AN AI BASED SELF-MODERATED SMART-HOME

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Abstract: Smart-home conception has emerged in recent years and played a very important part in the formation of future houses. Making our current homes more adaptable and self-directed is the main focus of smart home research. Achieving these goals won't be possible without giving our today's home enough intelligence to make rational decisions to operate itself which usually we as inhabitants of the home make these decisions in our everyday life to manage our home and achieve comfort that we desire. In this paper we present prototype of a system that overcomes this problem by giving the home enough intelligence to adapt to its inhabitants life style without the need for the inhabitants to exercise authority. The system makes use of multi-agent and prediction techniques to provide intelligent smart-home appliances automation. The final prototype will be downloaded into FPGA chip.

Pametni dom na osnovi umetne inteligence

Kjučne besede: Inteligentni dom, VHDL, večagentni sistemi , FPGA, napoved

Izvleček: Koncept inteligentnega doma se je pojavil v zadnjih letih in je odigral pomembno vlogo pri načrtovanju bodočih hiš. Glavni cilj raziskav na področju inteligentnega doma je ustvariti bolj prilagodljiv in samo-upravljiv dom. Takega cilja ne bo mogoče doseči brez, da bi domu dali določeno mero inteligence, s pomočjo katere se bo lahko odločal in se upravljal, kar je do sedaj bila izključno domena stanovalcev. V prispevku predstavimo prototip sistema, ki domu omogoča dovolj inteligence, da se prilagodi življenskemu slogu stanovalcev brez potrebe po njihovem avtoritativnem posredovanju. Sistem uporablja večagentne tehnike in tehnike napovedi za avtomatizacijo delovanja naprav znotraj inteligentnega doma. Končni prototip bo izveden kot vezje FPGA.

1. Introduction

Smart-home is a structure that is equipped with technology that makes it possible for the home inhabitant to operate the house using special techniques. These techniques might include programming an array of home appliances or by using remote control schemes. Recently many high profiled researches discrete such as IBM, MIT and Microsoft started to setup smart-homes to be used as test beds by researchers /1/.

The Artificial Intelligence (AI) designation; is the ability of a computer to perform rational tasks, such as reasoning and learning that human intelligence is capable of doing /2/. The aim of AI is to utilize the abilities of the human brain into computer powered devices. One of these devices is the smart-home appliance that can automatically adjust itself to the desire of the home inhabitants.

The physical picture of a home being rational is very plausible. A home that is capable of making coherent decisions could possibly offer a level of self-sufficiency that is not available in the current home environment. By automating the home many residents prefer that home tasks such as security and power consumption can be carried out by the smart-home systems automatically with out their need for exercising authority. The essence of smart-home study lies in the creation of smart environment saturated with computing and communication capability, yet gracefully enhanced integrated with the human users The complexity of a Smart Home solution lies in the variety of different protocols and media involved, and the requirements of the various services provided such as automation, security and power management etc.

During the past years many home appliances automation projects has emerged /3, 4, 5/. Although previous systems achieve the required home mechanization needs but on the other hand most of previous systems were software based and expensive to be implemented and commercialized and that's probably the main reason why previous systems were not used by the general public. In this paper we present a portable, low cost and fast hardware prototype of a multi-agent system that is designed to provide home automation without the need to be programmed.

In the next section we will look into the detail of the techniques used in our system and at the end we will illustrate the expected performance of the system and furthermore future work will be discussed.

2. Research methodology

The system main goals are to achieve high operational speed and efficiency and at the same time making it cost effective and portable. Due to the mentioned goals the system is implemented on hardware rather than software.

The system makes use of multi-agent techniques; each agent will be responsible to control a section of the home and automate the devices appliances usage according to the life style of the inhabitants. The agents are homogeneous and non-communicative; the only communication that the agents can perform is to share the overall environment state of the whole smart-home so as to make better predictions and device automations.

To correspond with the outside world the system makes use of X10 protocol to send and receive messages from and to the home appliances. The system has two modules; one of the modules is used to generate X10 packet and the other is responsible to receive and translate an X10 packet. Based on the information contained in the packet, the unit generates a message to each agent environment state maintainer. When the device state maintainer receives the message it updates the local view of the agent devices state.

The system is event driven. The events are themselves time driven and are controlled by a system clock. The time frame of the events is adjustable by the home occupants. Each time an event trigger is generated the agents will issue a device command based on their learned knowledge that were gathered by monitoring the users everyday device interactions.

