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BehaviorScope: Real-Time Remote Human Monitoring Using Sensor Networks

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1 Introduction

In this demonstration we present the BehaviorScope, a system for interpreting human activity patterns using a sensor network and its application to elder monitoring in assisted living[3, 1, 2, 5]. The BehaviorScope provides a runtime, user-programmable framework that processes streams of timestamped sensor data along with prior context information to infer activities and generate appropriate notifications [3, 5]. Human activities are described in high-level scripts that are directly mapped to a hierarchy of probabilistic grammars that parse low-level sensor measurements into high-level distinguishable activities. Activities of interest are pre-programmed into a specification that is used by the system to interpret the incoming sensor data stream. The system interprets the activities to generate summaries and other triggered notifications that are propagated to stakeholders via email and cell-phone text messages.

In addition to the interpretation of low-level data into high-level sematic form (human comprehensible activities), a key innovation in the BehaviorScope architecture offers a flexible, user-configurable time abstraction layer that encodes temporal information in the incoming data stream. This allows the probabilistic grammar hierarchy to consider the temporal aspects of data in the interpretation process, a feature that is not directly supported by the probabilistic grammar formalism [3]. With this property, the BehaviorScope architecture provides a unified abstraction for handling both space and time quantities when specifying activities. The time abstraction layer operates as a preprocessor to grammars, concurrently supports multiple time scales, and allows simultaneous activity recognition at different levels of spatiotemporal granularity. This accommodates the specification of a diverse set of activities with different temporal characteristics as well as the detection of activities that have varying temporal scales across different people. The system implementation also supports multiple time granularities at different levels of abstraction, allowing for the hierarchical processing of timing information.

The features and capabilities of the BehaviorScope will be demonstrated by connecting to different remote testbeds deployed in homes and in our lab at Yale that use a heterogenous set of sensors to infer behaviors. Demo attendees will be able to interact with the system in the following ways:

(1) Connect to remote deployments and examine the recorded data in real time.
(2) Issue queries, set conditions and get instant notifications about the monitored people via a mobile phone interface.
(3) Configure the BehaviorScope interpretation engine to translate the recorded data into higher level activities, and specify what notifications to receive via email and text messages.

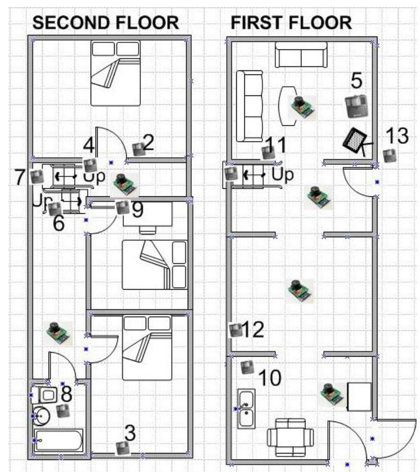

Figure 1. House Deployment

2 Deployment

An example home deployment layout is given in Figure 1. Two different sensing modalities are used to continuously monitor the elder person living alone. A network of PIR sensors records the rooms and corridors that the elder person visits over time. By examining the time-stamped sequence of PIR firings the system extracts the room transitions that are later used by the interpretation engine to understand the elder's person activity as it unfolds in time.

A sparser network of privacy preserving cameras, is used to obtain fine-grained information about the areas and loca-

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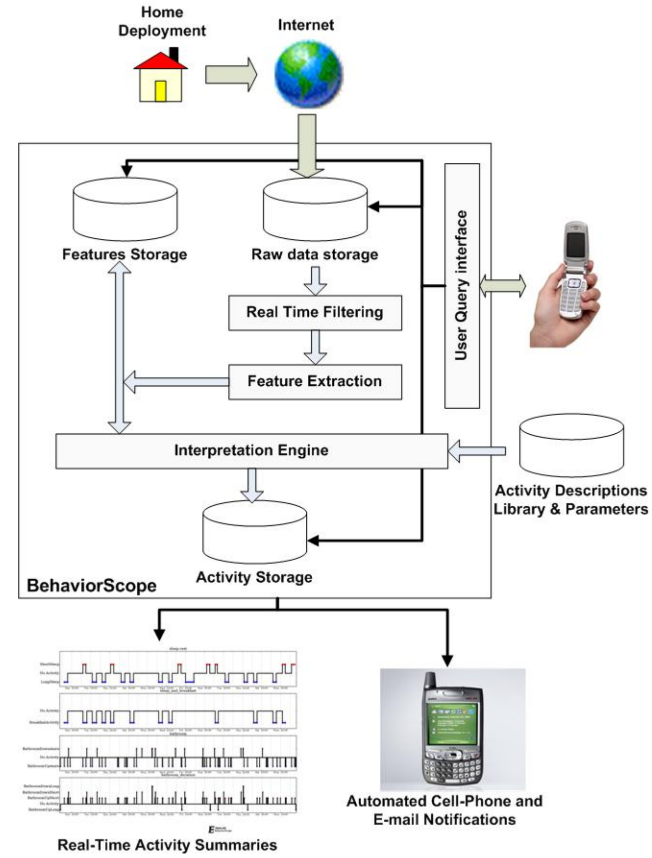

Figure 2. Behavior interpretation process

tions that the monitored person visits over time. This network is comprised of Intel $iMote2$ sensor nodes equipped with COTS camera modules we have designed for this application. The camera nodes are attached to the ceiling pointing down into the room, and have wide-angle lenses (162 degrees) that cover most accessible areas in the house. The nodes execute a lightweight localization and counting algorithm that can extract people locations with respect to the house floor plan [4]. The overlap of people locations with pre-defined areas on the floorplan triggers the generation of a sequence of phonemes for the monitored person that are exploited by the BehaviorScope to infer activities.

3 Data Interpretation and Time Abstraction

Figure 2 outlines the data flow process of the BehaviorScope. The recorded data from the wireless sensor network is routed to a local gateway where after it is preprocessed is transferred over the internet to a central BehaviorScope server. The incoming data is stored in a database after it is filtered by an online filtering process. The filtered data is analyzed to extract basic sensing features that are stored into a feature database at the same time as they are fed into the interpretation engine. The interpretation engine parses the incoming data stream against the provided

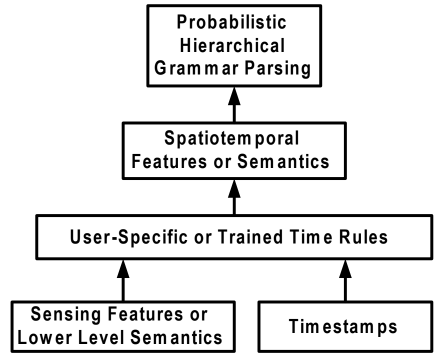

Figure 3. Time abstraction layer.

specification, to detect activities that are used to generate summaries and notifications for the end-users.

The interpretation of the sensing features is achieved using hierarchies of Probabilistic Context-Free Grammars (PCFGs) [1] and the time abstraction layer shown in Figure 3 [3]. The recorded sensing features are transformed to spatiotemporal features before they are parsed through the time abstraction layer. Based on either user-defined or automatically extracted parameters, temporal information is assigned to the sensing features by conditioning on their duration or absolute start and end times. The flexibility of our time abstraction mechanism lies on the fact that this temporal information encoding process is done on a per-sensing feature and on a per-grammar basis. Therefore, the same sequence of spatial sensing features can be concurrently mapped to totally different spatiotemporal features according to the type of the sensing feature considered or the type of the activity that has to be identified. Parsing sequences of spatiotemporal symbols generated on a per-activity basis, allows for the detection of higher level spatiotemporal activities at different levels of granularity.

References

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