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Smart Home System Using Sequential Pattern Mining

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Abstract: Smart home systems are one of today's active working issues because of the increase comfort, raised living standards, security, health, economic benefits. Smart home systems should interact with the activities of people living in a house and be remotely accessible, monitorable and controllable. A smart home system with the mentioned features has been developed in this study. The system collects data from the behaviors and interactions of the people in the house. It evaluates the collected data adaptively and outputs the results. It produces control signals by using the results. In addition, a simulation was developed to collect data from devices such as an IoT device. The resulting data is examined using rule subtraction from sequential patterns, a data mining method. In this way, the habits of the users in a house are added to the system as a scenario. By using scenarios and rules, the interaction with the user of the system is increased by predicting what the user can do next. The results show energy saving and comfort increase with the developed system.

Keywords: Smart home systems, Adaptive systems, Sequential pattern mining, Topological graph

Introduction

Smart systems consist of a combination of different software and hardware technologies that car perform many different tasks on a basic operating system. Smart systems have features such as decisions making, sensation, learning and problem solving. In addition attribute of smart system such as remote access and remote control. This is achieved by combination of hardware and software architectures.

Smart systems have a wide range of applications. There are examples used in many different areas, from personal products developed to end users, to professional factory automation. In addition, users should be able to recognize the smart system and keep the data that can be used later and make inferences and adapt to the changes.

Smart home systems are the sub-system that can interact with human life in intelligent systems. Sensors are systems that provide services to meet the needs of people equipped with local appliances and devices. Sensors used to locate people or objects, and to measure instant attribute such as temperature and energy use. Aim of the system is to benefit users in areas such as security, health, entertainments, communication, comfort and energy efficiency. By combining real and virtual systems with the common use of smart home systems and Internet of Things (IoT) devices, object human interaction is ensured.

There are different commercial products introduced by many companies in the concept of smart home systems. These systems consist of many different hardware and software that are wired or wirelessly installed in the home. When the systems used in daily life in smart home systems are examined, it can be connected to the smart home system and connected to the IoT devices in the rooms of the house. Operations determined on scenario basis are executed sequentially. For example, the most commonly used home arrival or home departure scenarios can be given. Similarly, a single command can be performed at the same time, such as switching off or on the alarm, opening or closing the blinds, switching on or off the air conditioner, turning the lights on or off, powering the electrical outlets at home, or disconnecting the electricity from specific outlets. As a different example, when travel mode is activated, the features such as closing the electrical outlets, randomly opening and closing the blinds at any time of the day, and the activation of the irrigation system can be activated automatically. According to the data from the gas or water sensors, it is possible to cut off the electricity or water from the house automatically.

Even though they have remote accessibility and remote control features from existing smart home systems, they do not have the features of learning and problem solving. However, movements of people living in houses may be similar. Even if there is no knowledge of the people living in the home, the next movements can be estimated. Thus, preparing for the next movement, comfort can be improved. In addition, it is possible to save energy by adjusting the temperature by using heating systems and blinds for people who do not like the heat according to the habits.

When the literature is examined, the objectives of smart home systems are to examine the health of people living at home. Studies on smart home systems, have been developed smart tools for old people. These devices is arranged to be controlled and monitored on a platform with the adjustment of objects such as entrance door, bed and floor. Using ultrasonic monitoring system established in the house, made to help people determine their location and determine habits.

Sensors and RFID were used in literature. In these studies, a smart system has been developed to define and model the life habits of users. User daily activity status is modeled as a sequential list. It is a list of sequential situations that are obtained by classifying raw data from sensors and RFID tags into decision trees for modeling behavior. User’s instant habits are determined by the most search after status and the most appropriate one according to the task.

When the literature is reviewed, there is a project known as smart home or sensor house to test useful new services. Home devices communicate, directly to each other sensors and home devices by using IoT. The house is designed to be like a home. There have living room, dining room, hall, kitchen, study room which could be needed for living persons. There is also a network operation center in the computer room for service. Rooms of the house are equipped with sensors to monitor the activities of people living at home. Cameras and microphones in each room are used to collect images and audio information. By using sensor such as pressure, IR, RFID tags, the movements of people living at home and the location of furniture can be determine.