The agent consists of three main units; prediction unit, decision unit and communication unit. The prediction unit is designed by using Active-Lezi algorithm /6/, the unit is responsible for predicting the future environment state based on the current environment state. On the other hand the decision unit is modeled using techniques of Reinforcement learning, the algorithm used for modeling the unit is Q-Learning.

The use of prediction unit with the decision unit makes better system performance since it is sometimes undesirable to directly predict and operate a particular home appliance. That's why we need the reinforcement learning techniques to be used so that the agent learns from previous experience and not letting the prediction unit perform unnecessary action. Finally the communication unit is responsible to handle the communication between the agents as illustrated in Fig.1

Before putting the system into operation the system needs to be trained. The training is done by collecting devices usage patterns of the home inhabitants, after data gathering phase the data is fed to the system. The system performance is improved by using more accurate training data. For detailed system superficial overview refer to Fig.2.

3. Decision unit

The decision unit of the system is responsible for performing rational decision. The unit is modeled according to Q-Learning algorithm. Q-learning is a reinforcement learning technique where action value function is used to assign values to actions that the system performs at a given state.

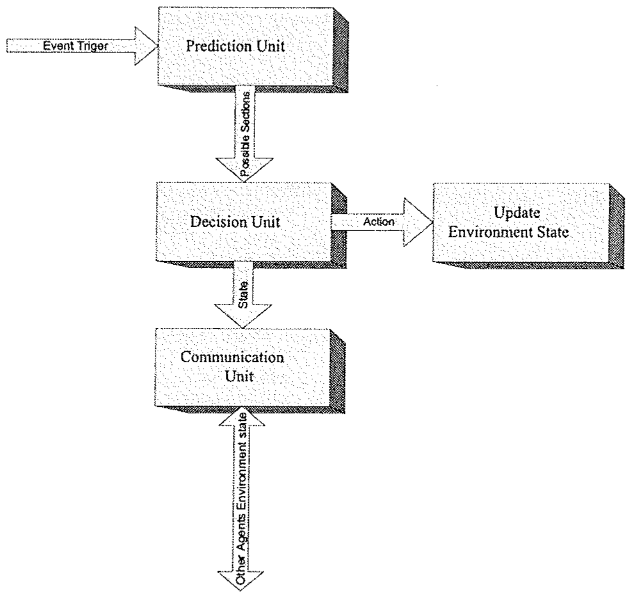

Fig. 1 The agent illustration diagram

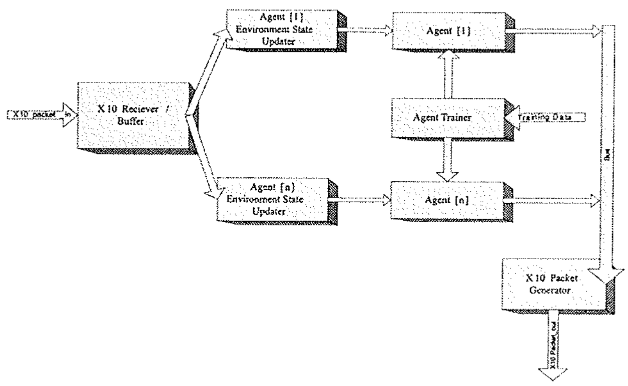

Fig. 2 Superficial illustration diagram of the system

Given the environment devices states as [S], and the device actions that can be taken on a given environment state as [A], we can form the Q value array of reinforcement learning as shown in equation 1.

$$Q = S \times A \quad (1)$$

According to Q-Learning algorithm the Q value array is used to store the rewards the agent has received by performing a particular action at a given environment state. Each time the agent makes a correct decision; the agent is given a positive reward or a negative reward. The reward is calculated based on the user feedback to the agents performed action, which can be sensed by the system through monitoring the devices state constantly.

The Q value function will be calculated as shown in equation 2.

$$Q^*(x,a) = (1-\alpha)Q^*(x,a) + \alpha(r + \gamma V^*(y)) \quad (2)$$

where Q* is the Q-learning value function, *x* is the environment states, a is the action that can be taken, α is the learning rate, γ is the value of future reinforcement and V* is the future Q-learning value function.

4. Prediction unit

The prediction unit is very important unit; due to the reason that it can minimize the error rate by predicting the future environment state, thus allowing the decision unit to take actions based on the predicted future state. The unit is modeled using an online predictor Active-Lezi.

