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A Formal Model for Smart Living Room

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Abstract— we are living in an era full of technology and the most powerful feature behind this technology is the communication between two or more things. We achieved globalization with the power of digital computers and their ability to communicate. The next shape of computers for interactive remote processing is the internet of things or wireless sensors network and for data storage, it is the cloud. These tiny computers with heterogeneous characteristics are very helpful in making the environment smart and interactive in different ways. In this paper, we are proposing an Ambient Intelligence architecture for safety and energy efficiency using sensors, further, we are formalizing the architecture for its accuracy and reliability. The three major sensors are smoke sensors for safety, glass break detector sensor for security, and motion sensor for energy efficiency. In addition, the working of all sensors is also formalized for its correctness. This paper doesn't include any physical experimentations, we will continue the idea of physically testing the IoTs in future work.

Keywords — Ambient Intelligence, IoTs, Wireless Sensors, Safety, Formalization.

1. INTRODUCTION

The technology plays an important role in our daily life, and it was started way back in 1960's with the invention of digitally data storing and processing. So far, we are using technology in many shapes and for now it is already emerged in each task of our life. The technology is spreading like an explosion because of the availability of IOT devices 24/7 using low battery consumption and ease to access by their wireless interface.

In this paper we presented a concept of smart room that is more secure and energy efficient than regular rooms and this model can be used in different scenarios with few alterations for making environment smart. Now a days, security and efficient energy consumption are the main objects behind different research initiatives. In Pakistan and many different countries security of women and children are at great stake [18], women as housewife and children during their parents office hours stay at home alone. Meanwhile while staying at home, we don't consider turning off all the lights or other electronic devices and such devices consume a plot of power that should be ceased because our country is already struggling with energy crisis. As we are developing more and more smart products the demand of energy is increasing rapidly, energy is required to run each and every device. So, to ensure the maximum and efficient use of energy, many authors have stated the concept of automatic and smart control of lighting and electrical products [8,10,12]. These devices turn on and off automatically without the interference of any human. To achieve this anonymity different types of sensors and microcontrollers can be employed but with these sensor and microcontrollers, not only we control the behavior of devices, but we can use the power of these devices in different field of our daily life i.e. security, health, safety.

This technology provides convenience and well-being to our daily life, also its positive impact gives stability with the help of IOTs. Although almost every proposed model have some flaws that produce an opportunity for others to work on the same topic. Different authors work on security, others work on reliability and few works on optimizations and the list goes on. So we have also tried for some positivity and word on a basic idea of smart room with the help of three basic sensors.

Our hopes are high with this proposed idea because this will impact positively to our

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society, it will not only make the environment secure but also reduce the operational cost that will eventually make our country free from energy crises.

2. RELATED WORK

We are not alone who have worked and proposed ideas in this domain. Wireless sensors are in discussion for the past few years and will remain a hot topic in research for a long time.

The internet of things is closely related to the exchange of information, where a lot of tiny devices connect and exchange information [6,7]. The essence of these devices is to observe the environment and produce data for some experimental purposes which can be shared and are available to use for other devices and computer systems [1].

In this paper work, the author is concerned about the consumption of power by electric devices. The author is trying to explain the advantages of these devices that we used in our daily life but is also persuading us to use such devices efficiently to save energy sources [2]. The author has presented an idea to control these electrically powered devices automatically with different sensors and microcontrollers, so if a person using electrical devices, doesn't care about the power consumption and leaves the room without turning off the devices, these tiny devices will do the work for them. These tiny sensors include motion detectors that can detect human essence and control the electrical power devices as programmed [5,11].

The goal of this paper is to educate the people to reduce electricity consumption. The nature of humans is unpredictable because sometimes we go out of the room without turning off the lights and other electrical products, sometimes we intentionally do that and think it is not consuming much electricity. But actually, the results are different. For this, the author has proposed a technique in which they are using the controller to monitor and control the electrical products in a certain room [8,10]. The controller is an Arduino device equipped with different IR sensors which can identify the presence of a human in a room and act accordingly. So, in ideal situations when someone is in the room, the lights and equipment remain on, but when the controller can't detect the presence of a human, it will turn the devices off and thus, save electricity [9]. The main aim of this paper is to control the extra and unnecessary use of electricity and as a conclusion, this will be beneficial for our country's economy [3].

