How the application of the Internet of Things in the homes of elderly people can assist and improve their healthcare.

Antonia Still

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Contents

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1. Introduction

The UN estimated the world's population of over sixties to be 962 million and the population of those over sixty to be growing at around three percent yearly (U.N, 2017). With the advancement of healthcare, people are living longer. Elderly people require careful monitoring because a minor injury can have detrimental effects. More elderly people needing to be cared for puts a financial strain on the national healthcare system. A potential solution to this issue is the Internet of things (IoT), which allows for discreet and adaptable devices. These devices can be useful in elderly healthcare, allowing the elderly to stay in their own home, whilst remaining safe and healthy. Research into how the IoT can be beneficial in the care of the elderly is significant because the IoT has the potential to monitor their physical and mental wellbeing, easing the pressure of the caregivers and ensuring the elderly receive the care they require. An Arduino with sensors will be used to code a thermostat system. The thermostat system could be helpful for elderly people living in their own home. The thermostat can detect temperature, humidity and light. Through the IoT the conditions in the homes of elderly people will be adjusted automatically. This in turn could prevent further health problems, such as hypothermia and so less elderly are likely to get ill, allowing them to continue to live independently.

Code for project: https://github.com/A-ntonia/Code-for-Project

2. Literature review

The IoT is the connectivity of computing devices to the internet. The IoT allows devices to connect with each other and thus transforms everyday objects into intelligent and responsive devices. Smart homes, created through connected devices which are remotely monitored, can be made reality through the implementation of the IoT. The potential of which could be useful in providing monitoring and assistance to elderly people in their homes.

There are several issues that will affect the use of the IoT in homes of the elderly, including scalability. The cost of implementing the IoT devices in elderly people's homes nationwide would be very costly. Faults in the IoT devices, such as false alarms or inaccurate results could be fatal, therefore constant monitoring and updating of the technology will also be required. Due to the nature of the IoT, the devices are susceptible to cyberattacks, which could compromise the health of the elderly person being monitored if the devices were to fail, along with issues of data privacy. This is particularly true in the case of video or audio monitoring.

However, over time the use of the IoT could save money for the healthcare system. An example of this is the possibility of wearable devices, which allow for early detection of health issues. This could warrant a referral of an elderly person to the doctor before the condition escalates and causes them to get extremely ill. In turn, the need for a hospital stay or additional medication could be prevented. Despite the weaknesses of the IoT, using them in homes of the elderly could benefit many: from those with dementia who forget to turn the heating on, elderly with dexterity or with disabilities, to those who lack the ability to feel cold. The elderly are not the only ones to benefit, with caregivers and relatives having the pressure on them alleviated. Through the application of the IoT in the homes of the elderly, sickness and even death can be prevented, one such example being hypothermia, as the IoT will monitor and control the heating in their homes.

Technology using the IoT to monitor the elderly in their homes is already mainstream. Azimi *et al*. (2016) looked at how the IoT can be used to monitor health, nutrition and safety of the elderly. Azimi *et al*. found that there are devices already being used in homes that monitor temperature, pulse rate and blood pressure among other vital signs. Nutrition monitoring of the elderly was found to be significant as the elderly are more likely to suffer from malnutrition and are often forgetful in taking their medication. Al-Shaqi *et al*. (2016) also found that devices using the IoT are already being used, including wearable devices. Wearable devices are convenient because they are discreet and can record real-time data of vital sign measurements, including calorie consumption and blood pressure. This data can even be sent to the caregiver or doctor to check, allowing the elderly person to carry on their daily life as normal.

Health and safety of the elderly was a shared concern among the researchers, yet Rodrigues and Pereira. (2018) shifted the focus towards the emotional aspects of elderly care, which the other journals lacked. Rodrigues and Pereira proposed that through applying a measurement system and facial recognition system, both of which are already established and regularly used, the activities and emotions of the elderly could be measured. The application of the IoT in monitoring emotion is important because emotions can reveal a lot about the mental health of the elderly. The elderly are particularly susceptible to loneliness and Rodrigues and Pereira demonstrates the role the IoT could play in combatting loneliness, such as the smart home being able to call a relative for them or being able to ask the person their favourite movie and putting it on for them.

Azimi *et al*. (2016) found that an issue relating to monitoring health, nutrition and safety was the resistance of the elderly towards new technology. This led to the idea of embedded devices. A smart home allows for remote and automatic monitoring through embedded devices. Majumder *et al*. (2017) looked at the current research and work done regarding the IoT for smart homes for the elderly. Through smart homes the elderly can be remotely monitored through unobtrusive and real-time monitoring. This allows them to live their life as normal, in their own home.

Although a major concern in relation to the IoT, privacy issues were overlooked by most of the researchers. Only Majumder *et al*. (2017) and Rodrigues and Pereira (2018) demonstrated detailed consideration of the privacy issues involved with the IoT. Whilst Majumder *et al.* found that some smart homes use video-based monitoring systems to detect falls, Rodrigues and Pereira discovered that the use of video monitoring was considered by some elderly to be an invasion of their privacy. Rodrigues and Pereira found that whilst many elderly people had no problem with audio monitoring, they refused video monitoring.

The issue of privacy arising from video monitoring could be overcome by the research done by Do *et al*. (2017). Do *et al*. researched RiSH (Robot-integrated Smart Homes). The RiSH would enable the elderly to remain in their own home, assisted in their daily life through robots. Do *et al.* suggests that RiSH could be realised through human position tracking, which estimates the human position through approximate location information. The use of sensors to monitor and track eliminates the need for imaging technology and so maintains the privacy of the elderly. Do *et al*. found that many activities are hard to recognise through motion sensors, but the activities do generate sound. The combination of sensors and sound event recognition ensures the safety of the elderly, while also ensuring their privacy. This includes safety against falls, as falls can be detected through sound. Although RiSH are posing solutions to the need for safety in the home of the elderly, the technology is still limited. The robot needs to connect to an external care-giver for assistance in the event of a fall, as robots are not advanced enough to physically assist themselves.