Active-LeZi algorithm is an enhancement of both LZ78 and LeZi-Update algorithms /6/. It incorporates a sliding window approach to address the drawbacks of both LZ78 and LeZi-Update. This approach also demonstrates various other desirable characteristics given below.

- The core model of Active-Lezi algorithm is Growing-Order-Markov model based on LZ78 algorithm, therefore Active-Lezi accomplish optimal predictability.
- Active-Lezi stores more information, which implies that as the input sequence (the experience) grows, the algorithm performs better. This is a desirable characteristic of any learning algorithm.

After simulating Active-Lezi algorithm by using input data pattern with high noise. We can see that the result gained from the simulation is very desirable since the algorithm achieves prediction of 100%. The simulation result is shown in Fig.3.

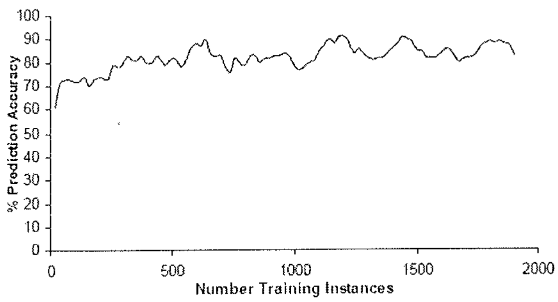

Fig. 3 Graph showing the prediction accuracy of Active-lezi

5. Results and discussion

The purpose of the research is to implement a home appliances automation system by using multi-agent techniques. The system will be later hardware synthesized. At the moment our system is still under development, so the testing of the system that we have so far performed has been done using software simulation.

During our testing phase we have implemented a synthetic data generator to generate training data to train the system. The synthetic data generator is used to produce devices usage pattern that accurately symbolize an actual home occupant devices usage routine. The data simply include the time, place and action of the event that is hypothetically performed by a particular home resident as shown in Table 1. After the data is generated it is converted into an accurate X10 protocol packets and then is fed to the system using the system training unit.

Table 1 Sample Synthetic Data Used To Train The Multi-Agent System

Date and Time	Action	Device	Location
2006-03-03 / 09:21	On	Lamp1	Living Room
2006-03-03 / 10:26	Off	Fan1	Bedroom
2006-03-03 / 10:29	On	Tv1	Living Room
2006-03-03 / 18:21	Off	Lamp1	Living Room
2006-03-03 / 20:22	Off	Tv2	Bedroom

The system has been simulated and tested using our synthetic data generator. Since the system is hardware based we have used Model-Sim VHDL simulation software to simulate the design. Based on our simulation results we realize that the system can perform accurately and the error rate is reduced by using more training data as shown in Fig.4.

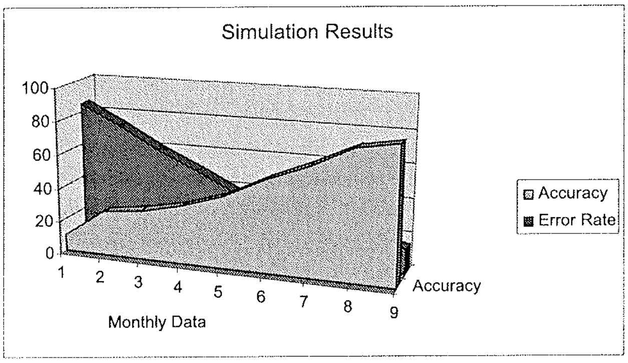

Fig. 4 Graph Illustrate The Simulation Results

Since the system is modeled using the techniques of reinforcement learning, there are few some important point need to be mentioned. In order to accommodate the home inhabitant preferences and learn accurately form the interaction of inhabitant devices, we decided to give a small reward value to every accurate action that the decision-making unit performs and a larger value to a particular action that the user performs. These make the system to adapt the inhabitant preferences faster and more accurate.

Since the actions are increased according to the number of home appliances, thus more the appliances installed in the home, the more complicated the decision making process becomes. The simulation results shows that the system without prediction unit has a dramatically fall in the performance. This proves that the prediction unit is highly important to minimize the number of actions to be performed on the predicted next environment state.

6. Conclusion

The purpose of this research is to implement a revolutionary home automation system that automates the home devices appliances usage based on the inhabitant's life style. The methodology used in this system is based on techniques of AI in particular multi-agent techniques. This system will be realized on hardware to overcome problems faced by other systems such as cost and portability. Moreover making use of muti-agnet techniques will make the system performs faster than previous home automation systems due to the fact that parallelism of multi-agent can help deal with limitations imposed by time-bounded reasoning requirements.

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