Adaptive Home Automation System by Using Smart Phone Based Artificial Intelligent

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Abstract

This paper proposes a an advanced intelligent home automation system to control the main home functions such as heating, ventilation, air conditioning, shading, lighting, security and food's preparation. The proposed system designed to detect motion or fire and to make decisions independently. Information about motion, heating, and lightning were collected from three nodes using special sensors that micro-controlled through Arduino with WIFI shield and Xbee to be sent to the Smart Phone for manipulation through Java-based Android application. Delta Learning Rule algorithm was used for decisions making as it is able to distinguish whether it is a dangerous situation or not. Furthermore, the proposed system has a property of generating an alert signal and sends it to the police or fire station through GMS messages.

Keywords: Smart home system, Home automation, Android mobile, Neural network, Delta learning rule.

الخلاصة

في الوقت الحاضر النظام الآلي للمنزل يعد من التكنولوجيا الموعدة للمستخدمين لتقليل التكلفة والتنعم بحياة مريحة. ويمكن أن يتحقق ذلك بجعل التحكم بالتهوية والتدفئة والانارة وتكييف الهواء، والتظليل ممكننا، وإضافة إلى ذلك، فان كفاءة الطاقة المستهلكة ايضا تتحسن بوجود نظام الحماية للمنازل والبنايات. في هذا العمل تم اقتراح نظام الاتمته الآلي، بحيث يتم التحكم في معظم الأجهزة في المنزل. أيضا عندما يكون الشخص خارج منزله فان النظام المقترح سوف يكتشف النار أو أي حركة غير مرغوب فيها من خلال اتخاذ القرارات بدلا منه.

في هذا المشروع فان الموبايل بنظام تشغيل اندرويد يتم استخدامه كوحدة تحكم حيث استخدامت ثلاث عقد لجمع قراءات حول الانارة، والتدفئة، والحركة. كذلك استعملت أجهزة استشعار (متحسس الكتروني) من قبل متحكم لجمع هذه المعلومات، ثمارسالها إلى الهواتف الذكية لاسلكيا من خلال WIFI لمعالجتها واتخاذ القرار المناسب في ما يجب القيام به. الخوارزمية الذكية التي تستخدم لأول مرة لاتخاذ قرار لقراءات أجهزة الاستشعار هي قاعدة التعلم للشبكات العصبية نوع دلتا. وقد وجد من خلال النتائج ان الشبكة العصبية قد جعلت النظام الآلي أكثر ذكاءا بحيث إذا كان هناك أي تحرك أو حريق في المنزل فان التطبيق سوف يتعرف عليه ويميز إذا كان خطرا أم لا، فاذا كان كذلك فان النظام سوف يعطي أمرا إلى الموبايل بإرسال رسالة GSM إلى المالك (أو الشرطة) يخبره عن الحالة الجديدة.

أضف إلى ذلك، ان السيطرة على جميع الأجهزة المنزلية تكون بشكل يوفر الراحة لكل حالة تلقائيا، كما ان البرنامج الذي يستخدم لعملية المعالجة هو برنامج جافا، ومن ثم يتم تحويل البرنامجج إلى تطبيق اندرويد من قبل برنامج Eclipse Juno IDE وتثبيته داخل الهواتف الذكية. في حين أن المتحكم الدقيق المستخدم هو اردوينو مع Xbee و واي فاي.

الكلمات المفتاحية:– نظام المنزل الذكي، اتمتة المنزل، هاتف الاندرويد، الخلايا العصبيه، طريقة تعليم.

1. Introduction

Smart home automation is a rich area of research and innovation as it provides safety, security, and comfort life for humanity. Such systems are portable, scalable and affordable so that more devices can be added easily to it [Johri *et.al.,* 2015]. Different communication technologies, e.g. –Wi-Fi, WiMAX, ZigBee, Bluetooth, and Global System for mobile communication (GSM), can be used by the system [Teymourzadeh *et. al.,* 2013].

People who might need institutional nursing or attention, because of physical or mental condition that limits movements, senses, or activities highly benefited from home automation to increase the quality of their life [Javale *et. al.,* 2013].

Home automation relies on two important systems they are the networking and controlling systems. Home networking uses wireless technique over wired network to achieve easy deployment and installation, reduce installation costs and the easy extension, coverage, and integration with Smart Phones [Elshafee and Hamed, 2012]. In home controlling systems where the use of computer is a fundamental. However, computers have some problems in monitoring for a remote control terminal. Therefore, the cost will be increased, and the monitoring range will be limited. These limitations can be reduced using smart phone as terminal unit by utilizing Wi-Fi and Bluetooth technologies to connect several devices wirelessly [David *et. al.,* 2015]. IEEE 802.15.4 standard may use by the wireless sensor network with ZigBee, that consider a standard radio frequency (RF) communication [Gill *et. al.,* 2009].