Monitoring the elderly through the IoT often presented challenges to the researchers, Rodrigues and Pereira (2018) noted that monitoring emotions is not simple, as there are times when a person can feel sad for a long time, such as when mourning. This does not mean the elderly person is depressed or unwell and they can continue having normal reactions to happy situations. Do *et al*. (2017) also found assisting the elderly remotely brings challenges. Whilst the RiSH could provide comfort, emergency and supportive services, consideration was given to the difficulty robots face in perception and decision making. Majumder *et al*. (2017) poses a possible solution to this in the form of predictive algorithms. Through predictive algorithms, predictive decisions can be made. If the robot predicts a health problem, the caregiver will be notified. Although, the need for referral to a remote caregiver still poses a problem when quick action and response is required in emergency situations.

Ambient Assisted Living (AAL) is an aspect of smart homes, using technology to monitor, support and ensure the safety of a person in their own home. Applied to the elderly, AAL could allow them to stay active, remain social and live independently. Al-Shaqi, *et al.* (2016) looked at the progress of AAL in relation to assisting the elderly to live alone longer. Al-Shaqi *et al*. found that the biggest downfall of current AAL models is that they have been designed with a sense of the person in their home having a consistent routine. Al-

Shaqi *et al.* suggests that there should be more emphasis and research into an irregular pattern identification.

Through AAL Al-Shaqi *et al.* (2016) found that elderly people can have their healthcare not only assisted, but also improved through personalised healthcare. Al-Shaqi *et al*. suggest personalising healthcare is possible through integrating embedded systems into wearable devices. Azimi *et al*. (2016) similarly believes personalised monitoring to be an essential part of a comprehensive monitoring system. Personalising monitoring and assistance of elderly people is important in treating the elderly as people and not numbers.

Azimi *et al.* (2016) found that a comprehensive, personalised system was lacking. One that will monitor health, nutrition and safety at the same time. Al-Shaqi *et al.* (2016), as well as Majumder *et al.* (2017) came to the same conclusion. A common platform of a “global industry standard” was proposed by Majumder *et al*. - which could be the solution for a unified system, that will increase efficiency and allow for widespread application of smart homes for the elderly. The products currently available are not interoperable and so cannot be connected and used together. Majumder *et al.* suggested that a common platform would increase “competition among manufactures”, which in turn will increase the alternatives available. Azimi *et al*. also presented a common platform through a hierarchical model, which emphasises the need for long-term, personalised and emergency monitoring. The combination of this hierarchical model, along with the idea of a common platform suggested by Majumder *et al.* would allow for a comprehensive system.

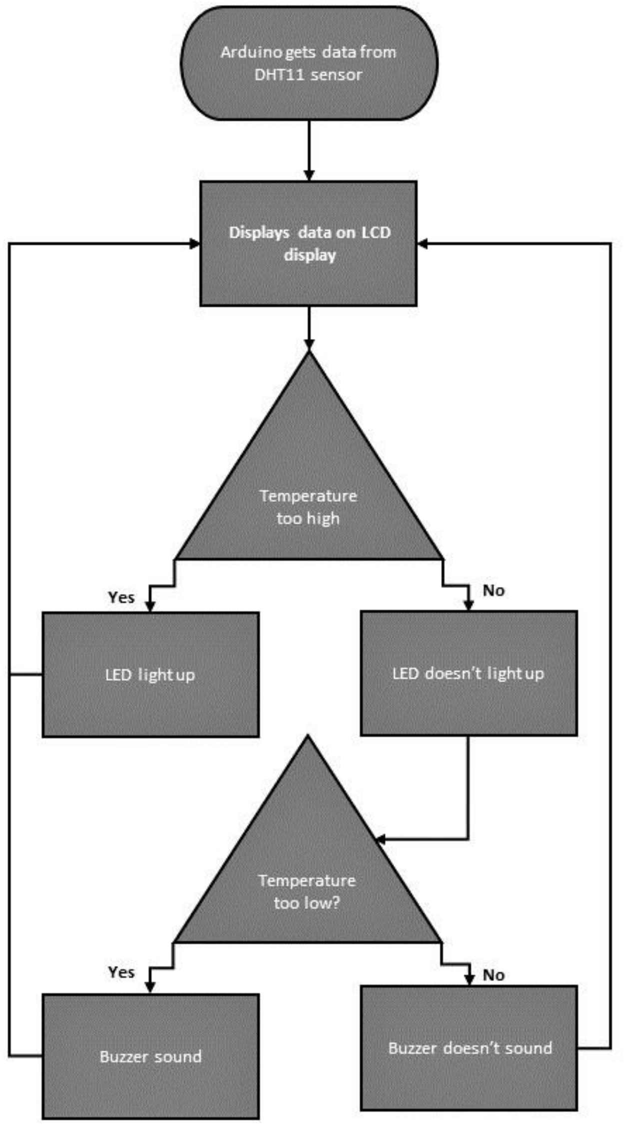
The research journals and experiments originated from Asia and mainland Europe. There was a lack of literature from the UK. Although, it is possible for this research and experiment to be replicated in the UK. This could pave the way for the IoT to become mainstream and accepted in society. This could save the NHS money in the long term and ultimately allow elderly people to remain in their homes safely for longer. One of the bigger challenges facing the IoT in the UK is public perception. In Asia people are more open and accepting of modern technology, whereas in the UK there is more resistance. Although this can change, it will take time. This project is interesting because the IoT is in infancy in smart homes in the west and through this project, it could be possible to help advance smart homes for the elderly. This project should help pave the way towards changing public perception.

There are limitations facing the IoT, including maintaining privacy, the cost needed to develop and implement the IoT in homes and the need for external help in the event of an elderly person having an accident. Although the researchers did suggest some solutions to these issues.

The benefits of the IoT in assisting and improving healthcare for the elderly outweigh the limitations. From the journals, the biggest gap in the IoT for the homes of the elderly is a comprehensive system, covering all areas of health and not just one specific area. The research shows that devices have been created using the IoT, including wearable devices, as well as sound being used to detect movement and identify activities. The combination of such technology could allow for an integrated, comprehensive smart home. The use of sound technology also demonstrates that challenges, such as privacy, could be overcome. Further studies could investigate embedded devices alongside alternative monitoring processes to maintain privacy, which could encourage a change in public perception. Research into personalising the IoT monitoring in homes would give researchers an insight into what the elderly population would like. Overall, the journal articles demonstrate the potential of the IoT in the homes of the elderly in keeping the elderly population safe, healthy and independent.

3. <u>Methodology</u>

The method used to code the Arduino IDE was planned using a flowchart.