This paper presents a model in which they are employing a web portal for admin access and using facial recognition for door unlocking using Lbph algorithms, this key less feature provides ease to access the system in multiple situations. This proposed idea is powered by a Raspberry Pi programmable device, its functionality can be extended easily by integration of new sensors and programming the interface. The author is claiming to achieve max of 20% energy efficiency by using its proposed technique [20].

In this solar power based smart home idea, the author has employed different techniques for its idea to work. For communication the author acquired Bluetooth, GSM, ZigBee and Wi-Fi. The solar provides energy through Optimum PowerPoint tracking controller. The author claims that his idea is usable in wide scope i.e., smart health care, smart ventilation, and smart people management. The author have also showed interest to use AI based modules to predict energy requirements and smart energy consumption by switching off the unnecessary household products [19].

A city is smart when it is known for its good governance, people living there have a quality of life. The city has the best available ICT infrastructure and excels in the field of economy [15,16]. This term is in studies for the last few years and will remain under research because this is how we manage the complexity of our daily life if we are living in huge and crowded cities, everything is needed to be smart and intelligent so that most of the decision will be made automatically and we don't have to deal with every aspect of life, like we have smart health, smart traffic, smart homes, disaster management, smart crime prevention, etc. [14]. These applications encourage the idea to develop future smart cities, these smart cities will be self-sufficient in different domains of life. In this paper the concept of IoT is used for dealing with electric devices, this paper aims to control energy consumption for smart city infrastructure and lessen the overall energy requirement for a smart city [4]

3. WHY WIRELESS SENSORS

They are small, low power, easy to use and inexpensive. All these qualities lead the research community to work on these tiny devices and use them in all aspects of our lives. We as researchers and those who are working and innovating these devices have the responsibility for improving the living standards for everyone, maximizing performance and minimizing energy consumption.

The three sensors we are using in this proposed methodology are discussed below.

A. Motion Sensor

Motion sensors are everywhere nowadays because they are so helpful and decreases physical effort of a person. Before these sensors, a human had to monitor the whole activity and identify the risk but now the motion sensors work consecutively with maximum efficiency and notify the owner if something is happening after detection and during this process the chances of failure/ inefficiency are minimized.

This sensor has three types, one is Passive Infrared Sensors, the second is Microwave Motion Sensor and the last one is Dual Tech Motion Sensors.

1) Passive Infrared Sensors

The working of these sensors is to sense moving objects by observing the change in temperature between the foreground body and background body. As the sensor senses the difference in temperature between these two layers up to the threshold level, it sparks the trigger that there is some movement.

2) Microwave Motion Sensors

The waves that are working in this sensor have different other applications. In this sensor, it emits microwaves radiations continuously to identify motion, as a speed gun works. It emits high-frequency waves and senses the frequency shift in reflected waves. If it detects the shift of frequency at a certain level it triggers the motion detector for further actions.

3) Dual Tech Motion Sensors

Nowadays dual or hybrid techniques are used everywhere to increase the efficiency of systems, the same concept is applied to the motion sensor to increase the overall effectiveness of the system. Because in both previous techniques, wind and a quick rise in temperature can ignite the sensor but using both of those technologies in combination will reduce triggering the false alarm.

Figure 1. *Room Occupancy Sensor*

B. Glass Break Sensor

The working of the glass break sensor is not like a window/door entrance sensor which triggers when the two parts of the sensor move away from each other. The glass break sensor works on frequency recognition. It triggers the controller when it recognizes the special frequency of glass breaking because it works on sound. Therefore, one sensor a room is sufficient. It consumes much less energy and it can last up to one year without changing batteries.

Figure 2. *Glass Break Sensor*

C. Smoke Detectors / Sensors

There are two types of technologies that are used in smoke sensors, the first is ionization and the second is photoelectric. From these two types of technologies, the Ionization technique is more responsive/effective to flaming fires.

