A Novel Approach to Predict Resident Activity in IoT based Smart Home

Rakshith M D\textsuperscript{1}, Harish H Kenchannavar\textsuperscript{2} and Thyagaraju G S\textsuperscript{3}

\textsuperscript{1}Computer Science & Engineering, SDMIT, Ujire
\textsuperscript{2}Computer Science & Engineering, GIT, Belagavi
\textsuperscript{3}Computer Science & Engineering, SDMIT, Ujire, thyagaraju

\textbf{Abstract}— The popularity of smart homes embedded with Internet of Things (IoT) technology has been an emerging research trend in the area of pervasive computing. Smart homes are intelligent enough to take independent decisions which are helpful in providing resident intended services resulting in increasing the comfort of the resident with the reduced cost. This paper proposes an approach where the resident activity is predicted in the IoT based smart home by using the following steps: 1) Acquiring the data by using networked sensors 2) Context generation 3) Predicting the primitive context & activity by applying rule based association analysis on the generated context 4) Predicting the derived activity by using finite state based behavioral pattern of activities. Some of the case studies are discussed which clearly illustrates how the resident activity is predicted by using state transition diagram where each activity is represented by a state.

\textbf{Keywords}— Smart homes, Internet of Things, pervasive computing, resident, sensors, context

I. INTRODUCTION

Resident activity prediction in smart home embedded with Internet of Things (IoT) has been an emerging research trend in pervasive computing environment. To predict the resident activity in smart home the context of the resident is very much important. Context is the situation of an entity. The entity here is the resident \& the context comprises of resident attributes such as location, identity, activity, etc. The contextual attributes are captured using sensors such as RFID, Bluetooth, etc. IoT enables communication between different real-time objects such as sensors \& mobile devices. It aims at increasing the comfort of the resident in smart home. The contextual data captured by sensors are used to provide resident intended services by applying artificial intelligence techniques such as fuzzy clustering, reinforcement learning \& association analysis. Some of the applications where the resident activity is predicted are as follows: Television, Mobile, Healthcare, Smart homes, Smart cities, Smart car, etc.

Smart home is a pervasive environment which is capable of predicting the activity of the resident thereby providing the resident intended services. Predicting the activity of the resident is very much difficult task because the behavior of the resident is uncertain \& he may not often perform the same set of activities as before. This problem can be solved by observing different actions and activities that the resident performs at regular intervals. Normally, the resident tends to perform activities such as Sleeping, Reading, Taking shower, Cooking, Eating, Driving, etc. Predicting the future activity of the resident by using previously performed pattern of activities is tedious task. Therefore in this paper, an approach has been proposed for predicting the activity of the resident in the IoT based smart home based on the following steps: 1) Acquiring the data by using networked sensors 2) Context generation 3) Predicting the primitive context \& activity by applying rule based association analysis on the generated context 4) Predicting the derived activity by using finite state based behavioral pattern of activities.

II. RELATED WORK

In Pervasive computing environment predicting user intentions in IOT based applications has become an emerging research trend. Some of the applications where user intentions are predicted by
using artificial intelligence techniques are: smart television, smart mobile, smart car, smart homes, healthcare, etc. This paper concentrates on predicting the resident future activity in smart home. Therefore some of the existing smart home systems where prediction of resident activity is achieved are discussed below:

**Aditi Dixit, Anjali Naik** [1], proposed a smart home system which focuses on three basic steps for logical development of a Smart Home. The first being creation of a mobility model and representation of event occurrences as strings. The second step is to predict the most likely next state or inhabitant action by using a prediction algorithm. It helps to identify the patterns that can be automated easily with least fault occurrence. Finally, the parameters that influence the selection of a prediction algorithm. For all the tested parameters the Active LeZi Prediction Algorithm has suitable performance in predicting the inhabitant next action.

**Mohd. Marufuzzaman, Mamun Bin IbneReaz** [2], proposed a new algorithm which predicts user action by using pattern matching and reinforcement learning techniques. Hardware description language VHDL is used for modeling the algorithm. The algorithm is tested using the synthetic data and the experimental result shows that the accuracy of the proposed algorithm is 87%, which is better than ONSI, SHIP and IPAM algorithms.

**Farzad Amirjavid, Abdenour Bouzouane, Bruno Bouchard** [3] proposed a smart home system which focuses on two things 1) Modeling the activities of the resident & to discover correct realization patterns of activities. The primary data about realization patterns of actions, operations, plans, goals and generally any objective that the smart home resident may desire to do will be obtained by applying sensors. 2) Retrieving the realization patterns of activities by mining the sensor data. This is accomplished by applying fuzzy clustering techniques which results in providing the recognizable prediction patterns of resident intentions. By comparing the realization patterns with prediction patterns of activities prediction of resident activity is achieved.