Flowchart 1: Details process of coding Arduino

The data was collected through sensors and sent to the serial monitor. From there the readings were checked against the 'tooHigh' and 'tooLow' variables. When readings were found to be adverse, the alert system caused an LED to come on or a buzzer to sound.

The free serial terminal program, Realterm, was used to capture the data from the Arduino IDE serial monitor and save it to a text file. This allowed for the data to be sent to an excel file and displayed as graphs.

The flowchart demonstrates how the Arduino code checked the temperature readings and responded appropriately.

4. <u>Hardware</u>

The hardware consists of the Arduino board and additional components, the most important components are displayed as images, with information about them.

- Breadboard
- **16x2 LCD display**
- **Arduino Uno board**
- USB cable
- 19 Jumper wires
- 2 Female-to-male Dupont wires
- **DHT11 sensor**
- **10K Potentiometer**
- **5mm Red LED**
- 2 x 220 ohms Resistors for LED and LCD
- **Active buzzer**

i. <u>The main components used:</u>

Figure 1: Arduino Uno Board

<u>Arduino Uno Board:</u> The main components, the Arduino Board connects to the power source through a USB cable and interacts with the other components through the power, analogue and digital pins.

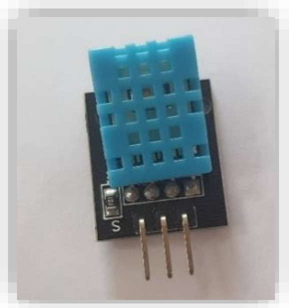


Figure 2: DHT11 sensor

<u>DHT11 Sensor:</u> The digital sensor detects temperature and humidity levels, allows for readings to be send to serial monitor.

Figure 3: 16x2 LCD display

LCD Display: The LCD with back light display has two rows and can display 16 characters on each row.

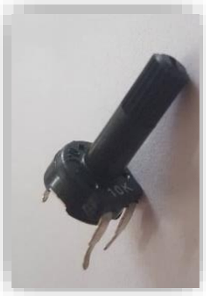


Figure 4: Potentiometer

Potentiometer: Provides variable resistance and allows for the contrast on the LCD to be adjusted.


Figure 5: 5mm Red LED

LED: 5mm red LED, used to warn the temperature has risen too high.


Figure 6: Active buzzer

Active Buzzer: Used to warn the temperature has fallen too low.

5. Results and discussion

Six tests were used to build the thermostat, shown through diagrams. Results are shown through graphs displaying the temperature and humidity readings of four different scenarios, reflective of daily living for elderly in their home.

i. Setting up and coding the Arduino

The labelled diagrams show how the five tests were carried out, the errors and how these were overcome.

a. Test One – LCD

Goal: get the LCD to display a message.

Hypothesis: LCD should display message, loop and display message again after desired time.

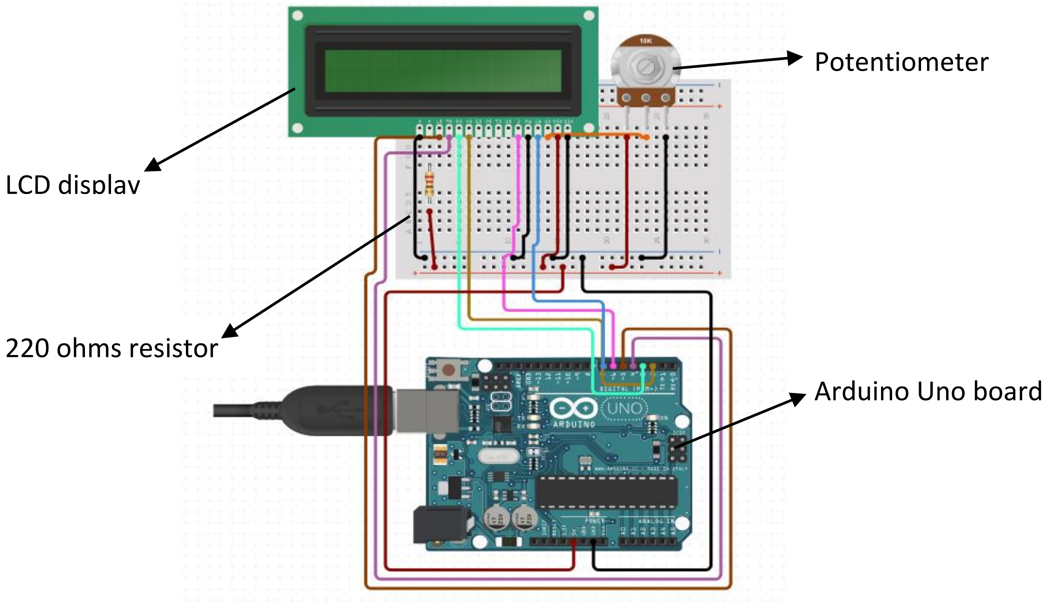


Diagram 1: Test 1: LCD to display message

The first test resulted in the LCD displaying black blocks and no text – this was rectified by changing the connection of the LCD's pin A from a wire to a resistor. This resulted in the text displaying on the LCD, but not aligned. The text was then aligned by using the command 'lcd.setCursor'.

b. Test Two - DHT11 Sensor

Goal: Get the DHT11 sensor to take readings.

Hypothesis: The DHT11 sensor will take temperature and humidity readings and display them on the serial monitor.

