CSC 400
Persim: Simulation of Human Activities in Pervasive Spaces

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Abstract

Today, the computing elements are pervading through our environment that brings cyber-physical research as an emergent computing paradigm. Computational and physical elements have become so intertwined with each other that computing is embedded in almost all everyday objects. This has opened a new dimension to various research areas such as assisted living, health care, elder care etc. Researchers are engaged in developing new algorithms and techniques in machine learning and data mining in order to detect activity, learn context, and act autonomously without any human intervention. Thus cyber-computing research involves building and instrumenting a smart space, recruiting participants, and finally collecting data from the space. To obtain data from physical deployments is crucial in order to longitudinally evaluate the accuracy and performance of the developed models and algorithms. But this is very challenging because of the huge cost, significant ground work, lack of access to human subjects, and the time consuming process of acquiring meaningful data from real world settings. Now, the community needs a ‘supportive’ research initiative which will look for alternative and practical approaches to overcome aforementioned challenges and accelerate experiments with the smart space. Realistic simulation is a promising idea to support the rising demand for test data. Simulation also allows a wider community of researchers to engage and collaborate to solve a specific problem. Hence, algorithms and models based on preliminary simulation studies would most likely to be a more robust and help researchers assess their ideas and algorithms quickly and cost-effectively.

In this proposal, an event-driven simulation tool – Persim is proposed to simulate hierarchical activities in pervasive space. The idea is to create a simulated environment of actual pervasive space via modeling activity and generating activity data in standardized format corresponding to the environment. Such simulations can be used in early stage research that can help researchers evaluate their ideas quickly and with reasonable accuracy. The tool is intended to create a knowledge base for human activities and emulate specific scenarios. It can also be used for automatic annotation of dataset based on the knowledge base.
Project Description

In order to design a simulator that is free from the limitations of actual space deployment and capable of generating human activities, we can face a number of challenges. Few of those are:

- How to define an actual space in terms of its intrinsic elements such as area, sensors, actuators and extrinsic elements or events like ‘a person is cooking’, ‘room temperature is changed from 60F to 62F’ etc.?

- How to support the large set of diverse and heterogeneous elements of the space and extend the utility of the simulator over time?

- How to define the semantic of an activity in terms of sensors?

- What parameters are essential for the simulation model to generate activity events?

- How to represent the simulated dataset to the world in a way to foster collaborative research?

Keeping these questions in mind, we have to design Persim as an event-driven, human activity simulator that is capable of capturing the physical elements of a space including its sensors, actuators and human activities. Data generated by Persim follows the Sensory Dataset Description Language (SDDL) proposed standard to foster collaborative research. The simulator is component based where the major components are Space, Sensors, Actuators, and Activities. An activity can be detected by one or more sensors. To define the semantics of the activity in terms of corresponding sensors, an Actuator-Sensor Mapping table is required. The mapping captures the dependency of a specific activity on a specific set of sensors by a causal relationship.

Persim should allow building a simulation “project” over multiple sessions before they are ready to generate data or make a multitude of changes to the sensory elements, the activities or even the structure of the output dataset. There are five essential steps to create a simulation project. First, a space and its various areas must be defined. User may choose space templates (e.g., single family home, apartment, assisted living facility, etc) and design customized simulation environment. In the second step, different types of sensors and actuators can be added into the various areas of a space. Each sensor or actuator is defined in terms of type, function, sensor event generator, domain value generator, among other important information. In the third step, activities and actuation rules can be added. Actuation rules specify the logic of the actuation
based on sensor events and in terms of invoking actuator(s). In the fourth step, two important mappings are prescribed by the user: activities-to-sensors mapping and actuators-to-sensors mapping. The former mapping specifies which sensors are relevant to the detection of each activity. In the latter mapping, each actuator is mapped twice, once to the set of sensors that could trigger it, and once again by the set of sensors that could be affected by that actuator when triggered. In the final step, simulation parameters like simulation start and end time, activities to be simulated have to be specified.

In this way Persim will generate activity data in any amount for diverse scenarios. Since data collected from a particular experimental setup is constrained by the hardware infrastructure and research-implicit goals/contexts, depending on the event captured by the dataset, it may not be useful to some researchers without minor alterations. Persim is designed so that the user can load a SDDL file of an experiment and create the simulated environment from it. This can assist the researcher to modify the underlying experimental setup of the already collected data and explore additional goals which were not thought of during data collection. In this way, Persim can be useful to extend the utility of a dataset for further research. Thus Persim is intended to open a new dimension of collaborative research in the area of human activity recognition and ubiquitous computing applications.

**Research Plan:**

The goal of the Persim project is to support activity recognition research in areas like assisted living, elder care etc. In this project we want to achieve the following:

1. **Activity modeling:** Modeling human activities is the most challenging part. We need to model human activities to properly to get the benefit of the tool. We can use hierarchical activity modeling to model complex activities.

2. **Create focused simulation:** Persim can be used as a tool to create focused simulation in order to achieve particular research goal. This can save a tedious and time consuming process of running the experiment in the real space and collecting data for all possible test cases. For example, one can simulate two sets of data of ‘wash hand’ activity for a person with or without Alzheimer disease. In the former case, the dataset can have a water flow sensor running at the end of the activity since the patient may forget to turn on/off the water. In later case, the water flow sensor should be off almost all the time. These two different sets of data can be very useful in the research of assisted living of patients with Alzheimer disease.
3. Reproduce experimental data: A researcher should have the flexibility to reuse the same simulation environment and generate data as many times as needed and at any extent. For example, a researcher may want to collect data for detecting the walking pattern of an obese person in the home setting. Often activity recognition algorithms do not perform well if sample data size is small. The researcher may find his/her test data to be too inadequate to detect the activity with reasonable accuracy. It may be infeasible and time consuming to recruit obese people for walking and re-do the experiment again to collect required data.

4. Create knowledge base: We can apply machine learning technique to create the knowledge base for both the simulated and actual activity. This can later be used for activity recognition and detecting potential danger in automated living units.

5. Validate activity data: We should also validate the fidelity of the simulated data against real world deployment.

6. Create inventory of datasets: Persim can be utilized to create specialized inventory of datasets and contribute to the critical problem of obtaining home-activity data. Therefore, instead of engaging huge of effort to build a smart home and collect the test data, researchers can focus on ‘actual’ research problem. By using the knowledge repository they can try different approaches quickly and cost-effectively and evaluate the accuracy of their early stage algorithms.