Internet of Things

The smart home

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Abstract

Internet of things

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This project report treats the basics of the rising phenomenon of Internet of Things, and the devices that can be connected to it. One of the primary goals of the project was to gain greater knowledge in the field of Internet of Things and how it can be approached from an Electrical Engineer point of view.

Three types of home devices were chosen to be implemented into the Internet of Things devices. Firstly, a coffeemaker was built so it can be activated from a mobile phone. This was made possible by using cheap electronics in the form of a control board, 433 MHz receiver and a relay.

In the second part of the project the window blinders was made controllable from the same application as the coffee machine. This was made possible by using similar devices and small DC servos and stepper motors.

The third part of the project was to make a automated irrigation system for a flowerpot. This could be made by measuring the moisture in the soil and thereby pump water from a reservoir in to the soil.

Finally a main control device was constructed to handle all the signals from the users smart phone and communicate these signals and commands to the various systems built.
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Vocabulary

- 433 MHz - a standard radio frequency (RF) communication protocol.
- Arduino IDE - Arduino code manager.
- Bit - Binary unit consisting either of a one or a zero.
- Blynk - App based IoT platform
- BYJ48 - Small 5 Volt stepper motor
- CAD - Computer Aided Design, a way to render and test objects in 3D
- ESP 8266 - WiFi enabled component for use in hobby projects
- FDM - 3D-printing technique, build up the model layer by layer.
- HUB - Command center of the systems inputs and outputs.
- IoT - Internet of Things, interconnection of devices to make them smarter
- I/O - Input/Output
- ISM - License free frequency bands, ranges from 6.765 MHz to 246 GHz.
- Neopixel ring - An array of controllable RGB LEDs in a circular pattern, product by Adafruit
- RGB - Red/Green/Blue color space, different intensities of the base colors can reproduce most of other colors.
- RF - Radio frequency.
- TCP - A communication protocol between devices. Responsive to the opposite device.
- XD-FST - Transmitter module for 433 MHz radio transmission, Amplitude modulated
- XD-RF-5V - Receiver module for 433 MHz radio transmission, Amplitude Modulated
Chapter 1

Introduction

1.1 Background

Internet of Things (IoT) connections is a growing trend in modern devices ranging from network controlled light bulbs to wirelessly controlled speakers and automated coffeemakers. As microprocessors have become cheaper and more accessible in the last couple of years the possibilities to create a low cost connected device has increased drastically. The price has gotten so low, that the average consumer can automate their homes and in the long run cut down on electrical costs, for example.

![Internet of Things](image)

Figure 1.1: The Internet of Things

The communication protocols of Internet of Things are many, and they all have their pros and cons. Some of the newer protocols such as Zigbee and Z-wave are very secure and can transfer larger amounts of data. one thing most protocols have in common is that they’re based on Radio Frequency (RF) transmission, with the differentiating factor being transmission frequencies, message bit-lengths and encryption. The disadvantage of the newer protocols are that they often are harder to communicate with, (because of their encryption) if you don’t have deep knowledge and the right kind of hardware for the given protocol.
1.2 Objective

The goal of this project is to gain knowledge in the field of Internet of Things and to implement the ascertained knowledge into building connected devices. The purpose of the devices should be to make everyday life easier by automating some tasks in the home environment by wirelessly controlling them to do scheduled tasks and responding to a user’s spontaneous input.

1.3 Limitations

Internet of Things is a very wide area including everything from automatic vacuum cleaners to smart power grids. Therefore the project was to be restricted to only treat the home automation part of the Internet of Things. That is connected devices that apply to the consumer, and not the industry.

On the communication end of things, the project was to be limited to the use of the 433 MHz protocol, one of the more basic communication protocols, but with a data transmission capability high enough for the needs of the intended devices that were going to be built during the course of the project. Regarding data transmission security, this wasn’t a concern since the applications that were going to be constructed weren’t going to send sensitive data or preform physical tasks that can be deemed as dangerous.
Chapter 2

Theory

2.1 Internet of Things

Internet of Things can be defined as network connected physical devices that benefit its users by simplifying and streamlining everyday tasks. These devices range from sensors and electronics to actuators. Over the last 10-15 years the availability of smart home devices has increased drastically and the price has decreased, which has made the market for connected products huge. According to predictions it is estimated that in 2025 the number of IoT connected devices will surpass 75 billion units, compared to the about 23 billion connected devices today.\(^1\) A few contributing factors to this is the increasingly stable wireless communications and that cheaper microprocessors are readily available.