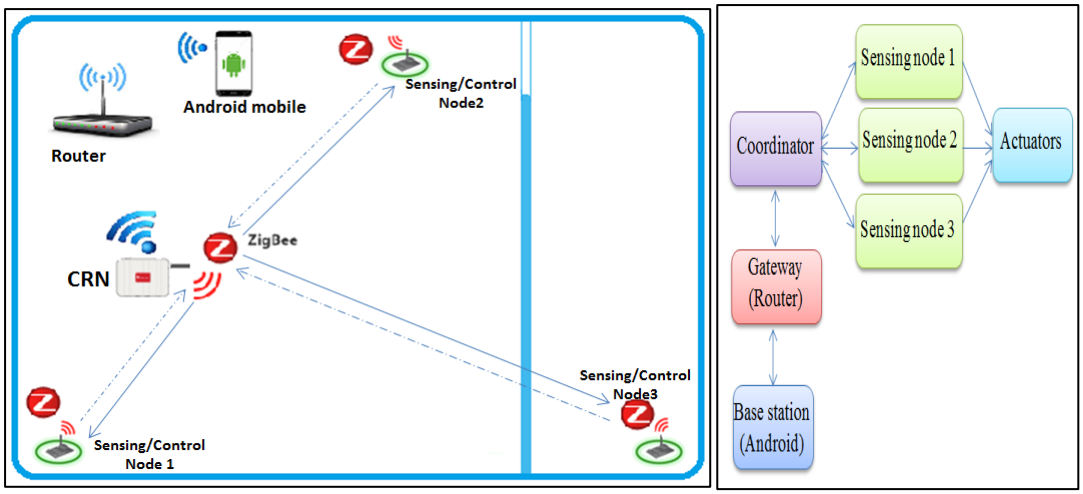
In the proposed system, each node has two modules with different types of design and implementation. The sensors/actuators modules and wireless module use a 9600 b/s as asynchronous wireless communication. To perform the connection between the mobile and the system, Wi-Fi shield connected to the coordinator node. Home data will be collected from the nodes and then sent to the coordinator node in order to be gathered and sent to the base station for processing.

Learning rule algorithm, variant of Artificial Neural Network (ANN), used to make the home automation more intelligent through giving the decisions automatically without interfering of human. The structure of the paper is organized as follows. Section 2 presented the architecture of the proposed system. The implementation of the system showed in Section 3 before the results discussed in Section 4. The paper summarized in Section 5.

2. The Architecture of the Proposed System

The proposed system consists of three components they are the control device for the proposed system which is the android mobile, wireless sensor networks and neural network algorithm. The information of home environment sensed at each node, the coordinator collected data using XBee. Local IP used to upload the collected data onto the server. The data read by the Android smart phone to be processed by Delta Learning Rule algorithm. Control commends, i.e. decisions, sent back to perform the home automation functions.

Figure 1 (a) and (b) depicted the project in which four types of nodes distributed into two rooms. Each node will have its position and name regarding to its task. There are three hybrid nodes they are controlling, sensing and coordinating. The hybrid nodes consist of sensors to gather home data like temperature, illumination level, humidity, movement detection and gas level.



(a) (b)

Figure (1) The scheme proposed system.

By taking the practical requirement into account, the proposed system allows "The Home owner" to manage the sensing nodes at suitable places in the room. Each node (sensing/control) has the ability to gather the readings data form sensors~~,~~. It will transmit these data wirelessly through ZigBee to the coordinator node. When all data collected by the coordinator from all nodes they will be sent to the mobile smart phone through Wi-Fi shield. The android mobile connected to the wireless sensor network through Wi-Fi shield. The sensed data manipulated automatically by DLR algorithm to display the sensed data on mobile screen. The proposed system is consists of hardware and software modules. The former component concerns the equipment used in hardware design while the latter deals with the GUI program and the DLR algorithm in the Android mobile smart phone.

2.1. Design of the Hardware

In order to sense and control physical world an Arduino board can be used. The programming durability, flexibility and scalability are the reasons that were dependent in selecting this microcontroller [Faris and Mahmood, 2014]. For home temperature and humidity sensing a DHT11 sensor is selected, which is a low cost sensor [Jabbas *et. al.*, 2016]. LDR (Light Dependent Resistor) sensor is used for sensing the illumination level in room, PIR (Passive Infra-Rad) sensor is used for sensing the human movement within the sensor range, Ultrasonic sensor is used to measure the distance and MQ2 sensor is used for sensing the gas level and to detect the smoke existence [Latha *et. al.*, 2015].

The designed system is consisting of sensing nodes where a microcontroller of Arduino UNO type is used in each node and a microcontroller of ATmega2560 type is used for the coordinator node (see Figure 2 (a) and (b)). . The wireless communication between the system nodes is achieved by using the ZigBee networking protocol. In wireless network, the using of the combination of both xBee and Ardunio works very well. The end nodes and the coordinator node are connected with each other using xBee to collect the home data and then transmitting these data from the coordinator to the base station (Android mobile) wirelessly through Wi-Fi. The module of the xBee series 2 (S2) is shown in Figure 2 (c). In order to connect the xbee to the Ardunio board a wireless SD shield is used through serial pins.

