CASASviz: Web-based Visualization of Behavior Patterns in Smart Environments

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***Abstract*—The need to prolong the ability for older adults to live at home independently has become an important area of smart environment research. In this proposal, we demonstrate a web-based visualization system (CASASviz) that integrates monitoring, analysis, and automated recognition of residents behavior patterns in smart environments. In our data collection module, we collect real sensor data from the CASAS smart apartment testbed. For our data adapter, we translate the raw data to various compatible formats for different visualization applications. In our visualization application module, we visualize resident behavior graphs that allow users to understand their behavior patterns in our smart environments.**

***Keywords*-smart environments; visualization; heat map; activity graph; behavior patterns**

I. Introduction

It has been a long-lasting interest in developing in-home based technology to improve the quality of care-giving systems, and in turn, to prolong the ability of older adults to live independently at home and avoid institutionalization. Researchers [1],[2] have pointed out that using assistive device and environmental interventions can reduce home care costs and allows older adult to live independently. To assist older adults and people with disabilities to live independently, concept of smart environments [3] has become popular. The goal of the current project is to improve the accessibility of smart environment technology to the public by creating a user-friendly, visualized interface that would allow easy access to the information gathered from smart home (e.g., data from different types of sensors).

To achieve this goal, three essential objectives shall be met: (1) develop a friendly graphic interface to better represent the data gathered from different sensors in smart home environments, (2) apply data mining and machine learning techniques to analyze, understand, and classify resident behavior patterns, and (3) ensure that the system is compatible in desktop and mobile platforms. To meet the first requirement, PyViz [4] has been developed to provide a user-friendly, rapidly deployable method for data visualization in the Center for Advanced Studies in Adaptive Systems (CASAS) [5] at Washington State University . In view of all three requirements, we extent Pyviz tool to develop a web-based visualization system, called CASASviz, to represent and explore residents' behavior patterns. To implement the CASASviz, we use Scalable Vector Graphics (SVG) [6], which is an application of XML-format that makes it possible to describe two-dimensional vector graphics. CASASviz also extends the suffix tree method to look for long-term and abnormal patterns of the residents. To be compatible with different platforms, we use web-based technologies. Thus, CASASviz can be used on Windows, Linux, and even smart phones without worrying about compatibility. Figure 1 shows the CASASviz interface on an iPhone device.

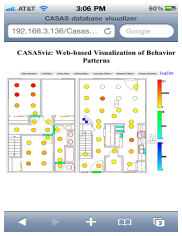

Figure 1. The interface of CASASviz on an iPhone platform.

II. CASASviz System Architecture

Figure 2 shows the system architecture of the CASASviz system. The functionalities of each component are briefly described as follows:

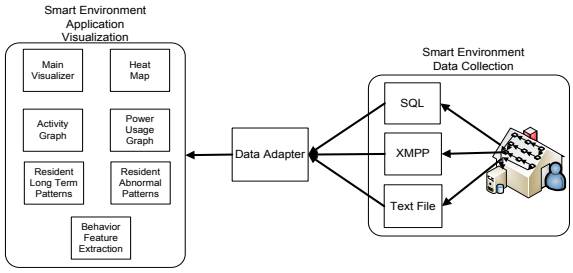

Figure 2. System Architecture of CASASviz System.

- The Data Collection module collects the sensor data gathered from our CASAS smart environment and stores the sensor data in an SQL database or the XMPP middleware. As an option, our system also supports importing the raw data from the data file.

- The Data Adapter module provides the interface for accepting different formats of sensor data and translates these sensor data into different compatible formats for various visualization applications.
- The Visualization Application module is an integrated web-based interface, which implements seven different visualization applications. We will introduce the details of these visualization applications in the following parts.

A. Data Collection Module

The smart home environment testbed that we are using to collect the data is a three bedroom apartment located on the Washington State University campus.

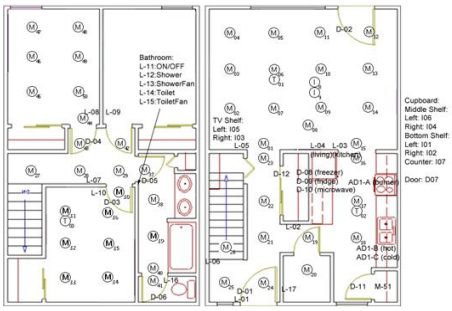

Figure 3. Three-bedroom smart apartment used for our data collection (motion (M), temperature (T), water (W), burner (B), telephone (P),and item (I)).

As shown in Figure 3, to track people's mobility, we use motion sensors placed on the ceilings. A power meter records the amount of instantaneous power usage and the total power usage. An in-house sensor network captures all sensor events. The data from the CASAS smart environment can be accessed for CASASviz in three different ways:

- PostgreSQL database
- Streaming live data over XMPP middleware
- Exported data File

All data is stored in a PostgreSQL database. CASASviz can query, load, and visualize events for a specified time period. Alternatively, the events from the database can be exported into a data file. The data file can also be loaded and played back by CASASviz. To track the resident's mobility in real-time, CASASviz can subscribe to the middleware and play live streaming events in real-time. After collecting data from the CASAS smart environment, the researchers [7] annotated the sensor events with the corresponding activities that were being performed while the sensor events were generated. The sensor data and activity labels used for our study are expressed by several features summarized in Table 1. These four fields (Date, Time, Sensor ID and Message) are generated by the CASAS data collection system automatically.

