Home Automation for Elderly Home Stay

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ABSTRACT

Most elderly people choose to live alone away from their children which can cause many injuries or even accidental death because nobody cares for them. The developed system is simple but efficient which is specially constructed for elderly people that live alone in a home. There are four sensors (door sensor, bed sensor, bathtub sensor, and gas sensor) that is implemented in the house and another device (fall sensor) which is to be worn by the user. These four sensors will not only ensure the safety of the user but also the safety of the house. When the alarm is triggered the buzzer will be turned on and the GSM module sends the emergency SMS to a third party user. The Human Machine Interface (HMI) has been constructed in order to give live data from the sensors to the users or to the third party user. Each sensor has been tested. The design encompasses a working functional system for elderly home monitoring.

KEYWORDS

Smart Home; Elderly home stay; sensors; GSM; HMI

1 INTRODUCTION

Home automation is the use of specific automation techniques in private homes to enhance comfort, energy efficiency and security of the residents. With rapid technology developments, these days the world is increasingly experiencing the use of microcontroller devices. With a basic knowledge of C programming an engineer could use a microcontroller such as Arduino to create a complex automation system for elderly homes.

In this project the home automation is focused on certain feature that developed for elders. Recently the problems connected with ageing population all over the world have become more and more severe. In this era, a lot of people are busy with their work some of them live with their parent or some might leave their parents to live at another house alone. But it doesn't mean people that live with their parent won't leave their parent alone at home someday. In this project the features that would be developed would help the elders to stay at home alone. This project would help them to live an easier life with lower risk of accident. This home automation would encourage the elders to be brave and to have more confident to live independently and their children or relatives would not be worried about them since they will get real time information of the elder's condition/activity.

2 OVERVIEW OF SMART HOME SYSTEM

Figure 1 below is showing the flow of the four sensor system that is integrated together to trigger the alarm. The Figure 2 shows the flow of bathtub sensor system that has a different purpose which is to control the water level.