Usage Areas and Economic Value of IoT Systems

Smart systems and IoT are complementary concepts of smart homes. Because of the system created on the basis of intelligent systems to ensure human interaction, the system allows the user to make his own decisions according to the needs of the user and certain rules. From the collected data, the system is learned according to the sensation of the environment and the results obtained from the perceived situation. IoT devices are used to collect information in smart home systems and to reflect the results of the collected information in an interactive way to the users.

Founded in 2002 and established to provide a standard in the communication protocol of IoT devices, Zigbee Alliance published a report on the grouping and economic value of systems using IoT devices in 2014. The report foresees that the total economic value in home, transportation, health, building and city groupings is more than $ 180 billion and this value will be more than $ 1Tr in 2020. In the report, the economic value of the smart home systems, which was $ 79.4 billion in 2014, was estimated to be $ 397.8 billion in 2020. It can be concluded that smart home systems are the most expected system based on systems using IoT devices.

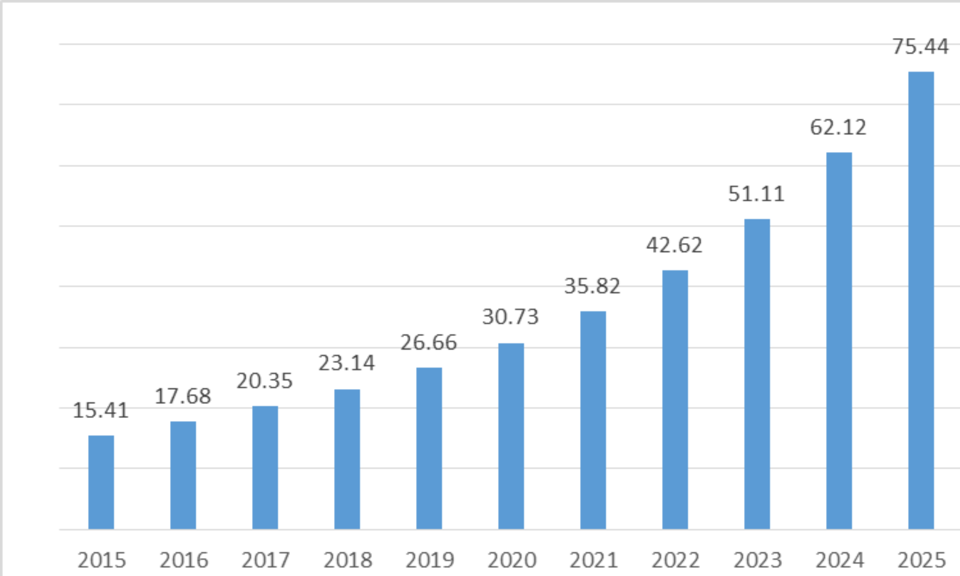

Figure 1. 2015 - 2025 Year Estimated World's Inter-Established Internet Connection Of Devices Around

It is predicted that the use of IoT devices in smart homes, smart cities and smart workplaces will increase in the following years. In 2025, around 75 billion devices worldwide are estimated to be interconnected.

Difficulty of Developing Smart Home System

The literature states that while developing smart home systems, there are difficulties in compliance, co-operation, management, data integrity, confidentiality and security.

Compliance with existing and changing lifestyles: Smart home technology and services must be tailored to the design, lifestyle and general home environment. Technologies that are inappropriate for culture and habits can disturb users and hosts. For example, cameras and microphones in the rooms may cause negative feedback from residents. Unexpected system formations can cause things to get out of control. The smart home should also be a system that can evolve; it must be able to adjust or adapt to meet the changing needs, demands and preferences of its users.

Management: The installation, updating and maintenance of the software and hardware of the smart home is a big problem. Smart home users may not be expected to have expert knowledge of installation, update and maintenance. Users should be able to easily manage their smart home system and technology and easily and without any need to know where and how to report the problems. The installation, management and maintenance of the system must be provided by developers and vendors, and the systems should be designed to be strong and simple to solve problems. Systems should identify the problems that may occur as much as possible and direct them to the relevant units. This increases the complexity of the service provided by the smart home system.