1) Ionization

As the name suggests it works on the principles of ionization in which the disturbance in the flow of current caused the alarm to trigger. This sensor has a small chamber in which current flows which we call ionization, while the chamber is filled with smoke at a certain level the flow of current disturbs/ reduces that reduction of currents triggers the alarm.

2) Photoelectric

This type of smoke sensor is more receptive to fires that cause smoldering over a longer period in the beginning. Photoelectric deals with a light source at a different angle away from the chamber, when the smoke enters the chamber it reflects the light in different directions, thus the light sensor senses the light and triggers the alarm.

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Both types of sensors are efficient for detecting fire/smoke are efficient, but it depends on the location where it is required to be used.

Figure 3. *Smoke Sensor*

4. PROPOSED METHODOLOGY

We have proposed a model for a living room that is secure from intruders, safe for living and consumes lesser energy. The picture below depicts an idea for our proposed living room model.

There are different sensors installed in this living room to make it safe and secure which are discussed in the previous section. The room is also equipped with items that are required for living, like an LCD TV, a bed, multiple cupboards, a mirror and a sofa. This room also has one window and a door. First, The glass break sensor is installed on the window glass. We can place it anywhere in the room but the closer we install it to the glass window, the more accurate it will work because it works on sound waves. Second, the room occupancy sensor is installed in the middle of the room and placed on the roof so the sensor can sense the motion and living bodies in the room easily. The third sensor is also placed on the roof because the smoke goes up and the sensor will sense it. While placing the smoke sensor we consider the electronic items as well kitchen related products in the room that can burn and produce smoke.

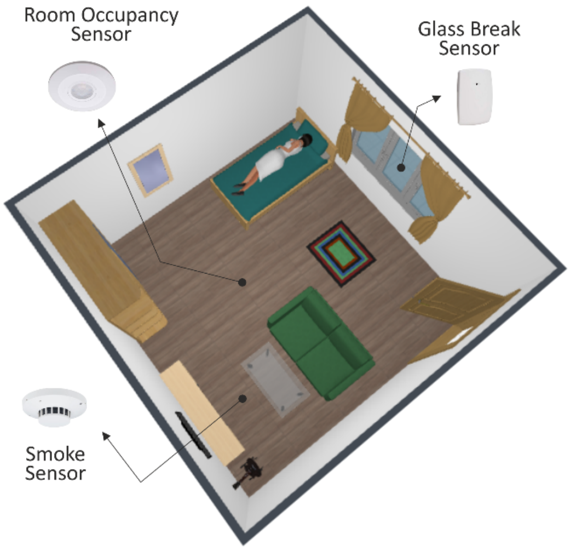
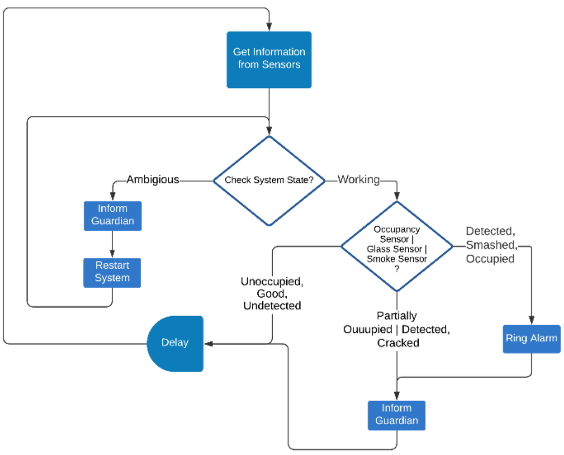


Figure 4. *Proposed Model for Living Room*

This flow chart depicts the working and the possible control flow of our system. At first, our system will be initialized and if it will be a success it will produce a signal for sensors to send their state, in case the system initialization halts or produces an error, the controller will reboot and inform the guardian about the errors. After successful initialization, the system will get the states of the sensors. We have three different sensors that represent their states with different words i.e. occupancy sensor give us the response of "unoccupied" if it detects no one in the room and it produces "occupied" signal if someone is detected in the room. Same as the glass sensor that produces the signal "smashed" on broken glass and the status "good" while the condition of glass is unbroken. The last sensor will produce "detected" and "undetected" in different situations.