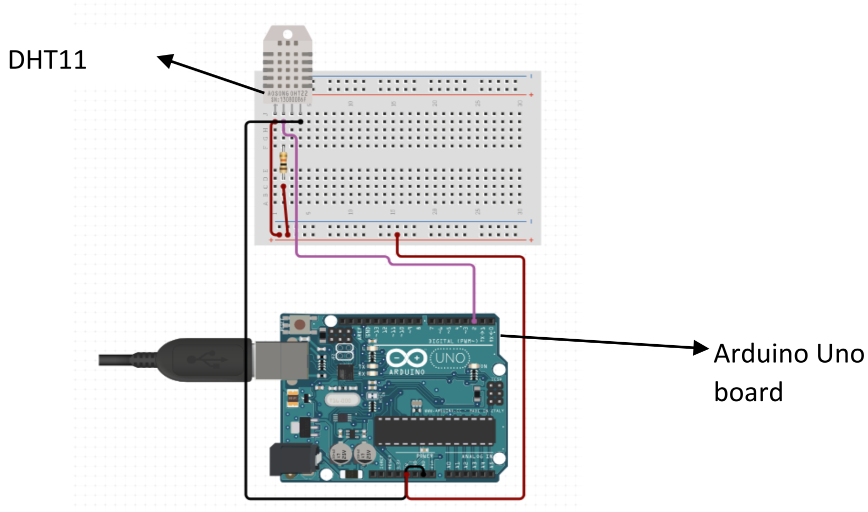
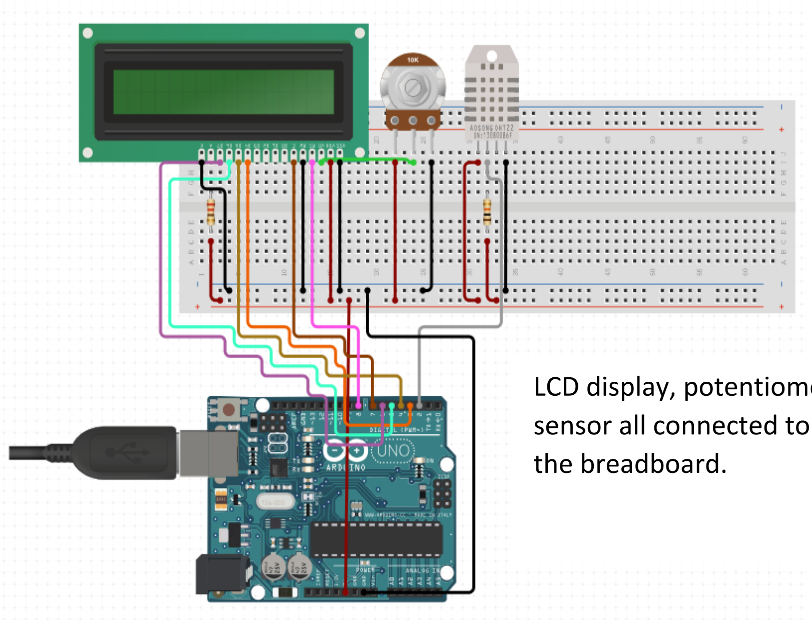


Diagram 2: Test 2: DHT11 sensor take readings

Error given "Dht does not name a type". Discovered that the 'dht.h' library was not installed correctly. After the dht.h library installed, the temperature and humidity readings displayed in serial monitor.

c. Test Three – combine test one and two

Goal: Combine LCD display with DHT11 readings.



LCD display, potentiometer, resistor and DHT11 sensor all connected to the Arduino board through the breadboard.

Diagram 3: Test 3: Combine test one and two

Hypothesis: LCD should display readings of the DHT11 sensor, wait for desired amount of time and then loop, taking and displaying readings again.

Error was found on LCD display, a backward 'E' symbol appeared next to temperature. Found it was the use of float that caused the symbol to appear. Error fixed by removing float.

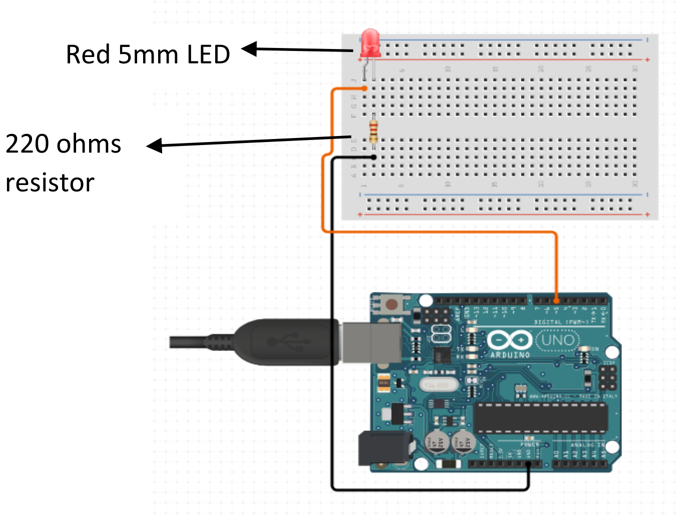


Diagram 4: Test 3: Get LED to blink

d. <u>Test Four – LED</u>

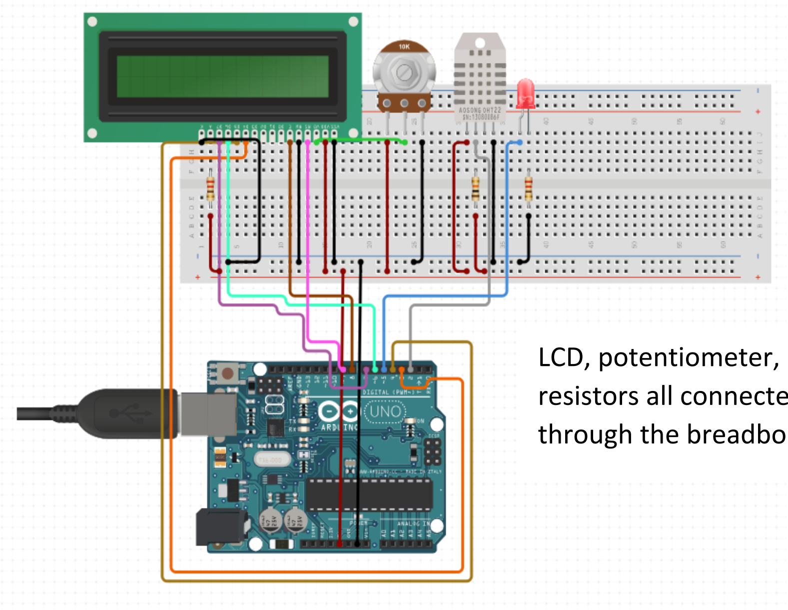
Goal: Get the LED to blink

Hypothesis: The LED will turn on for required time, turn off for desired time and loop.

No errors given.

e. <u>Test Five – Combine test three and four</u>

Goal: Combine LCD display with LED



LCD, potentiometer, DHT11 sensor, LED and resistors all connected to the Arduino board through the breadboard.

Diagram 5: Test 5: Combine tests three and four

Hypothesis: LED should display DHT11 readings, loop to check whether temperature is greater than 'tooHigh' and light up if it is.

No errors given.

f. Test Six – Add buzzer to test Five

Goal: For the buzzer to come on when temperature drops below variable ‘tooLow’.