When the available literature is examined, it is seen that researchers use many different communication networks to organize multi-sensory personal monitoring systems. Some of these networks use RS232, RS485 for cable communication, and electric line systems for control of buses, lighting, ventilation and sockets. Others use communication methods such as wireless, digital smartphones, 802.11, various frequency bands, Bluetooth, infrared or a USB port. There are still a number of different communication methods. Non-standard devices make installation and maintenance difficult.

Different communication methods have been used in different studies in the literature. Since a specific communication protocol standard is not accepted, the manufacturer of smart devices produces different communication protocols. As a result, it is difficult for smart home systems to develop in a common window. Manufacturers of systems using Bluetooth 802.15.1, Zigbee 802.15.4, or WiFi 802.11, which are standardized and accepted by specific groups, therefore stand out in the marketplace. However, there is no fully accepted standard communication protocol and there is a problem of co-operation between different systems.

Confidentiality, security and data integrity: By some users, smart home technologies are considered to compromise security and violate privacy. While users were doing their work in the house, they were worried about presence of third party software in the home. In addition, according to the researches, these users stated that were concerned about sharing their information with someone else. Some experts see security as a problem that can be overcome with simple solutions, while others expert see this situation to be greatest risk in smart home development. Sharing other customer information with other unauthorized systems may cause legal problems.

Experts define that these smart home systems are not being able to be captured or physically secured by remote access. In case of same protocols used and shared violation of privacy risk will be higher than that of a full independent system. In addition, customers do not use the system if they lose confidence in the system. Another way to supply security is to place the mechanism inside the smart home system or into the devices. In this case, the security of smart home systems can be provided with strong encryption systems similar to use in internet banking. Device certificates such as SSL / TLS certificates may be used in the identification of the devices, integrity of the data and the encryption of the communication between the devices. However, because of the logic of IoT devices and sensors makes it difficult to apply the methods known to be running with low resources and energy.

Application and Methods

The IoT devices used in the home environment are used in many areas such as management of energy efficient use of resources water and electricity, and security checks through the use of developed software and devices. The key role in comfort increasing systems is provided by sensor based devices. Sensors enable users to collect data and media information of their lifestyle. The collected information is used to determine the needs of users. Systems such as lighting systems, automatic opening and closing of blinds and curtains, heating and cooling processes, music broadcasts according to the time and place of the people, control of electrical appliances automatic garden watering can be given as examples. Smart home systems are built from different subsystems for different situations and scenarios to work. For this reason, there must be a main management control unit in order for the sub-systems to work together. In addition, data from different types of devices should be translated into a common format to ensure that data can be analyzed in a common area. According to the obtained from different devices by using data mining methods, decisions are taken to satisfy the needs and expectations of users. The system needs to adapt itself to changing user expectations.

In application, developed in TURKTRUST Inc., a software infrastructure has been developed that can interact, remotely access, monitor and control the activities of the people living in a home. ADLE system consists of components of an intelligent building control unit that can fit adaptively. An interface application has been developed in order to test the infrastructure in the smart house concept and to measure the tests. The developed interface collects data from the devices it listens using ADLE API and saves it as a memory. In order to estimate data collected from the application in a way that give notices the next step, an adaptation of sequential patterns, which is a data mining method, has been developed. A topological graph-based simulation has been developed that allows random data to be generated in a given order so that the adaptation of sequential patterns can be tested. The data obtained by the simulation was ensured with the generated simulation and the produced data were collected by using ADLE API. As a result, the data generated in the simulation were collected and adaptive learning was performed by using sequential pattern data mining method.

This application consists of 3 steps. In the first step, the user interface has been developed that allows for operations such as database entries using ADLE and general purpose APIs. In the second steps, a graphical-based simulation application interface was developed. The actions generated by the simulation based on the generated graph are captured by the listeners on the ADLE System and stored to database as a memory. In the third step, a sequential pattern data mining method developed.

Used Methods

Topological graphs and sequential pattern mining were used in the application development.

Graphs

In order to test the accuracy of the developed application, multiple sequential patterns must be collected or created. A small amount of manually generated or collected data may not be sufficient to show the accuracy of the results. In addition, adaptive learning takes place over time through repeated actions. So a data generator simulation needs to be developed for testing the smart home system. The data used in the tests should be produced randomly in a pattern that mimics the living habits of people living in a home. The model is based on the interconnected node structure based on graph theory.