Below is the flowchart that shows an overall working for our proposed model.

Table 1: Flow Chart for our system



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5. FORMAL MODELING & RESULTS

We have formalized our proposed system for any unseen problem identification. Below is the VDM-SL code for different components associated with our system.

In the types section, we are defining the data and its type that will be used during the system lifetime. Invariant defines the initial values for the system and initiates the system. We have three sensors involved in our proposed system. Further, we formalized the working of each module, modules are getting input from the environment, processing the input, and setting the system state according to the requirement. We have defined four different states for our system i.e., RINGING, SILENT, INFORMGUARDIAN and RESTART according to different situations.

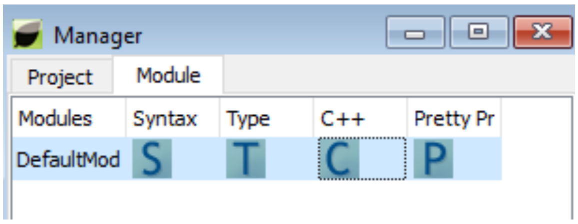

Figure 5. *VDM-SL Manager Module Verification for syntax and Type check*

The above figure V.I shows the correctness of the proposed system formalization, in which the compiler is checking for syntax, further it is checking for type and then generating equivalent formalization code in C++. Finally, the VDM-SL toolbox is reformatting the code.

Below is the final results for this research activity, the complete verified formalization code with the help of VDM-SL is mentioned for further proceeding and future research.

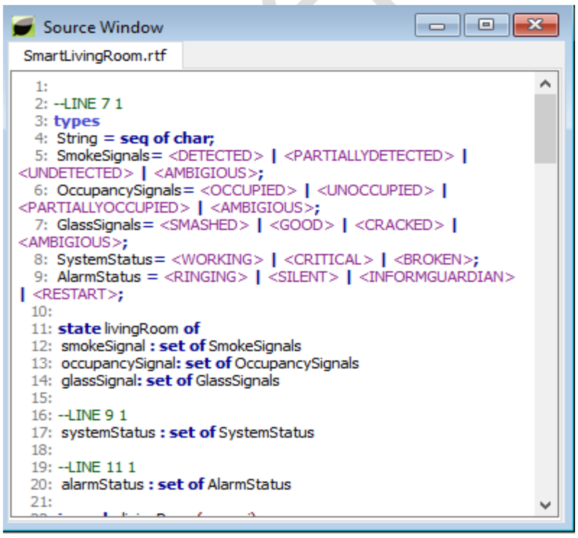

Figure 6. *Sample View of VDM-SL*

```
types
 String = seq of char;
 SmokeSignals= <DETECTED> |
<PARTIALLYDETECTED> | <UNDETECTED>
| <AMBIGIOUS>;
 OccupancySignals= <OCCUPIED> |
<UNOCCUPIED> | <PARTIALLYOCCUPIED>
| <AMBIGIOUS>;
 GlassSignals= <SMASHED> | <GOOD> |
<CRACKED> | <AMBIGIOUS>;
 SystemStatus= <WORKING> |
<CRITICAL> | <BROKEN>;
 AlarmStatus = <RINGING> | <SILENT>
| <INFORMGUARDIAN> | <RESTART>;
```

```
state livingRoom of
 smokeSignal : set of SmokeSignals
 occupancySignal: set of
OccupancySignals
 glassSignal: set of GlassSignals
 systemStatus : set of SystemStatus
 alarmStatus : set of AlarmStatus

inv mk_livingRoom(s,r,g,c,i)==
 (s subset {<DETECTED>,
<PARTIALLYDETECTED>, <UNDETECTED>,
<AMBIGIOUS>})
 and (r subset {<OCCUPIED>,
<UNOCCUPIED>,
<PARTIALLYOCCUPIED>,<AMBIGIOUS>})
 and (g subset
{<SMASHED>,<GOOD>,<CRACKED>,<AMBIGI
OUS>})
 or (c<>{})
 and (i subset{<RINGING> ,
<SILENT>,<INFORMGUARDIAN>})
end

operations
getInformationFromSmokeSensor(Smoke
SignalIN:SmokeSignals)
 ext wr smokeSignal : set of
SmokeSignals
     rd systemStatus : set of
SystemStatus
 pre SmokeSignalIN not in set
smokeSignal and systemStatus
={<WORKING>}
 post smokeSignal = smokeSignal
union { SmokeSignalIN };

SmokeSensorCondition()
 ext rd smokeSignal : set of
SmokeSignals
     wr alarmStatus : set of
AlarmStatus
 pre true
 post
```