**Byeongkwan Kang, Sunghoi Park** [4], proposed IoT-based home monitoring system which is developed by using a tri-level context making model for providing context-aware services. This paper concentrates on collecting the data & generation of information from sensors which results in providing the new services. The context aware services provided by the proposed IoT-based smart home system are as follows: 1) Disaster management service 2) Smart home health care service. Reinforcing the knowledge engine, collecting & processing data from additional sensors, visualizing data & information are considered as future scope.

**Phivos Mylonas, Giorgos Siolas** [5], proposed an approach which focuses on designing, modeling and providing a prominent and applied knowledge modeling personalization. The ultimate goal of this approach is to provide innovative personalized services to the users in smart home thereby enhancing their everyday life. It also shows how the users may be modeled through fuzzy knowledge formalisms & how the context may be modeled & integrated in smart home paradigm. Inclusion of user & context information by using unified semantic representation which helps in forming an adaptation mechanism which results in providing real-life, intelligent personalized services is treated as a future scope.

**Li Liu, Xiaodong Fu** [6], proposed a context-aware computing approach for heterogeneous smart home environments. This approach focuses on integrating large-scale home context information by using multiple heterogeneous sensors. The context aware inferences like rule, inference & pattern driven are used to define a semantic decision. Then an architecture that manages smart home environment has been developed to enhance the intelligence capabilities. The proposed approach is applied for intelligent home to discover more useful user activities & to provide personalized services. The development of a framework with more complicated scenarios, construction of a verified context-aware inference system, understanding & learning multiple users & more complicated behavior changes in smart home environment is treated as future scope.

**John Staton, Manfred Huber** [7], proposed an approach to assist in design & development of autonomous smart home algorithms which is robust & flexible enough to build simulation environment for smart home. With this regard plugin-based simulation architecture has been
designed that includes three different artificial intelligence based approaches which contributes towards modeling & predicting user intentions in a smart home environment.

Isaac Smolund [8], discussed about the problem of activity prediction which can be solved by using the intelligent technology that observes user’s patterns & predicts their needs. The author has also discussed the work of various researchers to clearly understand the field of activity prediction. These works include systems for 1) Recognition of activity 2) Development of a smart-home environment utilizing activity prediction and 3) Assisting people with handicaps by using technology. Data-driven activity prediction is considered as a future scope.

Serge Thomas Mickala, Younghwan Yoo [9], discusses about recognizing & predicting user activities Internet of Things based smart home environment. The process of activity recognition is usually carried out through following steps: 1) Activity pattern clustering & 2) Activity type decision. Even though many related works has been presented they had limited performance because they focused on one of these two steps. An unsupervised learning method called the K-pattern clustering algorithm has been employed to classify complex user activities. Artificial neural network based on the Allen’s temporal relations has been utilized for training the smart home environment & also to recognize & predict user activities. As compared with other data mining classification algorithms the proposed hybrid method provides higher recognition accuracy for various activities. Improving the activity recognition accuracy by using more sensitive sensors to collect more useful information in the smart home environment & also to apply efficient feature selection approaches to overcome redundancy can be treated as future scope.

Sukanya P, Gayathri K S [10], proposed a new pattern clustering algorithm called K-Pattern clustering to cluster the activities of the user in smart home environment. The feature provided by the proposed algorithm is it is able to detect the discontinuous and interleaved activity patterns of the user. Thereby it overcomes the disadvantages of the existing data clustering algorithms. After clustering the user activities the neural network is used as a predictive model to predict the future behavior of the user in smart home environment. Predicting the abnormal behavior where there are multiple users & also modeling the user behavior using semantic reasoning is treated as a future scope.

III. ARCHITECTURE OF THE PROPOSED APPROACH

The architecture used to predict the activity of the resident in IoT based smart home is shown in Figure 1. It involves the following steps: 1) Acquiring the data by using networked sensors 2) Context generation 3) Predicting the primitive context by applying rule base association analysis on the generated context 4) Predicting the derived activity by using finite state based behavioral pattern of activities.

The steps to be followed in predicting the activity of the resident in IoT based Smart Home are discussed below:
1) Acquiring the data by using networked sensors: This is the most important requirement to achieve resident activity prediction in IoT based smart home. The data is acquired by using IoT devices like sensors indicated by S1, S2...Sn. The acquired data values are associated with contextual parameters of the resident like: 1) location of the resident. This can be known by using GPS sensor which provides data values in the form of: latitude (40.5691) & longitude (-85.4370) 2) identity of the resident. This can be known by using RFID sensor which provides the data value in the form of: RFID tag (042728). Data related to real-time objects like light, coffee maker, etc are also acquired by using associated sensors like: light sensor, coffee maker sensor, etc & the data values provided by them are in the form of Boolean values-ON/OFF which gives the status of the device.