Graphs show the relationships between pieces of information. Each piece of information is specified as a node. The relationship between two pieces of information is called the edge. There may be more than one edges between two nodes. There are two types on edges, directed and undirected. If each node is connected to each other with at least one edge, it is qualified as connected graph but it is a unconnected graph even if it has a single node without edge. Graphs can be used in demonstrating the relationship between circuits in electronic, demonstration of the proximity of transportation areas between each other, computer networks and database relationship models. In the simulation application, linear ordered, directed and connected topological graphs were used. We have created a topological graph structure according to the user's behavior. In the Graph structure each node specifies a room and device. Graph structure is given in figure 2. For example, the node that represents the PIR device in the hall is called 1P. It is not important whether the shape between the nodes is linear or curved. From the graphs, simulation application creates a path that identifies the movements that the user does with the dept first method. So each path created from the graph specifies a sequence of actions for one person.

Sequential Pattern Mining

In the simulation application, each sequence generated from the graph defines a person's movements in the smart home. That sequence stores in database as a memory. As the stored memories increases, we can guess what can be done in the next step by finding the most similar memory we have previously stored. We decided that the most appropriate tool for this process was sequential pattern mining. And in literature there are many studies of sequential pattern mining for measuring the sequence similarities of each sequence. Because this method aims to find statistically appropriate patterns among the data with sequential values.

In an unexpected situation such as arriving home guest, a unique sequence may occur. In this case, even if the correct estimation rate of the next step is low, estimation rate will grow as adding of new sequences. Thus, adaptive learning is provided.

Architectural Structure of the ADLE API

ADLE API is designed to meet different types of intelligent building systems. Figure 3 shows the design of the ADLE system. While designing the system, we aimed to eliminate the difficulties of doing the aforementioned smart home systems. The design is also based on object-oriented programming principles.

SharedObject: It is the core layer of the ADLE API. Abstract classes, interfaces and definitions that adapts to different systems are defined in this layer. The use of abstract classes allows fast adaptation to existing systems so devices that uses different protocols can be adding to system easily.

ActionModel (AM): Defines classes which enable the two-way communication with the devices defined in the system and stored in the database. With using defined actions which inherits “IAction” interface defined in “SharedObject” layer, “ActionModel” class sends requests and receives responses from devices with the help of the adapters. It helps to find devices in the network and allows them to be listen. Notice the status changes in the devices and inform the Memory Model about the change. In “ActionModel” a command system has been developed that enables the system to achieve a high performance in many devices.

“ActionModel” enables integration into the data mining layer using defined DM Adapters. It sends the data to this layer or gets results from the layer. Third-party classes can be used to link data mining methods or devices. Adapters can be added to system which inherited from the interfaces described in the "SharedObject" layer so that the system can be easily adapted to changes.