Four modes of operation of the xBee is used in this system. These modes are~~:~~ Transmit, Receive, Idle and Sleep. During the operation of the design system, it will

go through all these modes, where it starts by transmiting and recieving the data between the coordinator and the end-nodes. Idle mode is activated when there is no transmitting or receiving any data. Sleep mode used with the end nodes to reduce the consumption in the power when they are not connected to the coordinator.

Various programming for mobile language is used to develop a Wi-Fi based Home Automation System with mobile platform such as Java Me, Windows, MoSync, Android, and other technologies [Jivani *et. al.*, 2014]. Wi-Fi uses 2.4 GHz radio waves, and it is a local area wireless technology. For connecting the system to the Internet or in electronic devices for data exchanged, the Wi-Fi is used and the specifications of this technology are being: wireless, transmitting data at high rate, having wide coverage area and capability of anti-jamming is high [Wang *et. al.*, 2015].

Arduino Wi-Fi shield that is shown in Figure 2 (e) was used in the designed system for connecting the base station (Android Mobile) wirelessly with the sensing system through the use of static IP address by uploading the data from the sense system and then receiving them by the base station through this IP and Vice versa. For system operating, the android smart phone is selected to be used. An android application is required to be performed in order to operate the system and finally installing this application on actual android mobile**.**

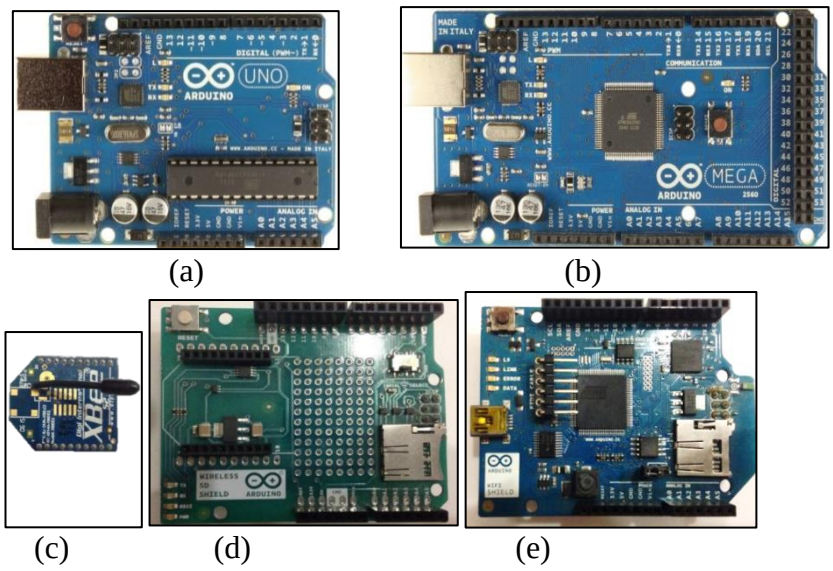


Figure (2) a) board of Arduino UNO b) board of Arduino ATmega2560 c) Module of XBee series 2. d) shield of wireless SD e) shield of Arduino Wi-Fi.

2.2. Design of Android Program

The Java application of the android mobile was designed using the Eclipse Juno IDE. The platform of the android is an open source development that enable designing of android application. The open screen of the designed system is containing two button to start and stop the system operation and view to the received data from the sensing system as shown in Figure 3. When the start button is clicked, first it checks that the device is connected to the local network if so, then it will attempt to connect to the server of the sensing system that is represented by the static IP otherwise the program will not works. In case that these two condition are exists and after connecting to the

server the coordinator will sent order to the end devices to collect the data and send them back to it. These data will be send from the coordinator to the base station through the IP in order to be processed and finally sending the control commends the the end nodes through the coordinator.

Figure (3): The main program GUI.

After receiving the readings of sensors by the base station, these data will be processed using the artificial neural network with Delta learning rule by using the database that has been learned early and also they will be displayed in the main GUI of the designed program. The displayed data are: temperature value in two rooms and it is in percentage degree, the humidity values in each room, Light illumination level at rooms in case if the lamps are ON or OFF in both rooms depending on the reading of the LDR sensor, the gas situation if its level is normal or not and at last the movement case in each room and if there is motion detected or not.

2.3. Delta Learning Rule Algorithm

ANN network consists of interconnected Neurons or nodes . It might be qualified as a directed diagram so that each neuron carries out a transfer function (activation function) as in Equation (1).

$$o_i = f_i\left(\sum_{j=1}^{n} w_{ij}x_j - \theta_i\right) \quad (1)$$

where:

θ_i: Node threshold (or bias).

x_j: j^{th} input of node.

o_i: Output of node i.

w_{ij}: Weight of the connections between nodes i and j.

f_i: is that activation function which is nonlinear usually, such as a Gaussian function , Sigmoid or Heaviside [Yao, 1999].

The Delta learning rule is one of the algorithms of ANN (see Figure 4). This algorithm is a supervised training mode also it uses a bipolar continuous activation functions as shown in Figure 5.