Hypothesis: should do the same as test five, but with added buzzer – which should sound when temperature reading is lower than the variable ‘tooLow’.

Error in creating iteration for LED, ‘i not declared in this scope’. Unable to get the LED to light up for a certain number of times, instead it would stay on. Code changed allowing the LED to only light up once and then loop back.

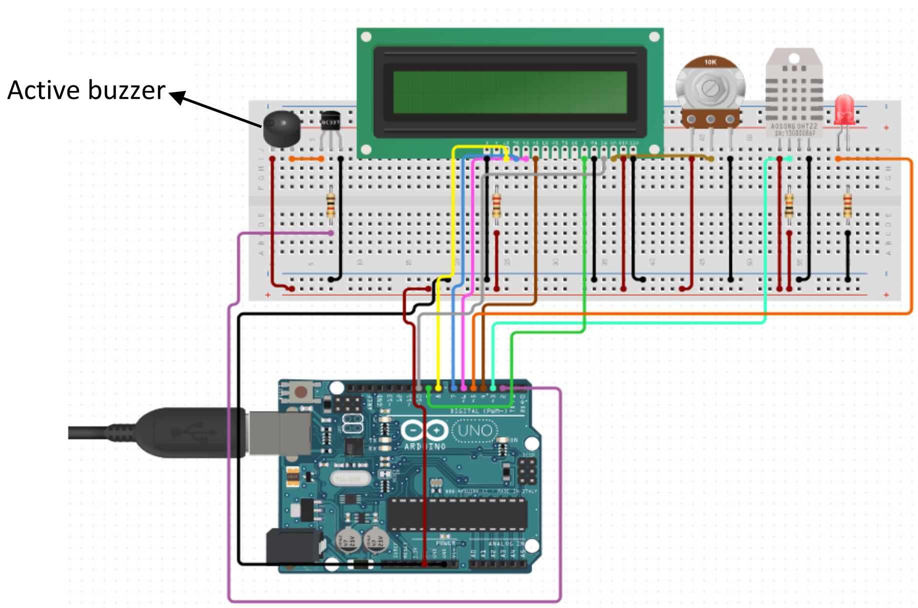


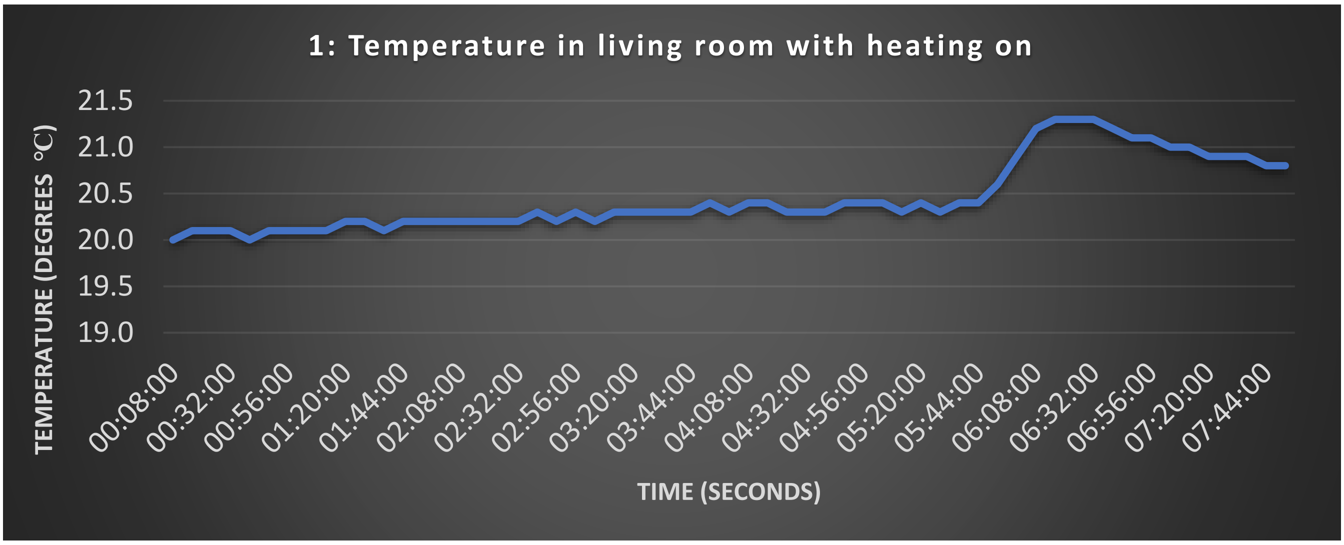
Diagram 6: Test 6: Combine test 5 and buzzer

ii. Results of readings taken through Arduino:

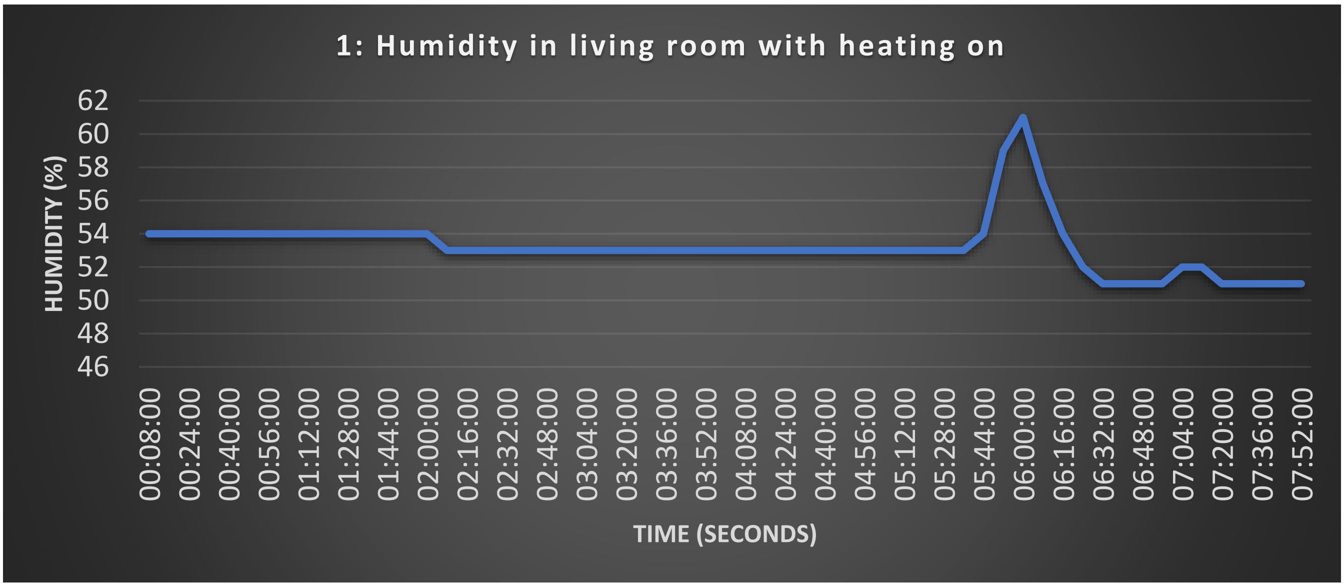
The Arduino was tested in four different scenarios, gaining temperature and humidity readings.