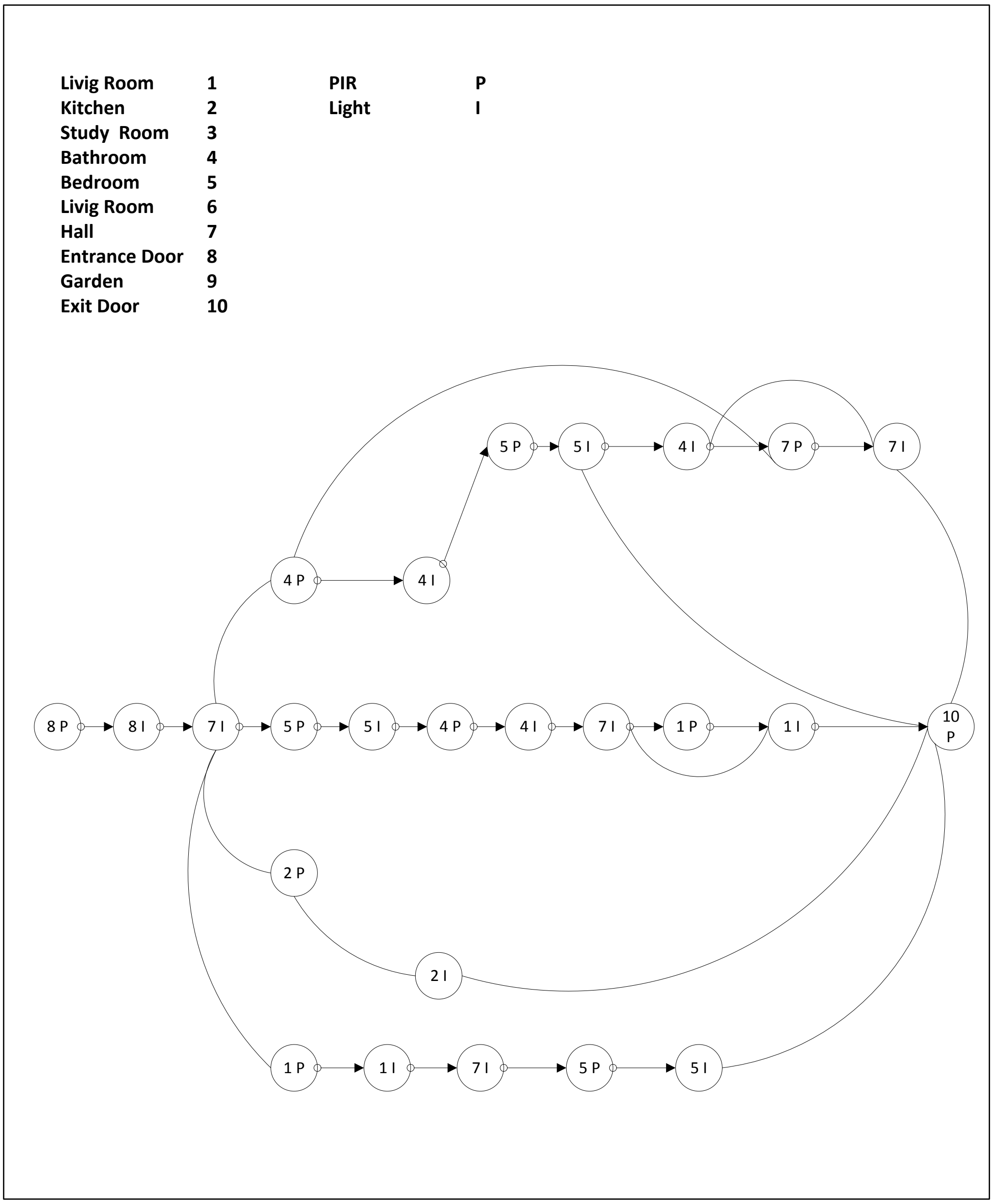

Figure 2. Topological graph for simulation

ItemModel (ITM): It scans the network to find IP-based IoT devices. It controls the availability of the devices by pairing the devices in the network with the devices defined in the database. When found on a new device attached to the network, it includes methods that allow users to register the new device to the system and store details of device to the database. With these features, it has been tried to reduce the difficulties of managing the system. Devices and actions are introduced to the system. Defines which action is taken on which IoT device. It triggers defined actions in defined IP based device objects by using the “Action Model”.

FieldModel (FM): Field Model allows field definitions on system. Field definitions can be nested. In other words, new field definitions can be made within a different area. In the study, the areas inside the house were made using the “FieldModel” model. Each field contains a list of device objects. These objects inherit from “ItemModel” so can be controled from “ActionModel”.

MemoryModel (MM): This class, detects the changes by checking the data which collected by the “ActionModel” and converts detected changes to the “AdleMemoryObject” objects defined in the “SharedObject” layer. A list of “AdleMemoryObject “ objects is kept both in the system and saved in the Database.

System Control Unit (SCU): Inherits from the “AdleSCUBase“ abstract base class which defined in the “SharedObject” layer. It is the administrative class of the system and works as a mediator for all layers. In the study, SCU class is located in the application user interface project. It allows all the layers to join the system and control them from one place. It is also the business layer of the Smart Home System. Therefore, it may vary in different type of smart building applications. Serves as a cache by storing defined field and device definitions in the system. Resolves which classes are used by abstract classes or interfaces, according to the rules specified in the Manifest files. Runs data mining methods according to the workflow. Provides collection of data from IoT devices. The scenarios defined in the database are controlled by the SCU class and are executed according to the situation. Sends user-entered instant requests via “ActinModel” to IoT devices.