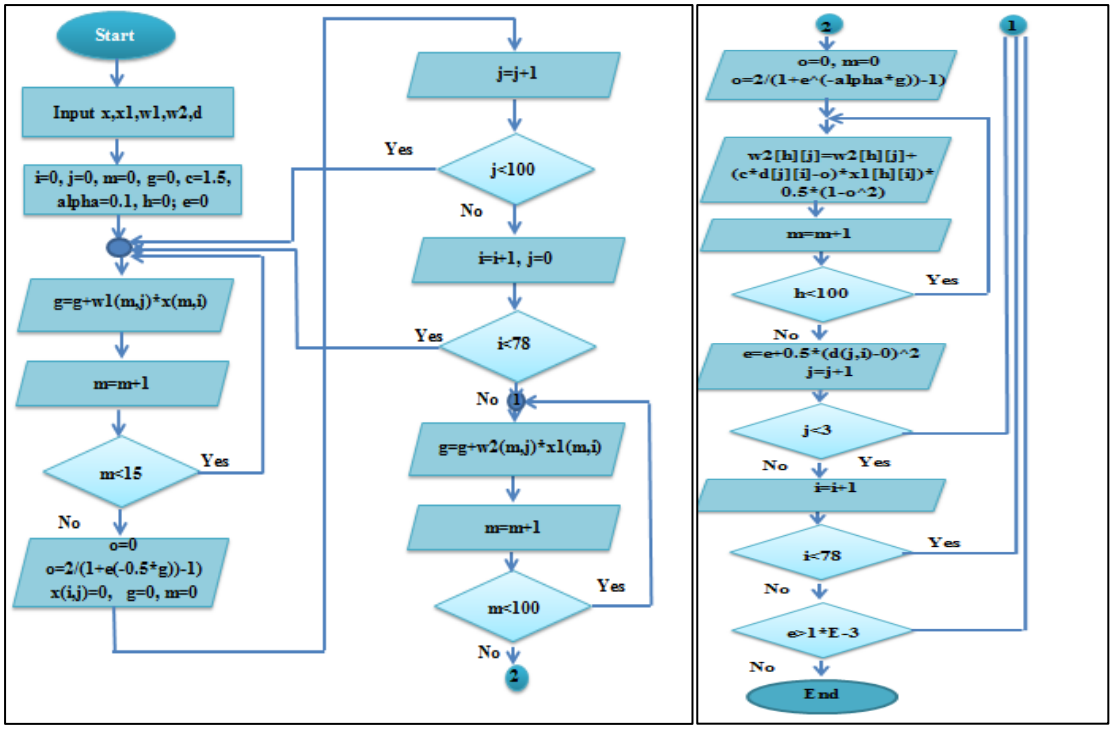


Figure (4): Flow Chart of DLR Algorithm

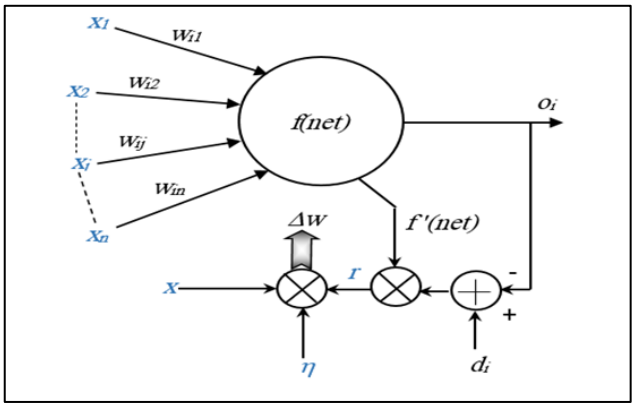


Figure (5): DLR Neural Network.

Equations (2-9) show the learning algorithm [Zurada, 1992]. The gradient in error is shown in Equation (9).

$$f(net) = 2\left(\frac{1}{1+\exp(-net)} - 0.5\right) \quad (2)$$

$$r=[d_i-f(w_i^t x)]f'(w_i^t x) \quad (3)$$

$$E = 0.5(d_i - o_i)^2 \quad (4)$$

$$f'(net) = (1 - o^2) \quad (5)$$

$$\Delta w_{ij} = \eta(d_i-o_i)\, f'(neti)xj \quad (6)$$

$$\Delta w_{ij} = \eta(d_i-o_i)\,(1 - o_i^2)\, x_j \qquad j=1, 2, 3, \ldots, n \quad (7)$$

$$w_{new} = w_{old} + \Delta w \quad (8)$$

$$E_{new} = E_{old} + 0.5(d_i-o_i)^2 \qquad i=1, 2, 3, \ldots R \quad (9)$$

Here r represents the learning signal, d is the supervisor signal of neuron i, whereas x appears as the input vector. $f(w_i^t x)$ is the neuron i output, while w is the weight of neuron i, and η is a learning positive constant that fasting the learning

process, moreover *t* is the training or iteration number of the new weights. ***f(net)*** represents the activation function whereas $f'(w_i^t x)$ represents ***f(net)*** derivative, and here $net = w_i^t x_i$..