a. <u>Test One: Temperature and humidity levels in Living room with heating</u>

The first and second graphs demonstrate the temperature and humidity levels of a living room with heating.



Graph 1: Temperature readings in Living room with heating on

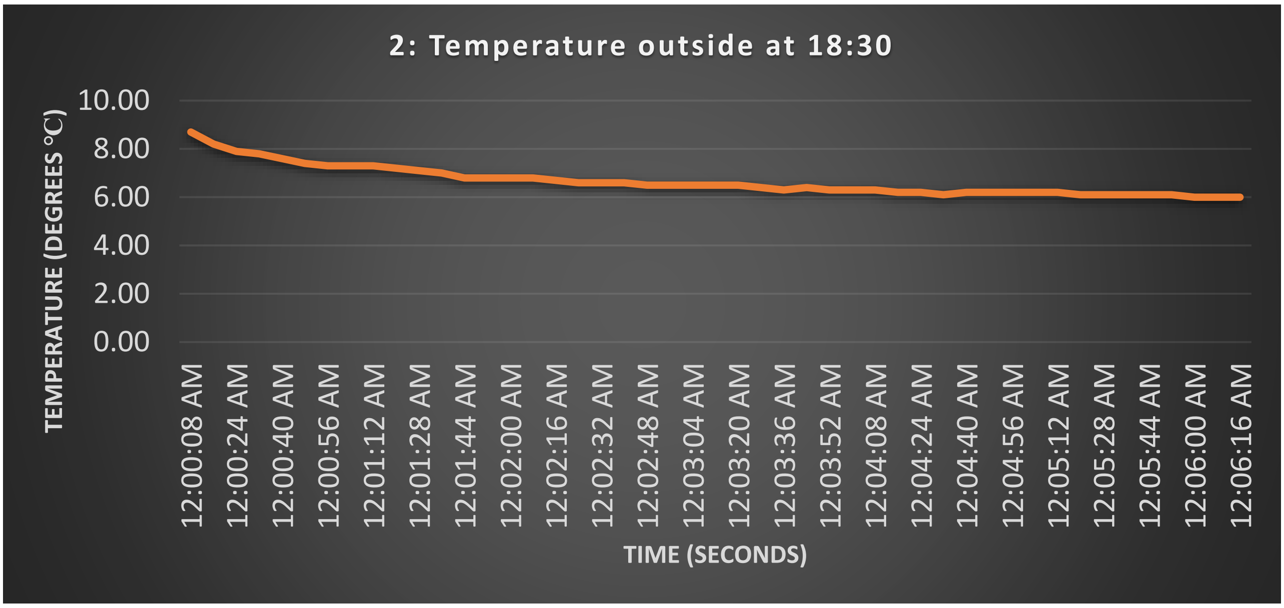


Graph 2: Humidity readings in a Living room with heating on

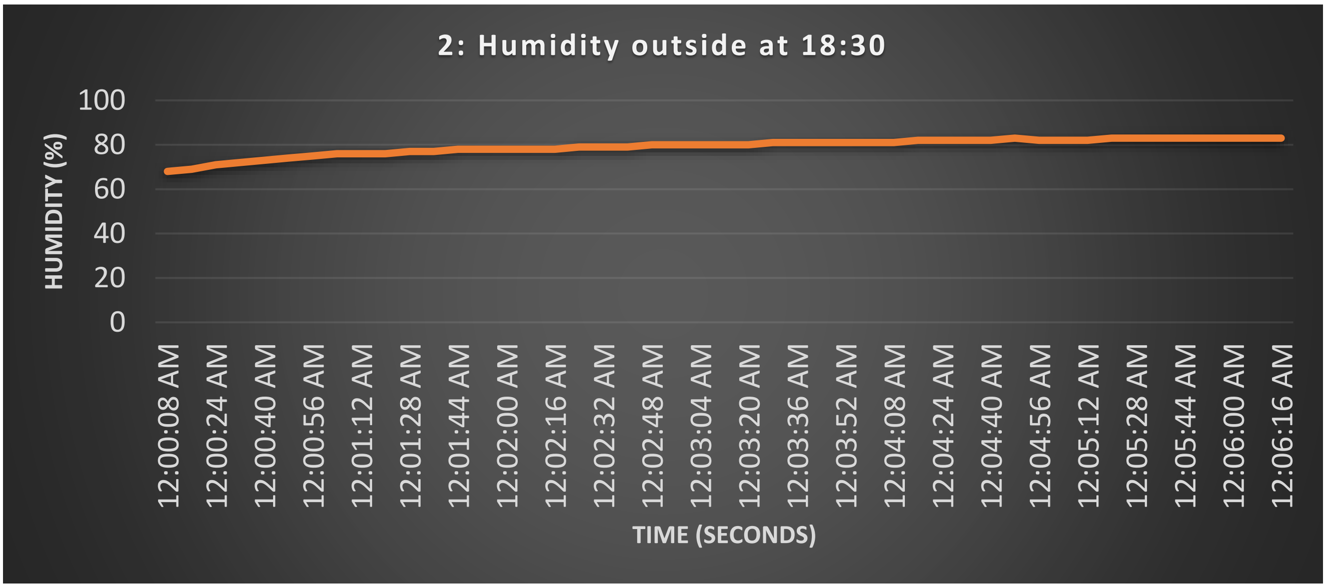
The temperature and humidity levels are safe and shouldn't result in the LED or buzzer alerting of adverse results. These are the readings that would be expected when the elderly person is at home with their heating on. The alert system should not alert the carers here.

b. Test Two: Temperature and humidity levels outside at 18:30

The third and fourth graphs demonstrate the temperature and humidity levels outside at 18:30.