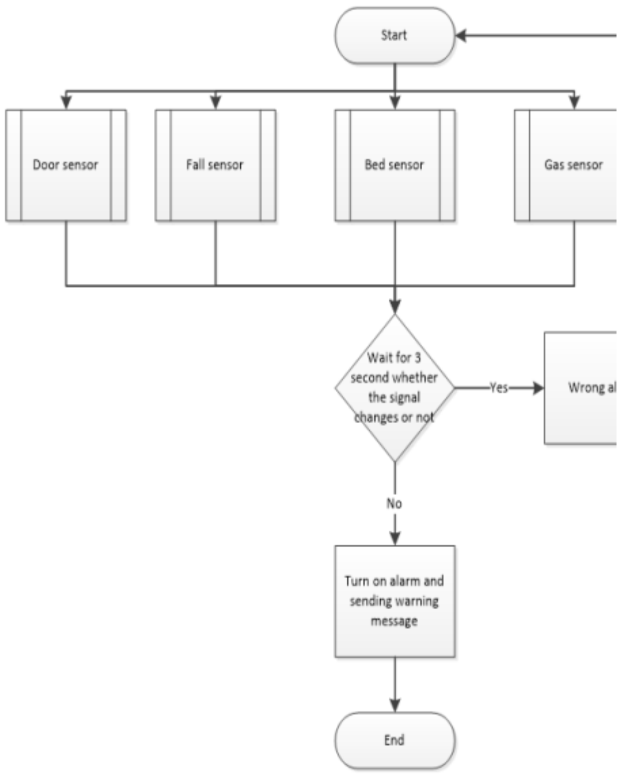

Figure 1: Flow chart of the system

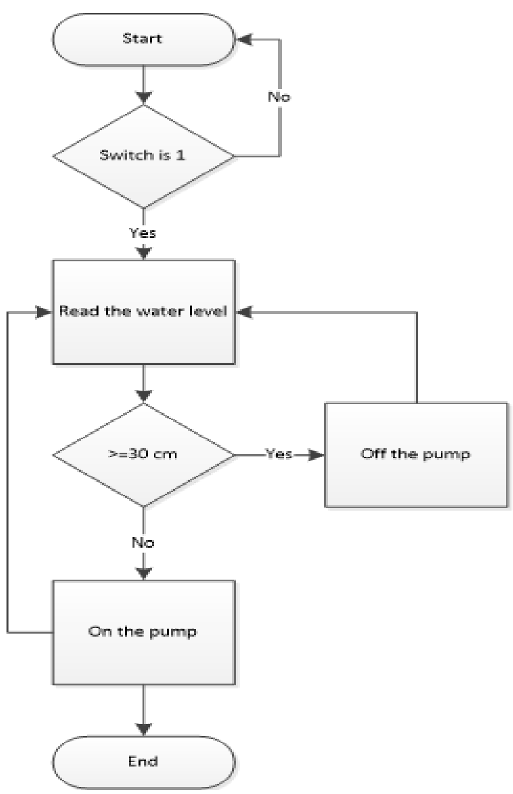

Figure 2: Flow chart of the bathtub sensor

The door and gas sensors were installed in order to keep the house protected from intruders. The bathtub sensor was to prevent overflow of water and give the user the level assurance when filling the bathtub with water. The bed sensor was to alert the user so that he/she could sleep on time in order to maintain their well being and finally the fall sensor was to send an alert for if a person were to fall down. Some features were also developed such as the door of the house could be opened by the user by simply pressing the button on the fall sensor. The sensors are connected to the Arduino so that the Arduino could carry out tasks after receiving the output from the sensors. The four sensors are wire connected except for the fall sensor which is connected wirelessly to the Arduino. The sensors would send signals to the microcontroller if something dangerous was happening. The microcontroller would process the signal and proceed to the next stage which was to trigger the alarm and send a warning text message to the third party mobile users.

3 SIZING THE COMPONENTS

3.1 Gas sensor

According to Ramya and Palaniappan (2012), the dangerous concentration of Liquefied Petroleum Gas (LPG) is larger than 1000ppm. The sensor (mq-5) could read the concentration from 200 to 10000ppm. For the signal from the sensor calculations to convert voltage to ppm (parts per million) was necessary with the formula used as follows;

$$\frac{Rs}{RL} = \frac{Vc - VRL}{VRL}$$

RL = 20KΩ. Ro (constant) is the sensor resistance at 1000ppm of H_2 or any gases in clean air and Rs is the sensor resistance at various concentrations of gases. The VRL is the voltage output that is sent by the sensor to the microcontroller. It is stated that the sensor could sense the gas from 200 to 10000 ppm so when the sensor senses clean water, it would still sense 200ppm of LPG gas. Rs/Ro = 0.7 (from datasheet given) in 200ppm of LPG gas. The output voltage that sent by the sensor in clean air must be obtained through the microcontroller which is 1.87V.

$$\frac{\mathrm{Rs}}{20000} = \frac{5 - 1.87}{1.87}$$

$$\mathrm{Rs} = 33475.93\Omega$$

Then,

$$\frac{33475.93}{\mathrm{Ro}} = 0.7$$

$$\mathrm{Ro} = 47822.76\Omega$$

Since Ro is the resistance inside the sensor so it would be constant. Once the Ro is determined, the relationship between Rs and RL can be used to convert the data for the sensor from voltage to ppm. For example, for 1000 ppm the Rs/Ro would be 0.28.

$$\frac{\mathrm{Rs}}{47822.76} = 0.28$$

$$\mathrm{Rs} = 13390.37\Omega$$

Then,

$$\frac{13390.37}{20\mathrm{k}} = \frac{5 - \mathrm{VRL}}{\mathrm{VRL}}$$

$$\mathrm{VRL} = 2.995 \text{ Volt}$$

So when the Arduino reads the voltage across the RL as 2.995V this means the concentration of the gas is already dangerous and the alarm would be triggered.

3.2 Bed sensor

$$Vout = \frac{R}{R + FSR}(Vin)$$

In order to get the value of the pull down resistor (R), some values are used (100Ω, 250Ω, 1000Ω and 4000Ω).