3. Implementation of the Proposed System

The node of coordinator represents the main part in the proposed system. It considered as the central node of the system and if it is not works the system will be useless and inactive because all the end-device nodes in the system will remain waiting permission of the coordinator to perform orders or to read sensors data. The components that the coordinator node is consisting of Arduino ATmega 2560, Wi-Fi shield, xBee and wireless SD shield as shown in Figure 6.

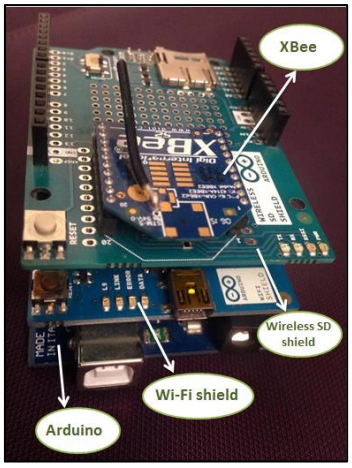


Figure (6): The Central Node (Coordinator node)

Main tasks that the coordinator node was performed were including: starting ZigBee networking, communication managements between the nodes of the system, collecting the data of the sensing nodes and then arrange these data in order to be sent to the base station (Android mobile) through Wi-Fi connection performed by Wi-Fi shield. the coordinator works start by sending packet to the end devices so as to start collecting the data and then receiving these data from each node. The data will be arranged and then send wirelessly through Wi-Fi connection to the base station. The connection between the sensing system and the base station (android mobile) is performed by using the Wi-Fi shield where both of them are connected to the same router using the IP server.

In the designed system, the Base station is represented by Android smart phone, which can be used in the range of the router coverage area. The software program that used for this system is Java program using the Eclipse Juno IDE. The system can be controlled automatically using the designed program install in android mobile which is exists in the router range.

The operation of the proposed system can be summarized as following:-

- Connecting the base station (android mobile) with sensing system coordinator node through Wi-Fi.
- Wake up packets is send to the end-devices in order to get the sensors readings.
- The sensors readings of each end-device will be sent back to the coordinator.
- After receiving the data from all end devices by the coordinator it will be arranged together in order to be sent through Wi-Fi to the base station.

- In base station, the received data are manipulated using the Delta learning rule of Artificial Neural Network (ANN) in order to make decision to control the system using Android Java program. These decisions will be sent from base station to be performed also sending alarm SMS messages.
- The alarm messages are to tell the home owner about the dangerous situations including theft and fire.

The control commends that are sent to the coordinator will be send back to the end- devices in order to be performed.

4. Results with Discussion

The brain of the proposed system was represented by DLR Neural Network, which trained by almost cases that might the homeowner face, to take the final decision about these different cases. Delta learning rule may consider the intelligent element that makes the proposed system smarter (thinking) so that it is used to take the decisions of several cases if its dangers or not, and control some of home devices. Here the homeowner is not necessary at home or the proposed system works automatically. The system will send an SMS message as a notification to police or his phone number if there is a dangers case. In the test of the proposed system, several cases have taken and they can summarize by automation control case study security case study and study.

Each case consist of the readings of 11-sensor so that 78 cases are taking into account after that the data will trained by the DNN as you can see in Figure 7that show the learning of inputs data from coordinator, also, the process required about 2280.78 seconds to give an error 0.001. The training stopped after 113259 iterations.

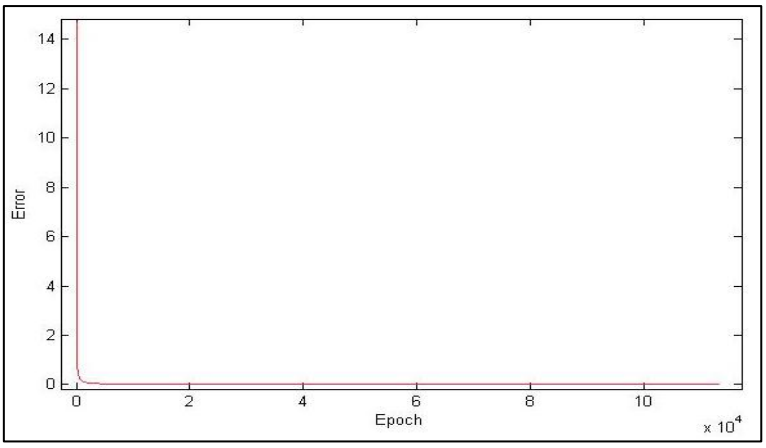


Figure (7): DLR Training Process of the Received Data

4.1. Normal Case

In room (1), Node (1) and (2) are placed, while in room (3) there is Node (3). The normal conditions can be represented by the normal case that was based according to the readings of all sensors, which may consider as the desired values. Figure 8 shows the GUI of the two rooms for normal case.