Graph 4: Temperature readings outside at 18:30



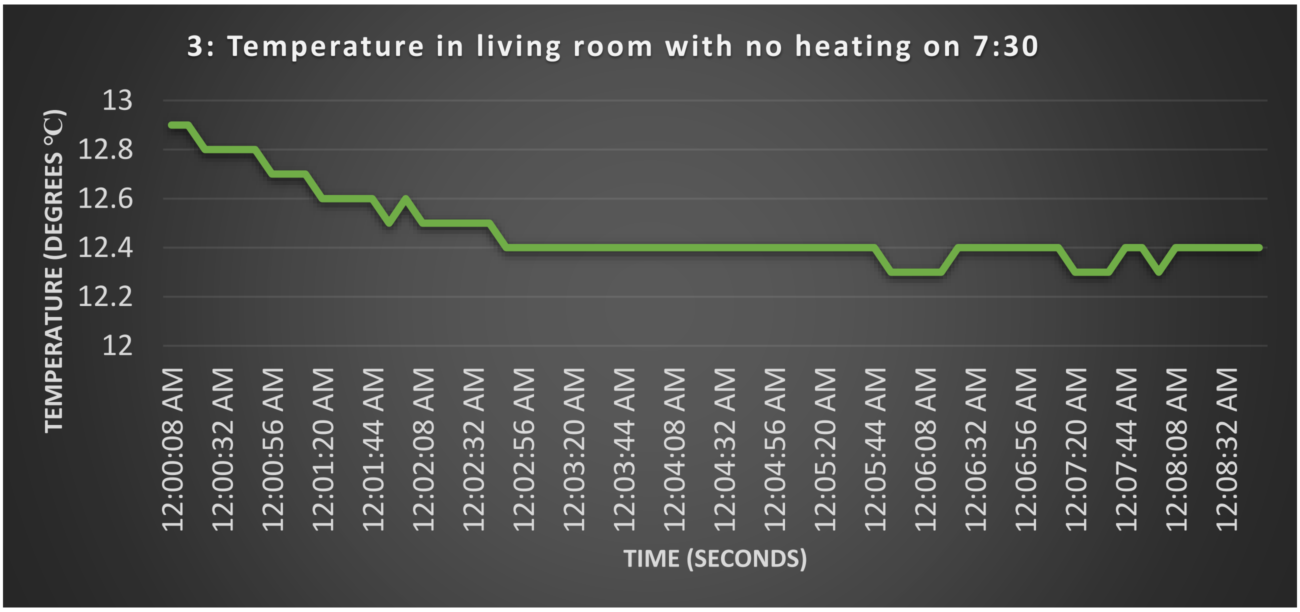
Graph 3: Humidity readings outside at 18:30

The third and fourth graphs demonstrate unsafe temperature and humidity levels. The readings were taken outside and are the kind of readings expected if the elderly person was to go outside wearing a thermostat. The carers should be alerted that the elderly person's temperature has dropped. The carer can check their location. If the carer was to see the elderly person's location as being inside their home, they should investigate further to check the status of the elderly person.

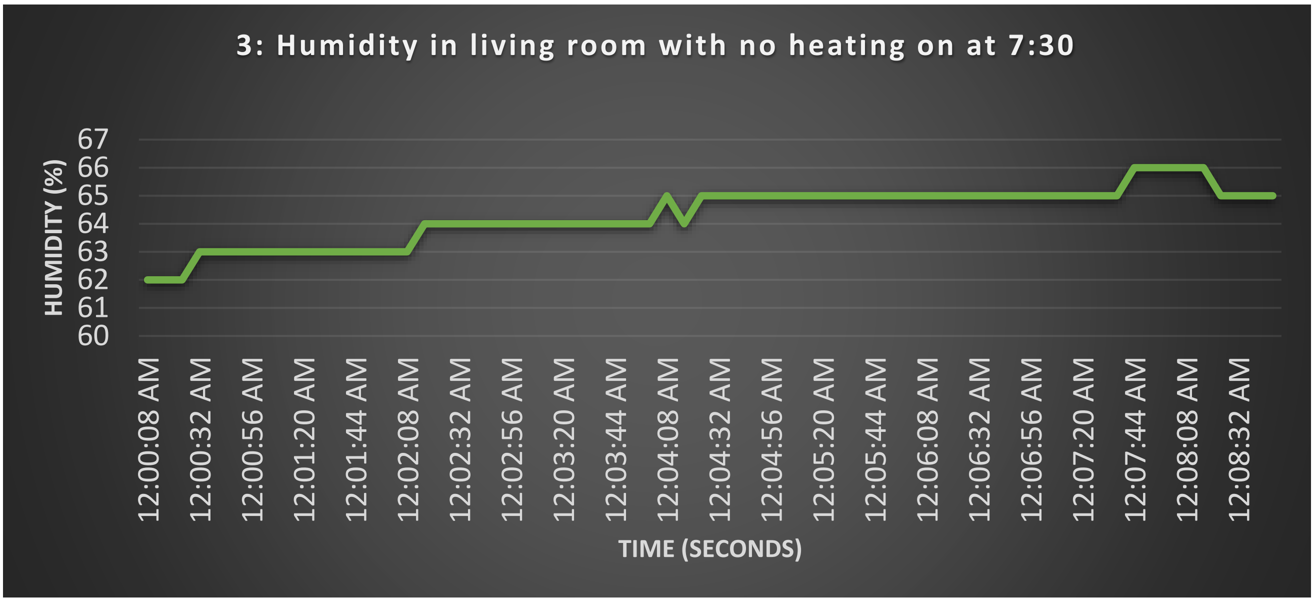
c. Test Three: Temperature and humidity readings in Living room with no heating 7:30

The fifth and sixth graphs demonstrate temperature and humidity readings which would cause the alert system to sound.

These readings can be expected when the home has no eating on. With the use of the IoT, the heating system should come on when the temperature has dropped so low.