Simply put, the Internet of Things consists of smart devices, that is devices that are connected either directly or indirectly to the Internet. These devices range from lawnmowers to connected toothbrushes.

2.2 RF-Communication

RF communication (Radio frequency communication) is a common method to send and receive signals between two or more devices. The usage of RF-transmitters/Receivers in home devices are most often in the industrial, scientific and medical (ISM) radio band of frequencies. The ISM radio band spans from 6.765 MHz to 246 GHz, and is limited to 100 mW in transmission strength.\(^2\) One of the most commonly used frequency band for IoT products is the 433 MHz band. The reason for this is first and foremost the economical aspect, the receivers and transmitters in this band are very cheap, and work perfectly fine in smaller homes and where the performance isn’t a priority.

2.3 Microprocessors

A microprocessor is an integrated circuit that functions like an entire processing unit. These microprocessors are often no bigger than a finger, while still retaining many features of a full sized typical computer. These processors are today an integral part of how we build embedded system and therefore almost a necessity within the concept of IoT devices.

One model in particular is the ATmega328. These are used in many Arduino boards which is an easy to use hardware, that comes with it’s own open source software tools. The board itself allows the user to configure ones device with marked connectors and built in LEDs.

\(^{1}\)https://goo.gl/j8HWVr
\(^{2}\)https://goo.gl/m7S5Ug
2.4 Stepper motor

A stepper motor is DC-motor that can be controlled by switching input and output poles in the motor and thereby making the rotor take one step, hence the name. These motors are somewhat easy to build and smaller versions can be cheap to purchase. The stepper motor consists of a stator, rotor, bearing and a shaft as can be seen in figure 2.1 below.

![Stepper motor](image)

**Figure 2.1: Stepper motor**

The stepper motor is rotated by switching input and output current through the stator windings. The fundamentals of this is illustrated in four steps in figures 2.2a to 2.2d. In figure 2.2a the stator winding marked with 1 is magnetized when current passes though it, and attracts the gear shaped rotor so that the rotor teeth and stator teeth align. In step 2 stator winding 2 is activated and 1 is deactivated, this makes the rotors teeth align with the teeth of stator winding 2, the motor has now made one step. The stepper motor makes step 3 and 4 and if this is repeated in succession the stepper motor will step continuously.

The stride length of the stepper motor is physically determined by how the rotor and stator gears are constructed. The number of steps needed for a revolution is typically 200 steps which makes the stride angle 1.8 degrees.

![Stepper motor steps](image)

**Figure 2.2: The stepping process.**

The stepper motor is often used in occasions where great rotational accuracy is sought, which in some cases is the desire in IoT devices.
2.5 Peristaltic pump

The peristaltic pump works by applying pressure on a tube and squeezing the fluid through. By repeating this procedure continuously under pressure is created in the tube propelling the tube in the same direction the squeezing. As depicted in figure 2.3 the squeezing armature can be mounted on a DC motor allowing water to pumped through as the motor rotates.

![Figure 2.3: Operation of the peristaltic pump.](https://goo.gl/qcpwKF)

2.6 CAD - Computer Aided Design

Computer Aided Design is a wide term for all sorts of designs that are made using a computer. One of the most common applications of CAD is 3D-modeling. 3D-modeling is a fast and efficient way to prototype and test hardware for the users specific needs. These 3D-models are created digitally with high precision and can with some software be tested for potential weaknesses, which can be reduced and improved digitally, before a physical product is manufactured.

During the entirety of our project, CAD was used for one sole purpose, to design enclosures, accessories and prototypes. We wanted to create custom enclosures for the electronics to get at form fitted and well adapted solution. The process of going from a digital file to a physical object will be discussed in more detail below.

2.7 3D-Printing

During the course of the project several custom 3D-printed parts where made. The 3D-printer that was used was of the Fused Deposition Modeling (FDM) type which creates the model by applying melted plastic filament layer after layer. The heated nozzle that extrudes the filament often moves in the XY-plane, and the heated printer bed moves with the Z-axis. These are operated by stepper motors because of their accuracy.