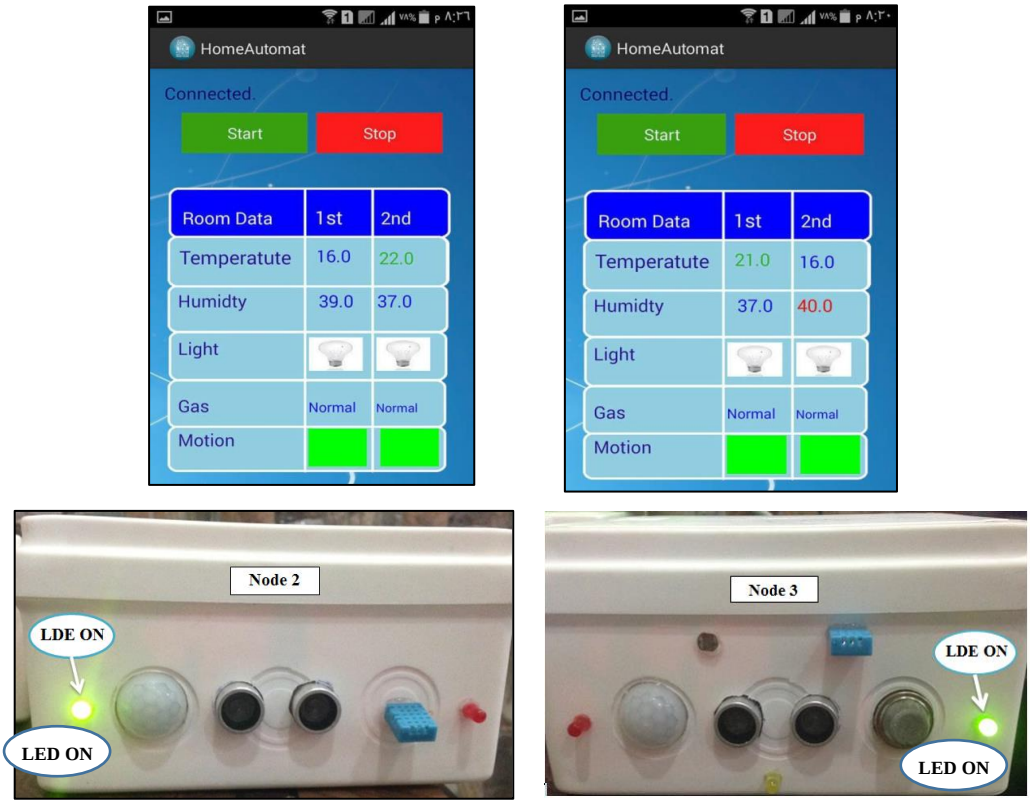
Figure (8): Normal Case

4.2. The Cases of Temperature

The temperature sensor readings are splitted into three values. The first one taking when the value of temperature is lower than 17^{o}, so that its viewed as a blue color in the screen of mobile. The second value taking is when the temperature exceeds than 25^{o}, so that it is viewed as a red color in the screen of mobile. The last value taking is when the amount of temperature is between 17^{o}- 25^{o}, such that it is shown as a green color in the screen of the smart phone.

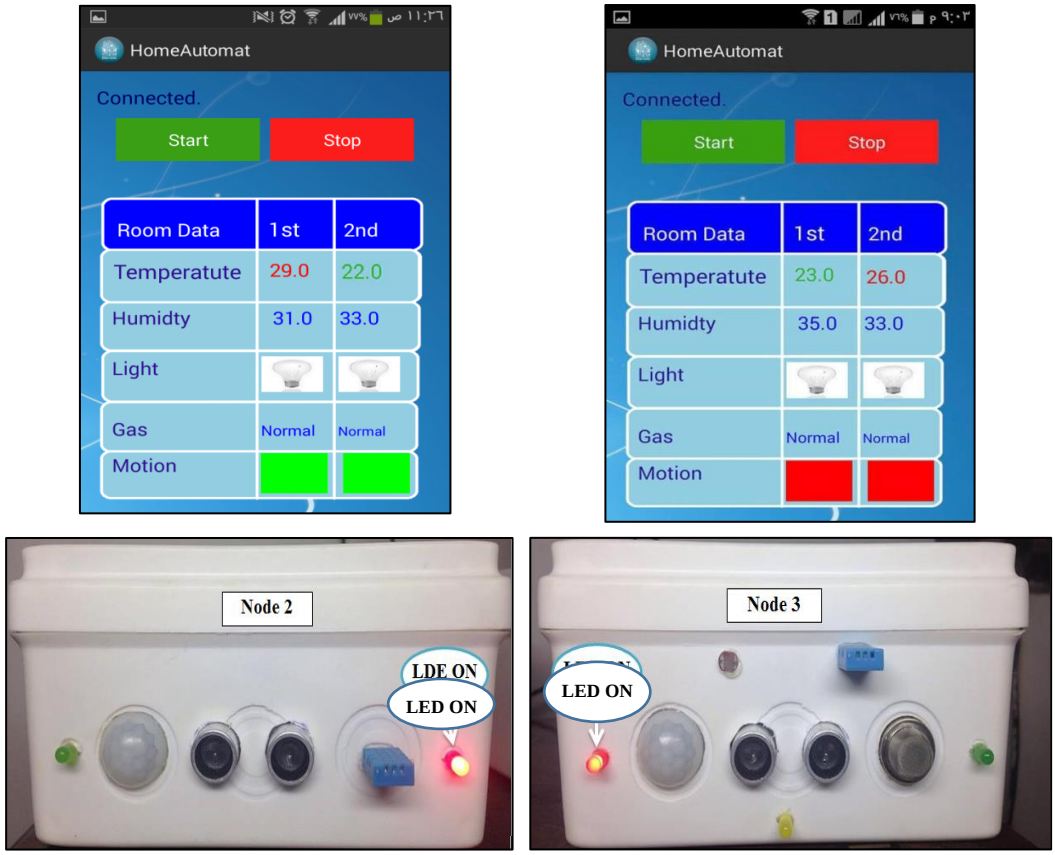
The program of ANN in the Android application is used for controlling the temperature. If the temperature is low, a control commends will be sent by the program to the system to turn ON the heater. The heater case is illustrated in figure (9) where a green LED represents the heater. Here for room 1 the LED is placed in Node 2, while in room 2 the LED is implemented in Node 3.