When 10N (1kg) force is applied (FSR=1KΩ):

$$Vout = \frac{100}{100 + 1000}(5)$$

$$Vout = 0.4545V$$

When 100N (10Kg) force is applied (FSR=250Ω):

$$Vout = \frac{100}{100 + 250}(5)$$

$$Vout = 1.43V$$

Output range = 1.43 – 0.4545 = 0.9755 Volt
2. 250Ω
Output range = 2.5– 1= 1.5 Volt
3. 1000Ω
Output range = 4– 2.5= 1.5 Volt
4. 2000Ω
Output range = 4.44– 3.3= 1.1 Volt

From those calculations shown above, it could be seen that the widest output range is when the R is 1000ohm or 250ohm. To choose more efficient values other samples used are at 500Ω, 375Ω, and 300Ω. After the same calculations were applied the widest output range was when the pull down resistor was at 375Ω which is 1.64V (3-1.36V).

3.3 Ultrasonic sensor

The accuracy of the ultrasonic sensor could be questionable since the temperature around the bathtub would not be constant or would not be in room temperature (because of the steam from the hot water). According to Fisher and Sui (2013) the emitted and reflected sound waves (used by ultrasonic sensor to measure distance) were depending on the speed of sound. The speed of sound could be calculated by using this formula:

$$V = 331.4 + 0.6 * 25$$

The result (V) would be used in the Arduino programme to enhance a more accurate measurement. The temperature (T) would be measured in real time by using LM35 (temperature sensor). The programming code for ultrasonic sensor usually uses the default value of the speed of sound

(346.4m/s) which takes 25°C as the rated temperature. The speed of sound will always be constant in this case which causes inaccuracy in readings. This is shown is the sample calculations shown below;

When T=25:

$$V = 331.4 + 0.6 * 25$$

$$V = 346.4\ m/s$$

When T=30:

$$V = 331.4 + 0.6 * 30$$

$$V = 349.4\ m/s$$

It had a 3m/s difference when the air temperature was changed which is quite high and would reduce the accuracy of the ultrasonic sensor.

3.4 Fall sensor

The output of the accelerometer could be used directly to sense the tilt without any calculation. In reality the value could be converted to degrees but in this project, it was not required. This sensor was calibrated wirelessly in order to attain precise tilt values as the values are critical in order to know the position of the sensor. For now power consumption would be calculated theoretically in order to verify battery lifespan for powering the whole circuit.

Arduino mini: 50mA
Accelerometer: 350µA
Large LED: 20mA
Small LED: 16mA
Buzzer: 11mA
Wireless module: 26µA

The values above were obtained according to the datasheet of each component. The battery that used was a Li-po battery which had 3.7V and 600mAh. When there was no emergency (stand-by mode) then an Arduino mini, small led, adxl335 and wireless module will be ON which consumes 66.376mA. When there is an emergency then everything will be On consuming 91.376mA.

Standby mode:

$$Time = \frac{600mAh}{66.376mA}$$

$$Time = 9.04\ Hour$$

Emergency mode:

$$Time = \frac{600mAh}{91.376mA}$$

$$Time = 6.56\ Hour$$

4 DESIGN IMPLEMENTATION

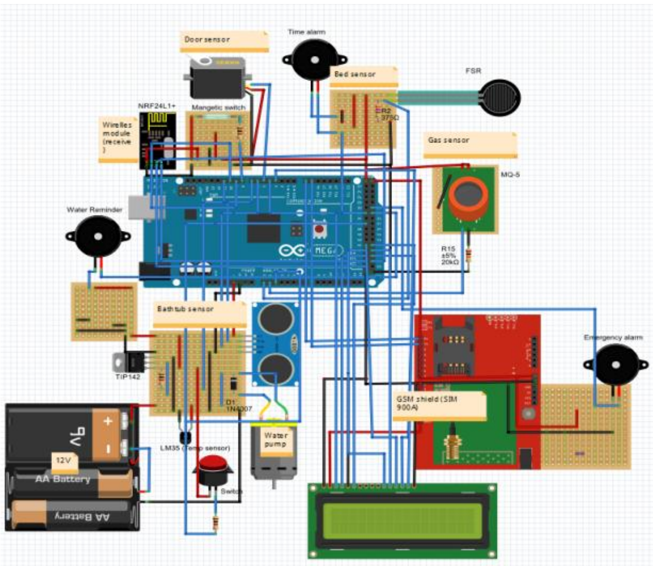

Figure 3: Wiring diagram of the system

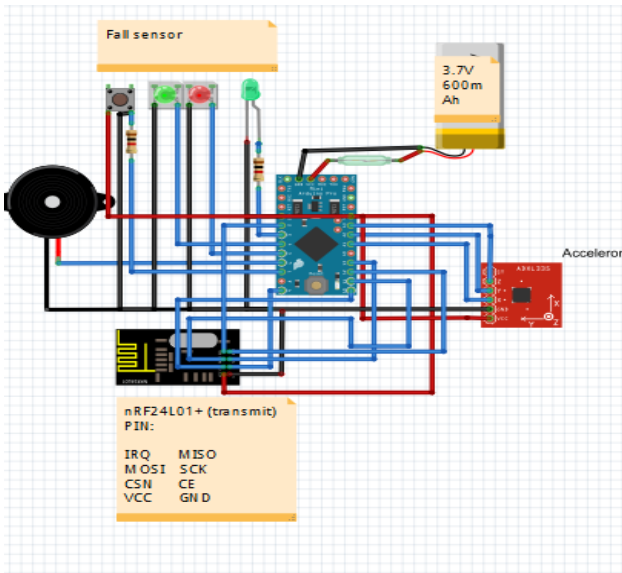

Figure 4: Wiring diagram of fall sensor

Figure 3 shows the wiring diagram of the four sensors and as well as the fall sensor by using the Fritzing Software. Figure 4 shows the wiring diagram of the fall sensor. For the bathtub sensor, there is no warning message that would be sent to the third party user. The bathtub sensor would only control the height of the water and give reminder to the user that the water in the bathtub has been full. To activate the pump of the bathtub, the user must press the switch in order to start the mechanism.

The bed sensor uses Force Sensing Resistor (FSR) to sense pressure on the bed. By using the voltage divider rule, the value of the FSR could be obtained. In this case, higher the pressure then lower the value of the FSR. The initial value of the FSR must be obtained since the FSR would be pressed on to by the bed weight pressure. The parameter is set or calibrated based on the value that the sensor would show when the user was laying on the bed.

Since LPG is the most common gas that used in the house the gas sensor used must be able to sense the gas. The voltage that was shown by the gas sensor would be increased significantly but since the value is in voltage, it couldn't be determined that the gas was or not dangerous for the environment. According to Ramya and Palaniappan (2012), LPG would be dangerous when it reaches more than 1000 PPM (Parts Per Million).

The door sensor was integrated with the fall sensor. If the user that wears the fall sensor came home, then the system would automatically connected to the fall sensor and the door would automatically open for a certain amount of time (based on setting). If the user that was inside the house wanted to go out, the user would have to press the button that was placed on the fall sensor then the door would be opened for a few seconds prior to closing. The duration on how long the door would be open could be set depending on the user. A magnetic switch installed at the door would monitor the status of the door whether it is open or not. This magnetic switch was used to prevent robbery.

The fall sensor is wearable device that has a radio transmitter to transmit data to the main microcontroller (Arduino Mega). The fall sensor was to be used by clipping the sensor around the waist (at pants). The waist area was chosen because it gave steady and good orientation on the position of the user. The waist area would minimize the error of false reading on the falling position, such as the waist area would only change orientation if the user is laying but when the user stands or sits the position will maintain.

Figure 5: HMI of the system

Figure 5 shows the HMI of the system developed by using Labview. When the main microcontroller receives a signal, it would wait and keep reading it for 3s prior to ensuring that the signal is true and then the status of the system would change to "caution". If in that duration, the signal is converted back to normal then the status would show "false alarm" but if it is still true, then the alarm would be triggered and SMS would be sent to the third party mobile user. This feature was made in order to minimize errors caused by the sensors. In sending the emergency SMS, the system would only send the SMS one at a time. For example when the system status is in emergency, the GSM module would be triggered and the SMS goes out to the third party mobile user. The system was programmed not to send a second SMS until the status of the system is reset or back to "fine". This feature was used in order to avoid wasted SMSs.