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```
      if smokeSignal = {<DETECTED>}
      then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif smokeSignal =
{<PARTIALLYDETECTED>}
        then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif smokeSignal =
{<UNDETECTED>}
        then alarmStatus =
{<SILENT>}
      else alarmStatus =
{<INFORMGUARDIAN>,<RESTART>} ;

getInformationFromOccupancySensor(O
ccupancySignalIN:OccupancySignals)
 ext wr occupancySignal : set of
OccupancySignals
     rd systemStatus : set of
SystemStatus
```

```
pre (OccupancySignalIN not in set
occupancySignal) and (systemStatus
={<WORKING>})
 post occupancySignal =
occupancySignal union {
OccupancySignalIN };

OccupancySensorCondition()
 ext rd occupancySignal : set of
OccupancySignals
     wr alarmStatus : set of
AlarmStatus
 pre true
 post
      if occupancySignal =
{<OCCUPIED>}
      then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif occupancySignal =
{<PARTIALLYOCCUPIED>}
        then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif occupancySignal =
{<UNOCCUPIED>}
        then alarmStatus =
{<SILENT>}
      else alarmStatus =
{<INFORMGUARDIAN>,<RESTART>} ;

getInformationFromGlassSensor(Glass
SignalIN: GlassSignals)
ext wr glassSignal: set of
GlassSignals
pre GlassSignalIN not in set
glassSignal
post glassSignal = glassSignal
union { GlassSignalIN };
GlassSensorCondition ()
ext rd glassSignal: set of
GlassSignals
     wr alarmStatus : set of
AlarmStatus
 pre true
 post
      if glassSignal = {<SMASHED>}
      then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif glassSignal =
{<CRACKED>}
        then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      elseif glassSignal = {<GOOD>}
        then alarmStatus =
{<SILENT>}
      else if glassSignal =
{<AMBIGIOUS>}
        then alarmStatus =
{<RINGING>,<INFORMGUARDIAN>}
      else alarmStatus =
{<INFORMGUARDIAN>} ;

CheckSystemStatus()output:bool
 ext wr systemStatus : set of
SystemStatus
 pre true
 post if systemStatus ={<WORKING>}
       then output=true
      elseif systemStatus
={<CRITICAL>}
       then output=false
      elseif systemStatus =
{<BROKEN>}
       then output=false
      else systemStatus =
{<BROKEN>};
```

For each sensor we have a method that gets data from the sensor and gives it to the system for processing, after processing the system status will be set according to situation demand.

6. CONCLUSION & FUTURE WORK

This paper presented a model for a smart and secure living room, in future the same model will be enhanced and the factor of making it energy efficient will be introduced. The presented model is also formalized and validated with the help of the popular formalization tool VDM-SL [17]. The work we have proposed in the paper is related to Sensors and IOTs which are currently the most demanding research area. Our proposed solution is not yet artificially intelligent it can't predict the devices using unnecessary energy, but in future, we will be integrating AI-based devices that can process data on the fly and predict which device to turn on/off to save energy. The concept of smart homes is in the boom, every researcher is trying to contribute to this field. We have created the base for our future research everyone is encouraged to show their interest and take this research to next level, slowly we will be integrating more and more ideas into this system and this will become a complete model for smart, modern and energy-efficient home with its formal verification.

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