When the value of temperature is high, the system will turn the air condition ON. This operation is happen because the ANN program in the android application was trained earlier for this condition to send a control commend to it. Figure 10 shows these commend as a red LED light in both Node 2, and Node 3.



a) Room 1 b) Room 2

Figure (9): Low Temperature Case



a) Room 1 b) Room 2

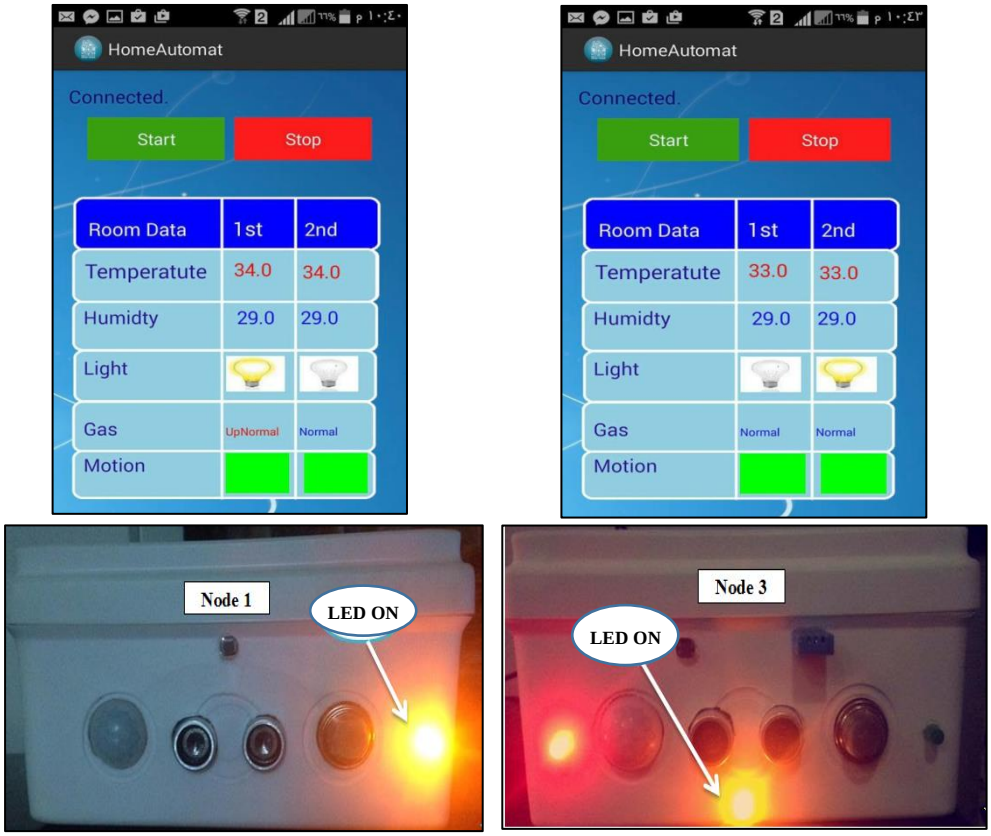
Figure (10): High Temperature Case.

4.4 The Cases of Light

In the room, the illumination level is designed in the proposed system to sense and control by turning the lights automatically OFF or ON according to LDR readings value with the aim of ANN program. Here the lights in the room will turned ON when the illumination level is below a specific value set by the homeowner, otherwise the lights will turned OFF. Figure 10 states the situations of lambs so that the lights are replace by a yellow LED.

For example, in room 1 when the level of illumination is low, Node 1 will receive a control command through the coordinator to turns the lights ON, as seen in Figure 11 for Rooms 1, and 2.