Table I
SAMPLE OF SENSOR EVENTS AND ACTIVITY LABELS USED FOR OUR DEMO

Date	Time	Sensor ID	Message	Label
2009-07-14	17:10:00	M045	ON	Computer ends
2009-07-14	17:10:06	M046	ON	
2009-07-14	17:10:08	M046	OFF	
2009-07-14	17:12:26	M017	ON	Cooking starts
2009-07-14	17:12:27	D014	OPEN	

B. Data Adapter Module

Since there are three different data sources assessed to our CASASviz, we develop a Data Adapter module to translate three different original data formats to a compatible interface for various visualization applications. And we use the adapter pattern expressed in UML to implement the Data Adapter module in our CASASviz system.

C. Visualization Application Module

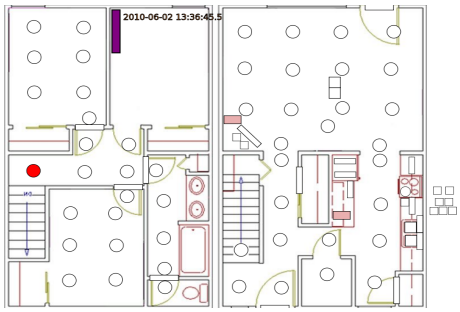

Figure 4. CASASviz main visualizer interface.

1) Main Visualizer: Figure 4 shows the interface of our CASASviz main visualizer. As shown in the figure, the red circle represents the location of the resident in our CASAS smart environment. Through XMPP middleware, we can monitor the resident's mobility in real time. We also provide playback mode from a captured file or SQL database storing the sensor readings for reviewing the mobility history of the resident.

2) Mobility Heat Map: Figure 5 illustrates the mobility heat map of our CASASviz visualization, which describes the frequency of the sensor events triggered by the residents by incremental colors. The heat map uses three different color sets (yellow, green, blue), which represent the frequency of motion sensors, door sensors, item sensors respectively, in the specified time window. Higher frequencies are represented by dark colors and lower frequencies are represented by lighter colors.

3) Activity Graph: As seen in Figure 6 a graph of annotated activities can be generated from a single or multiple annotated data files and each color stands for a monitored activity. With the help of an activity map, researchers can identify changes of behavior patterns of

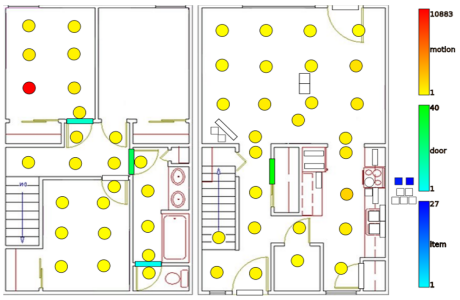

Figure 5. CASASviz Mobility Heat Map.

an inhabitant and look for anomalies in this data. Visually comparing differences between human-generated and AI-generated annotations has also been done using Activity Graphs.

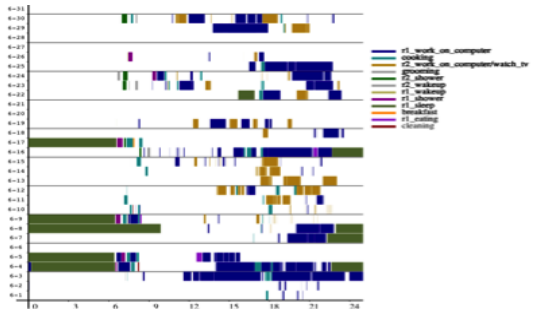

Figure 6. CASASviz Activity Graph.

4) Power Usage Visualizer: In smart environments, power usage is also an important factor to represent behavior patterns of the residents. As shown in Figure 7, CASASviz provides an energy usage visualizer to express energy fluctuations that occurred during the time the user defined. This graph can be used to identify trends and abnormalities of power consumption.

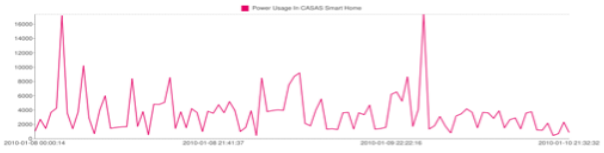

Figure 7. CASASviz Power Usage Visualizer.

5) Long-term and Abnormal Patterns Visualizer: To discover long-term and abnormal behavior patterns of the residents, we extend a data structure of suffix tree as an efficient sensor event representation to analyze the global structural patterns of sensor events. Intuitively, for a sensor stream S, we consider a sensor pattern p in S to be an anomaly, if the frequency of this pattern does not satisfy a pre-specified threshold. If the frequency of the pattern is one of the highest in all the patterns, we define this pattern will be a long-term behavior pattern for the resident.

6) Activity Feature Extraction: In smart environments, we need to use machine learning techniques to make predictions and recognitions. Before using these learning algorithms, feature extraction module extracts useful features or attributes from the raw annotated data that would be helpful in prediction and recognition. The following is a listing of the resulting features that we used in our ongoing prediction experiments.

- Activity length in time (in seconds)
- Time of day (morning, noon, afternoon, evening, night, late night)
- Weekday / weekend
- Number of kinds of motion sensors involved
- Energy consumption for an activity (in Watt)
- Motion sensor (ON/OFF)

III. Techincal Requirements

This demonstration will require the use of one large size monitor or television with a DVI/VGA connection, and 3-prong wall outlets to power our laptop. We also need an Iphone or Android smartphone to display our webpage.

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