kitchen, bathroom). We will then produce rules based on the actions detected at home (for example, the estimated time for each task and at what time of day it occurs), and also according to the precise location where these actions occur (for example, if the individual is in the kitchen, then in all probability a meal is being prepared), and according to the sensors that detect the specific action (if sensors in the oven are triggered it is very probable that a meal is being prepared). In the case where there is a discrepancy between the learned rules stored in the system (for example, the individual did not eat lunch or has not taken its medication), then the system will activate alarms for the specific monitored individual. It is possible that the specific expected action can happen later in the day, in which case the alarm can cease; however, in case the expected ("normal") action does not occur within a reasonable timeframe, this could indicate the need for the caretakers to intervene.

In addition, using the GPS-based location tracking system, we will trace the individuals outside their home so as to trigger an action in case an individual deviates from its normal path. Finally, an additional avenue for possible research would be to implement and train a prediction system for the actions of the subject, relying on Neural networks or Markov chains. This way, with some training of the system, we will be able to predict with certain accuracy the subjects next action at home or outside the home (for example, which locations the subject is probably about to visit) and further reduce the probability of wrongly identifying a persons behavior.

III. Architecture

The system architecture comprises two major components: the Monitoring Environment consisting of the software and hardware components that collect, format and encrypt sensor data for the monitored individuals, and the Diagnostic Environment consisting of the software components that: 1) identify high-level events, 2) construct a behavior model for each individual, 3) allow entering handcrafted monitoring rules, 4) use the behavior models and the hand-crafted rules to detect conditions that require a caretakers attention, and 5) extract generic patterns representing correlations between known diagnoses and aggregated behavioral models, which are then compared against individuals behavioral models and diagnostic data to assess possible health risks. Specifically, the two major components have the following sub-components:

A. Monitoring Environment

1) Indoor Area Component (IAC): It will be installed in homes and public places, comprising off-the-shelf environmental sensors embedded in various locations within an appartment, monitoring the individuals within their home environment, as well as an Indoor Gateway to gather, aggregate and process these data, producing a stream of standardized messages and allowing multi-interface communications with the URC (see below).

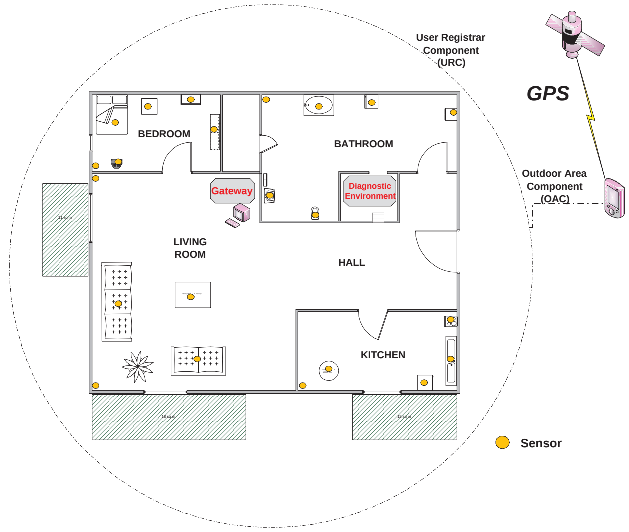

Fig. 1. System Architecture

2) Outdoor Area Component (OAC): This is software for GPS-enabled cell phones that generates standardized messages containing location data and transmits them to the URC (see below). This allows the system to keep track of monitored individuals and for their caretakers to contact them.

3) User Registrar Component (URC): This component, residing at an external location, will gather and redistribute the standardized messages for each tracked individual to the Diagnostic Environment that has registered to receive them.

B. Diagnostic Environment

1) Event Recognizer Component (ERC): This will employ machine learning to identify higher level events from lower level sensor and positioning readings. The ERC will be trained to recognize the appropriate events by the caretakers.

2) Behavior Modeling Component (BMC): This will employ unsupervised statistical machine learning to create personalized behavioral model(s) of each monitored individual, based on data received via the URC over a training period. These models will then be used to detect deviations from normal behavior. Deviations will be visible as high-level events, allowing caretakers to specify rules to handle them.

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