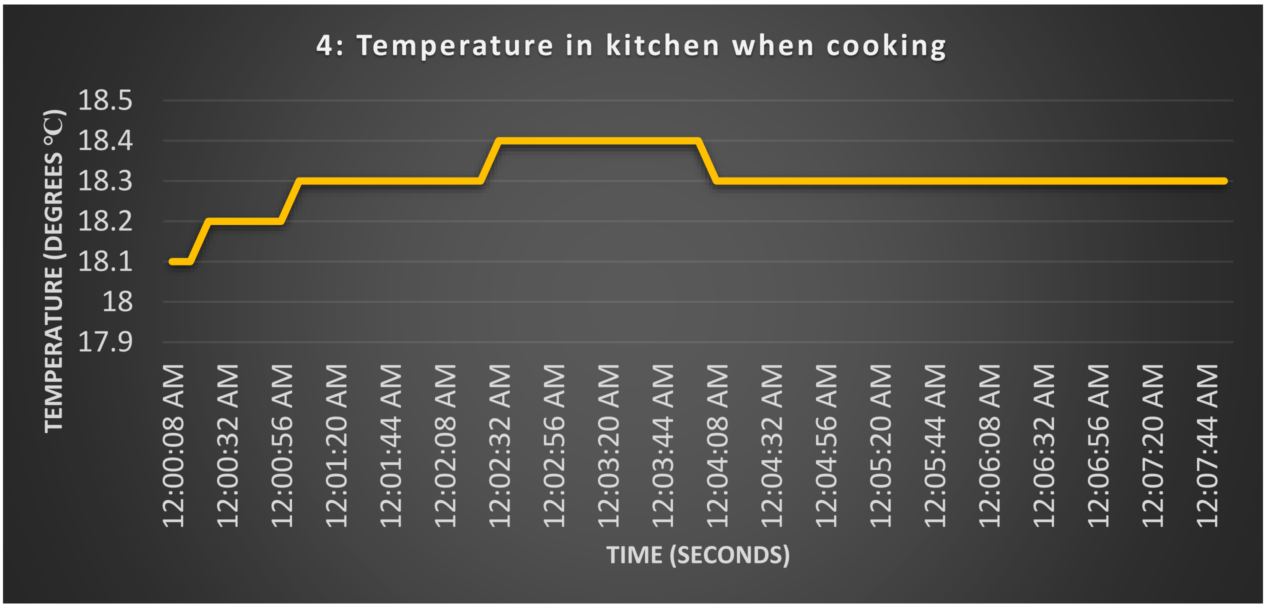
Graph 5: Temperature readings in Living room with no heating 7:30



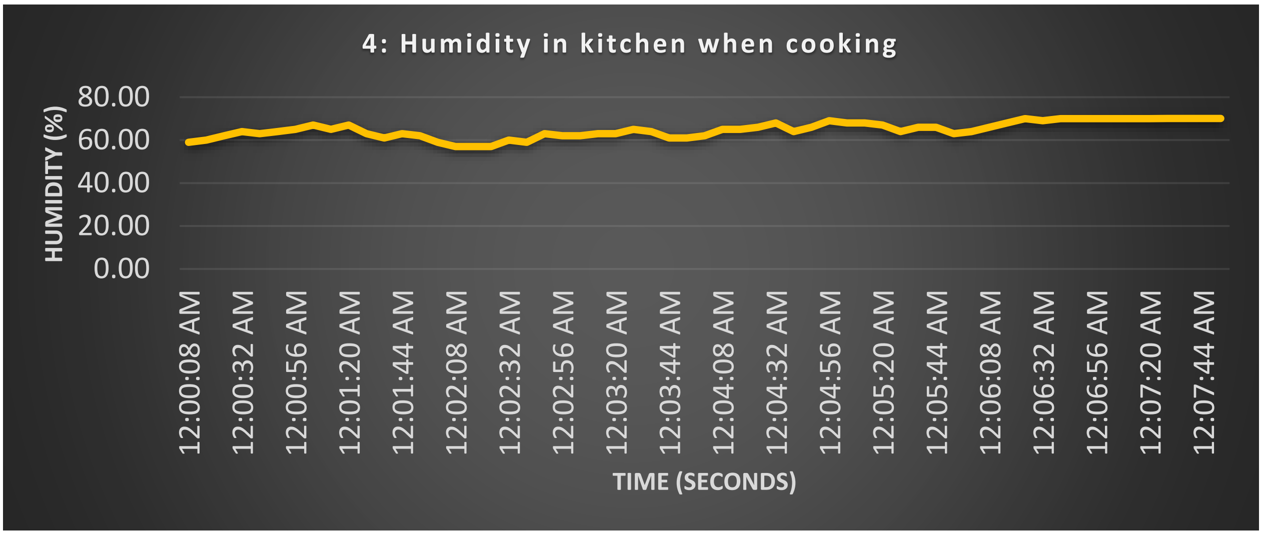
Graph 6: Humidity readings in Living room with no heating 7:30

d. Test Four: Temperature and humidity readings in kitchen when cooking

Graphs seven and eight demonstrate the temperature and humidity readings in the kitchen when cooking.



Graph 7: Temperature readings in kitchen when cooking



Graph 8: Humidity readings in kitchen when cooking

Graphs seven and eight demonstrate the varying temperature and humidity levels in a kitchen. This test shows how the readings can also be indicative of the status of the elderly person. As seen here, the changing humidity levels indicates the person is cooking, or they could be in the bathroom. The alert system should not and did not come on.

6. Conclusion

The use of the IoT, through connecting smaller devices, such as the Arduino, it is possible to monitor elderly people in their home and in doing so assist their health carers. The use of the Arduino to build a functional thermostat, with alarm system, is a small example of how the use of the IoT can assist in daily life. Taking away the need for a continuous human presence, small devices, such as the Arduino, enable a persons' condition to be monitored. This is demonstrated through the results, in which graph eight shows the humidity readings in the kitchen when cooking. From the graph, it can be seen the humidity level is fluctuating and would indicate to those monitoring that the elderly person is in the kitchen or the bathroom.

The thermostat warning system could be implemented on a larger scale in the future. With the use of the IoT elderly people can remain in their own home for longer, the thermostat will ensure their home is kept at a safe level and when the temperature rises or falls below this level an alert will be sent to their carers. This could also be extended further by reducing the size of the thermostat to fit into a wearable device. This would monitor the elderly person's temperature constantly, alerting the carers if the temperature levels were to be outside a safe range. Other IoT devices could be combined with this one, such as blood pressure monitoring or fall detection. The combination of which would allow for constant monitoring.

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