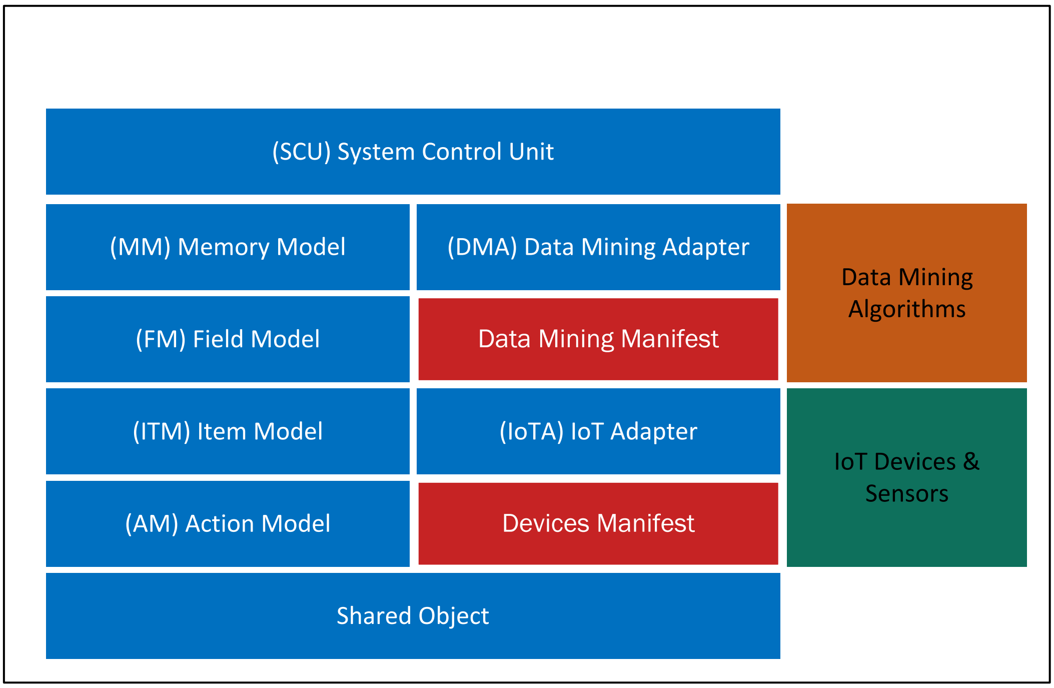

Figure 3. ADLE system architecture

Developed Smart Home Application

Home modeling was performed by using the application interface created for testing purposes. We modeled the house with ADLE API using the application graphical interface. The model consists of three rooms, a living room, a kitchen, a bathroom, a hall and a garden. A PIR and light were added to each room in the model with the "ItemModel" of the ADLE API. When the system is first starts up, field and device mappings are done by connecting to devices or test environment by using “Adapter” defined in “ActionModel“ class with “InitSystem“ method defined in SCU class. System informs users, if a device is found that is not defined in the database or if there is no response from a device defined in the database. Using the BeginSimulation method, the events generated over the previously defined graph are captured. Once each graph round is completed, the sequenced data is examined by data mining methods and stores data in database. Each step of the examination, system tries to decide what the next step is. If the decision is correct, the accuracy rate increases and if it is wrong, then the accuracy falls. The more data stored in the database, more chances of finding the sub-sequence in data and the accuracy of the next step estimate increases with the data mining method. In Figure 4 Some important methods are given about the ADLE system.