2) Context generation: By using the data acquired by networked sensors like: GPS, RFID, light, etc the context of the resident is generated. The general form the context is given below.

\[
\text{Context} = \{a_1, a_2, ..., a_n\}
\]

Where \(a_1, a_2, ..., a_n\) are contextual attributes of the resident

Therefore, generated context \(C = \{\text{Kitchen, 4567, ON}\}\)

According to the above generated context the location of the resident is Kitchen which is provided by the GPS sensor in the form of latitude & longitude, 4567 is the RFID tag which specifies the identity of the resident acquired by using RFID sensor. ON is the value provided by Coffee maker sensor. Similarly different context can be generated by using different sensor values for location, identity & status of the device.

3) Predicting the primitive context & activity by applying rule base association analysis on the generated context: The resident’s locations in smart home are as follows- Living room, Kitchen, Bathroom, Parking area, etc & the resident’s sequence of activities are as follows- Sleeping, Reading, Taking shower, Cooking, Eating, Driving. Predicting the primitive context & activity of the resident can be achieved by applying rule base association analysis. For example, to infer the primitive context & activity of ‘Sleeping’ we need the sensor values generated from weight sensor & light sensor. Let us assume that weight of the bed is 50kg & weight of the resident is 100kg. If the value generated from weight sensor is 150KG, value generated from RFID sensor is 1234, value generated from GPS is Living room based on longitude & latitude, value generated from light sensor is OFF then it can be predicted that the resident is sleeping on the bed. Therefore it can be concluded that the predicted primitive context & activity is: Living Room^1234^150^OFF-> Sleeping. Similarly we can predict the primitive context along with the activity for different generated context/situation.

4) Predicting the derived activity by using finite state based behavioral pattern of activities: This can be achieved by learning resident’s behavioral patterns using finite states. The set of activities performed by the resident are as follows: Sleeping, Reading, Taking shower, Cooking, Eating, Drinking, Driving. The states used to represent each activity are as follows: A1, A2, A3, A4, A5, A6 & A7. The state transition diagrams below shows the sequence of activities performed by the resident in a smart home. To infer the final activity performed by the resident the following case studies are discussed below. By using the state transition diagram the predicted patterns of activities are obtained which in turn helps in predicting the final activity performed by the resident in smart home environment.

Case Study 1: This illustrates how the resident activity of ‘Eating’ is inferred using different states in a smart home environment. By using the current state information which indicates the activity performed by the resident at a particular instance the resident’s final activity can be predicted.
For example, consider the state transition diagram shown in the figure 2. It indicates different sequence of activities performed by the resident in smart home. The resident begins his activity from Sleeping (A1). After performing A1 he can perform either of three activities Reading (A2), Taking Shower (A3) & Cooking (A4) to perform final activity Eating (A5). To perform the activity of Eating (A5) the resident has to perform the below pattern of activities:

P1: A1 → A2 → A4 → A5
P2: A1 → A4 → A5
P3: A1 → A3 → A4 → A5

By the above obtained pattern of activities it can be predicted that to perform the activity of Eating (A5) the resident has to at least perform the activity of Cooking (A4).

Case Study 2: This illustrates how the resident activity of ‘Driving’ is inferred using different states in a smart home environment.

Consider the state transition diagram shown in the figure 3. It indicates different sequence of activities performed by the resident in smart home. The resident begins his activity from Sleeping (A1). After performing A1 the resident performs the activity of Taking Shower (A3). After performing A3 the resident can perform the activity of Cooking (A4). If resident performs Cooking (A4) he must and should perform the activity of Eating (A5) to perform the final activity of Driving (A7). After performing the activity of Taking Shower (A3) the resident can directly perform the final activity of Driving (A7) without performing the other activities like: Cooking (A4), Eating (A5), Drinking (A6) or the resident can perform the activity of Drinking (A6) to perform the final activity of Driving (A7) without performing the other activities like: Cooking (A4) & Eating (A5). To perform the activity of Driving (A7) the resident has to perform the below pattern of activities:

P1: A1 → A3 → A4 → A5 → A7
P2: A1 → A3 → A7
P3: A1 → A3 → A6 → A7

By the above obtained pattern of activities it can be predicted that to perform the activity of Driving the resident has to at least perform the activity of Taking Shower (A3).

The above 2 case studies shows how the derived activity of the resident can be predicted by using finite state based behavioral pattern of activities. Therefore the derived activity of the resident according to case study 1 is: **Cooking** & case study 2 is: **Driving**.
IV. CONCLUSION & FUTURE WORK

The research work presented in this paper proposes an approach to predict the activity of the resident in IoT based smart home. This can be achieved by 1) Acquiring the data by using networked sensors 2) Context generation 3) Predicting the primitive context & activity by applying rule base association analysis on the generated context 4) Predicting the derived activity by using finite state based behavioral pattern of activities. Case Studies discussed in section III clearly indicates how the resident activities in the smart home are tracked using different states represented by state transition diagram. Practical implementation of the proposed approach by using a suitable programming language & hardware devices is treated as future scope.

REFERENCES