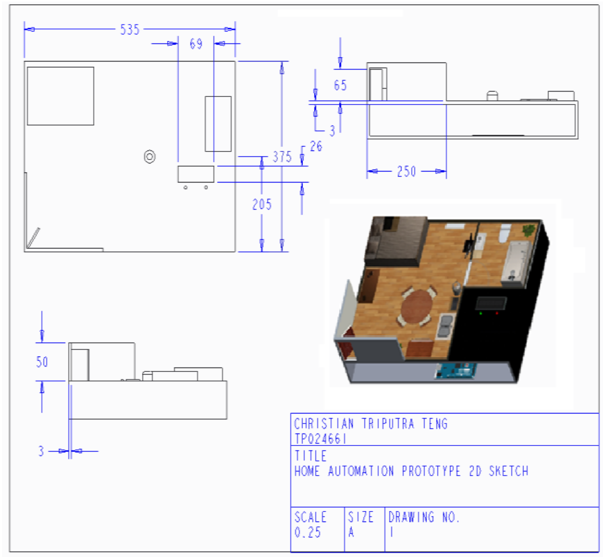

Figure 6: 3D drawing of the prototype

The Figure 6 shows the 3D drawing of the prototype by using Creo Element Software.

Figure 7: Prototype of the system (1)

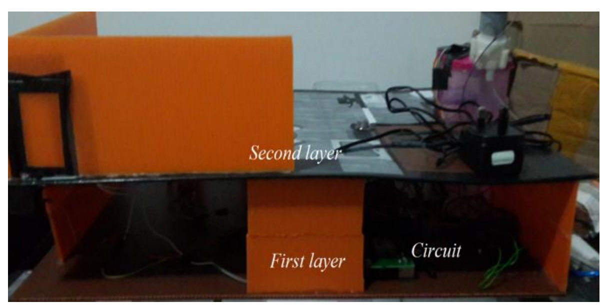

Figure 8: Prototype of the system (2)

Figure 9: Prototype of the fall sensor

The Figure 7 and 8 shows the prototype of the system and the Figure 9 is the fall sensor.

5 RESULTS

5.1 Fall sensor

Table 1: Fall sensor data collection (4 positions)

No.	Sensor Reading			
	Falling Forward	Falling Backward	Falling to left	Falling to right
1	Success	Success	Success	Success
2	Success	Success	Success	Success
3	Success	Success	Success	Success
4	Success	Success	Success	Success
5	Success	Success	Success	Success

According to the testing, in the first attempt the sensor could detect all the falling position without any failure. The sensitivity of the sensor could be adjusted by changing the parameters.

5.2 Bed sensor

Table 2: Bed sensor data collection of FSR values

Weight (gram)	Sensor Reading (ohm)				
	Value 1	Value 2	Value 3	Value 4	Value 5
0	3663	3750	3706	3579	3663
800	2307	2289	2289	2289	2307
900	2217	2234	2217	2199	2217
1000	2165	2182	2148	2165	2148
1100	2116	2110	2116	2084	2084
1200	2084	2068	2053	2100	2053

When there was zero load on the FSR, the FSR should show infinity value but since the FSR is put in the middle of the bed so FSR was pressured by the bed then when there was no load on the bed it would show 3579 to 3750 ohm. From the values above, the sensor would give the difference of 70 ohm for every 100 gram of weight pressured on to the sensor.

5.3 Bathtub sensor

Table 3: Bathtub sensor data collection of 3 different measurements

No.	Temp (^{O}C)	Real Measure (using ruler, cm)	Measure with temperature sensor (cm)	Measure without temperature sensor (cm)
1.	55	2	2	3
2.	55	5	5	6
3.	55	8	8	7
4.	55	10	10	11

According to the testing that shown in the table above, there is slight different when the temperature sensor was used. The measurement of the ultrasonic sensor with temperature sensor has more accurate reading compared to measurement without temperature sensor.

5.4 Door sensor

Table 4: Reliability of door sensor

No.	Period (second)	Status
1.	5	Success
2.	4	Success
3.	6	Success
4.	4	Success
5.	4	Success

The table above show how long the sensor would be triggered when the fall sensor device was connected to the main board and also show whether the door sensor succeeded to open the door or not.

Table 5: Time to trigger the door sensor

No.	Period (second)	Status
1.	13	Success
2.	12	Success
3.	>30	Fail
4.	14	Success
5.	11	Success

The table above shows how long the sensor would be triggered when the fall sensor device's button was pressed while connected to the main board and also show whether the door sensor succeeded to open the door or not.