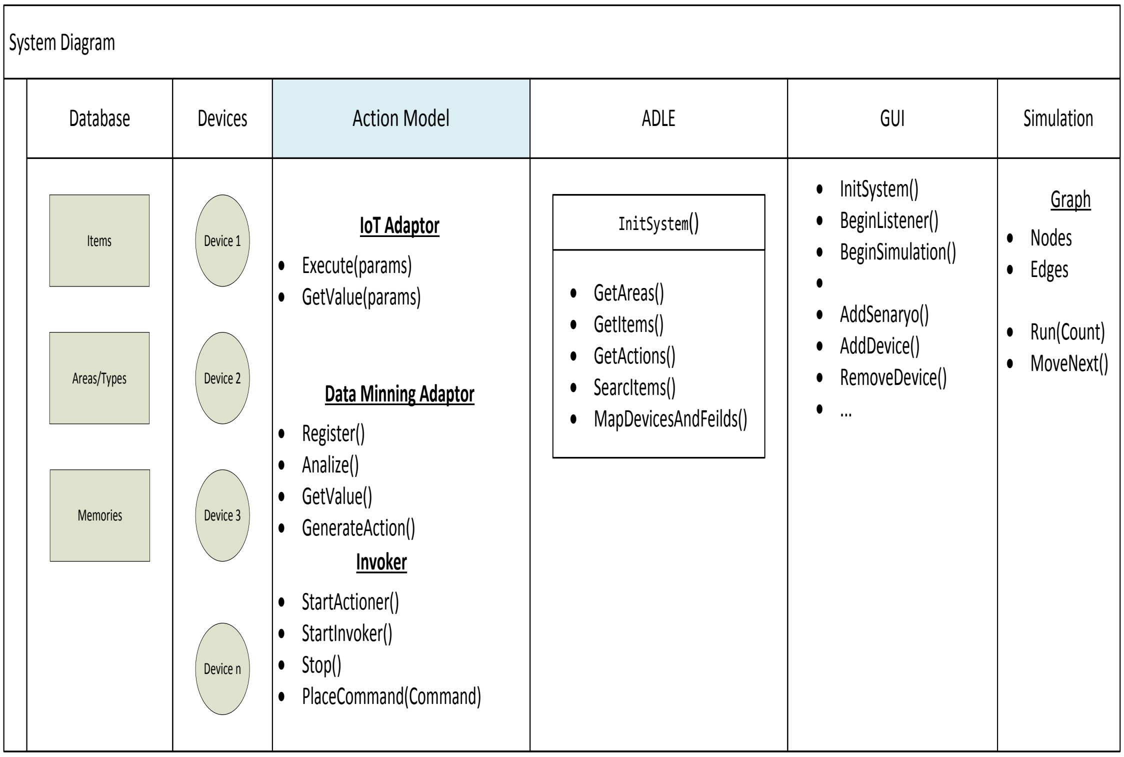

Figure 4. System diagram

Results and Discussion

In this study, we are aimed to develop an adaptive learning application with sequential pattern mining method and to explain the working principle of ADLE system. In the literature there is no study using the graph theory. Data production issues are often missing in the literature. In particular, producing data to the system using graph theory, in the developed application the results of the tests have increased. It also helped the system to produce more accurate results when a previously unknown situation occurred, such as a guest coming home.

In the application, adaptive learning is provided by using the sequential pattern mining method, which is decided to be the most appropriate to the system. In the tests, there was an accuracy rate of approximately 50% in the estimates generated by the data generated by 250 iterations. When the number of data is over 1000, the accuracy rate is around 90%. This proves that the system will make even more accurate predictions over time as the data increases. Foreseeing the actions of the people living in the house will increase comfort at home and saves energy because it reduces the heating or cooling process in unnecessary areas.

In future studies, it may be possible to collect data from multiple households instead of a single home and to investigate them together with data mining methods. Thus, the system will be able to make more accurate estimates even when it is first time working in a house without data. Efforts should also be made to overcome the challenges of developing the smart home system. There are many studies on these issues in the literature but they have not yet been resolved. Storing the habits of people living at home, increases the importance of data security. Furthermore, due to the lack of literature, the study on the production of test data for smart homes should be improved.

In conclusion, in this study, we explained the use of the ADLE system, developed in the scope of TURKTRUST R & D activities in the concept of smart homes. Using the ADLE system and sequential pattern data mining method, we tried to estimation of the actions of the people living in the houses in the next step. In addition, the concept of IoT and the development of smart home systems were discussed. The results showed that energy saving and comfort increase can be achieved with the developed system.

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