In this project, the proposed system can manipulate more than one case at time as depicted in Figure 11 (b), which shows that there are two cases in room 2. The first case, the light is low, while the second case the temperature is large, so two emitted LEDs are seen in Node 3.



a) Room 1 **b) Room 2**

Figure (11): Cases of Light

4.5. The Cases of Gas

In each room, the Gas level is being monitored such that the program of ANN examine if there is a state of fire when the Gas reading exceeds a specific threshold. In this case, SMS message will be sent to the owner via android program or to the Fire Station near the homeowner as you can see in Figure (12).

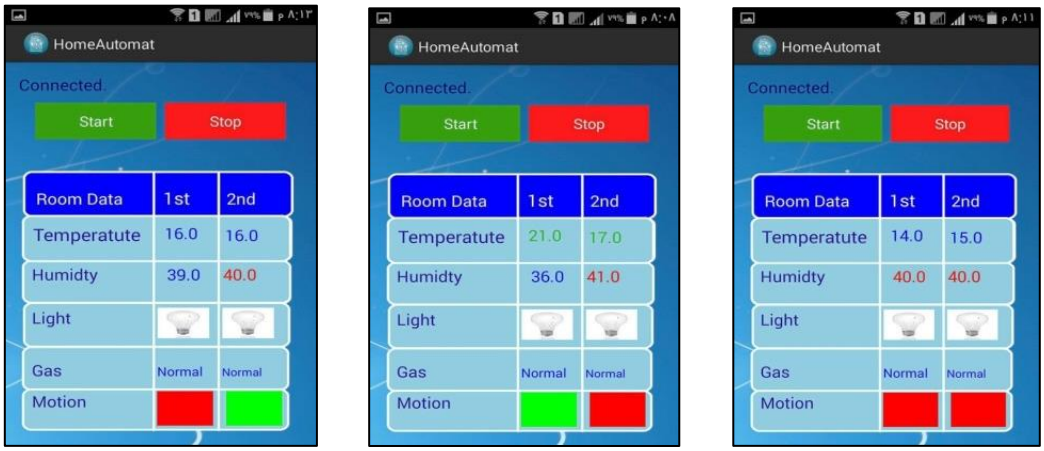
Figure (12) shows that when the Gas in one of the room is above the specific value (normal), the Temperature is checked by the ANN program such that if the value of temperature exceeds 60^{o}, then a Fire case is happened, otherwise if the level of Temperature is normal or below 60^{o}, then a Gas case exist.

a) Room 1 (Fire case) **b) Room 2 (Gas case)**

Figure (12): Fire Cases

4.6. The detector of Motion case

Ultrasonic and PIR sensors are used for motion detection in the proposed system by measuring the range (distance) for windows and doors and check if they are open or closed; also, they monitor any movement in each room. When the homeowner is out of his home, ANN program also manipulate these data to accomplish the home security by sending an SMS messages to him and using an alarm system. Figure (13) shows the tested cases of the two rooms.



a) Room 1 **b) Room 2** **c) Two rooms**

Figure (13) cases of movement detection

From figure (13-a), the android mobile application pointed a red color in the screen of mobile if there is a motion in room 1, while in the second room there is no motion. Similarly, Figure 13(b) states a motion in room 2; while Figure 13 (c) shows the response of the system when there is a motion in both rooms.

In the paper of [Jivani, 2014] you can see that a voice control massage sending by the application of android mobile inverter to the home GSM system for controlling the appliances of homeowner manually. For a comparison with the system proposed in this project, the proposed system controls all appliances of the home by a smart way automatically because of utilizing the intelligent algorithm (ANN) as depicted in the results.

The project of [Kumar and Vasu, 2015] control through internet functions like (smoke detection, light controlling, and temperature sensing) through an android mobile so that the main screen consist of a list of almost functions but without movement detection. To control them, the user can select any one, and he can if he wish disable or enable the intended device. As compared with the system proposed in this work, the proposed system has good security because the existing of the movement sensor, which can detect any movement in each room. In addition, it is smarter so that if there are two or three cases at time, then you can see the system gives a suitable decision for it like the case of fire that depicted in section (4.5).
78 different cases trained by ANN Delta Learning Rule so that if any case happened, then the case will manipulate and the decision will take quickly.

5. Conclusion

In this paper, an automated home system was proposed and implemented using ANN and wireless sensing network. It composed of some sensors, ZigBee network, Arduino, Android mobile and Wi-Fi shield. Android mobile phone is used for controlling and monitoring the home. Furthermore, it utilized Wi-Fi for system connection. Light, doors and windows, temperature, movement, and fire detection and motions are auto controlled by the Android application which utilizing ANN to take the decision automatically for each state. Different mobiles are used to test the Android program. It is found that it works fine in each of them. Most cases are trained and tested. Android and Arduino platforms that used by the proposed system considered as a Free Open Source Software such that their price is very suitable for a common person and the implantation cost is low. With the help of ANN Learning Rule algorithm, the proposed system manipulates the interred data (sensor readings) and gives the suitable decision for each case automatically. The system gives a decision despite there is more than one case at the time as the fire case. For future work, the security of the system IP cameras can be improved the cameras can be accessed through the web. Furthermore, Beagle Bone or Raspberry Pi can be used instead of Arduino to make the manipulation process faster.

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