5.5 Gas sensor

Table 6: The stable state of gas sensor

No.	Time (minute)	Value in voltage
1	0	3.3
2	2	1.96
3	4	1.88
4	6	1.87
5	8	1.88
6	10	1.87

According to the testing, the gas sensor would sense clean air and stabilize the value in 4 minutes. The value attained was 1.88V.

Table 7: Gas sensors value according to distance

No.	Dist. (cm)	Value 1 (Volt)	Duration 1 (Min)	Value 2 (Volt)	Duratio n 2 (Min)
1	15	3.86	4.41	3.39	>5
2	10	4.02	4.33	4.21	4.45
3	5	4.26	4.25	4.41	4.23
4	2	4.72	>5	4.71	>5
5	0	4.79	>5	4.95	>7

On the second experiment, the gas was sprayed in different distances. In order to assure the accuracy of this experiment, the testing was repeated twice in the same condition.

The GSM module was tested and succeeded to send the warning message to the third party mobile user. The Human Machine Interface (HMI) that was designed by using Labview succeeded in connections and showed the data or the status of the sensors.

6 DATA INTERPRETATION

From the results obtained, the Gas Sensor must use 20k ohm so that it could sense LPG gas accurately. According to the calculation that has been done LPG gas would be considered as dangerous when it reaches 1000 ppm or the Gas sensor would show 3V (theoretically). This 3V cannot be used to compare the theoretical value versus the practical value since the 1000 ppm cannot be found in practical. But when it reaches the maximum value that the gas sensor could sense 10000ppm, it should give the output of 4.46V (theoretically). In the testing section, the maximum value that the sensor could sense was 4.95V. The discrepancy between the theoretical value and the experimental value was 0.49V. This discrepancy would affect the accuracy of the Gas sensor. This discrepancy occurs because the Gas sensor needs more time to burn up so that the minimum value (sensing clean air) is less than 1.87V.

Table 8: FSR value in 1N and 10N (datasheet)

Force (lb)	Force (N)	FSR Resistance	(FSR + R) ohm	Current thru FSR+R	Voltage across R
None	None	Infinite	Infinite!	0 mA	0V
0.04 lb	0.2 N	30 Kohm	40 Kohm	0.13 mA	1.3 V
0.22 lb	1 N	6 Kohm	16 Kohm	0.31 mA	3.1 V
2.2 lb	10 N	1 Kohm	11 Kohm	0.45 mA	4.5 V
22 lb	100 N	250 ohm	10.25 Kohm	0.49 mA	4.9 V

The reason why a 375 ohm resistor that used (connected series with the sensor) was to have a wider range of the sensor resistance value in sensing the pressure or weight of the user, according to the result that obtained from the testing the sensor could differentiate the weight in every 100 gram with the different of 35 ohm. And according to the datasheet of the sensors where the sensor used was 10k ohm, in 1 kg to 10 kg the sensor resistance value would be different from 250 ohm to 1000 ohm (750 ohm). It could be concluded that, from the practical results that every 100 gram would give 35 ohm of difference and when it reach 750 ohm then it could sense only until about 2142 gram or 2.142 kg where theoretically when 10k ohm is used 750 ohm different would sense to 10 kg where it has narrower range. So this proved that by using 375 ohm resistor, it would give a wider range for the sensor to sense the weight and make the sensor more sensitive.

7 CONCLUSION

Four sensors had been constructed and modified. The sensors would monitor the condition around the house which are the gas concentration in the kitchen, the presence of the user on the bed on a certain of time, control the amount of water in the bathtub, and enhance the security of the house by installing door monitoring. One more sensor that was used which is fall sensor that must be worn by the user in order to prevent dangerous conditions (death) if the user accidentally fell down. The objective to implementing all sensors had been successfully achieved.

The sensors would be integrated with the Arduino microcontroller which also connected to the GSM module that would send SMSs to third party mobile users if there were any emergency case. The GSM module had also been integrated and tested which works fine.

The HMI was also created in Labview software in order to ease the third party users in monitoring the status of the sensors. The HIM had been constructed and could show every reading from the sensors. The objective of developing Human Machine Interface (HMI) for monitoring all the sensors had been successfully achieved.

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