2.8 Arduino

Arduino is a powerful open-source platform designed for electronics projects. The software is open source, which means that all users can contribute and improve the experience. The company Arduino has several hardware platforms with different kinds of I/O. The hardware connected to the Arduino is controlled with the Arduino Software IDE with the help of programming.

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3 https://goo.gl/qcpwKF
4 https://goo.gl/HU4yQy
The Arduino boards have a lot of advantages. These are that they are inexpensive, cross-platform and have a simple and clear programming environment, according to Arduino themselves \(^5\).

\(^5\)https://goo.gl/B1VRCh
Chapter 3

Experimental Details

3.1 Planning

Due to lack of knowledge in the subject of IoT the first natural step was to read other articles and study other projects on subject of IoT in general. Furthermore a lot of hours was spent experimenting with and understanding the chosen protocol of communication that was going to be utilized for our devices which was 433 MHz. Once a fundamental understanding and specific goals were established, a preliminary time plan for the project could be split into the following stages:

- Collection of information/Theory
- Construction of base code
- CAD - Design phase
- Fusing code and 3D-printed parts to form the smart devices
- Report writing

The stages were general and did not have a mid-project deadline, but underlying milestones and deadlines for each of the stages were set. This included finishing a 3D-sketch or getting a specific piece of code ready for example. These deadlines were more flexible and kept the workflow high, if priorities needed to be shifted momentarily.
3.2 CAD & 3D-printing

One of the project goals was to design and program smart devices to work in a IoT environment. Besides the programming part of things the devices would get a physical appearance similar to a real world product. This was not only done for the appearance but also for practicality, in the respect that the hardware enclosures would be specifically fitted for the products needs. This is why we used CAD to design our hardware.

Several accessories where made for the different products, that including tailored boxes with cutouts for sensors and processing units and containers for fluids or electronics. Unfortunately not all of the designed parts where printed on time, since network errors occurred several times during our printing sessions. The 3D-printing process takes a long time, and a loss of signal aborts the printing, and a restart was needed.

Figure 3.1: 3D-designs.

In figure 3.1a we have the HUB, the command center that controls all of the smart devices that has been made, and pre-existing retail devices that one might already have in ones home. The HUB consists of two half spheres with cutouts for an Arduino Uno and a neopixel ring below it to indicate that a command has been sent. In the top sphere a 433 MHz receiver and transmitter is placed along with an ESP8266 for WiFi-connectivity.

The redirector in figure 3.1b is made for the automated blinds control, to take the wires of the blinds and
redirect them along the window sill to the enclosure where the stepper motor which winds the blinds up and down.

3.3 Programming

In order to make the whole system work the microprocessors (Arduino boards) had to be programmed. Arduinos own open source software (IDE) for programming works well with pre-built libraries, hence one could easily utilize a pre built library handling the 433 MHz communication. Other libraries simplifying control of the stepping motors was also used in the finished scripts. The finished scripts consists in broad terms a series of if-cases depending on the given signal registered by the 433 MHz receiver and the Human user interface.
Chapter 4

Results

4.1 The HUB & user interface

The HUB, which is the brain of the IoT system has two tasks. These tasks are to receive and transmit data depending on what the users tell it to do via a mobile device. The Blynk-Arduino communication works very well, once the Arduino board is connected to the Wi-Fi network and the Arduino runs the pre-built Blynk script. However, in order to get more complex scripts to run side by side with the Blynk system, the Blynk script had to be modified with certain loops that execute depending on a virtual variable in the Blynk system. One of these more complex scripts is for example the RF-transceiver scripts.

![Image of user interface - Blynk](image)

Figure 4.1: User interface - Blynk

The demo application can be seen in Figure 4.1 above. The separate controls can toggle and sliders can control the system manually, and the water level indicator can be seen on the right.
4.2 Automatic irrigation system

The structure was built to be divided into five different parts the main flowerpot, reservoir, electronic box, watering tube and the greenhouse roof. The main flowerpot is placed upon the reservoir with water. Once the moisture meter in the soil signals that the soil is dry and needs watering water is pumped with a peristaltic pump from the tank into the soil. To ensure that the reservoir never goes dry another measurement system monitors the water level in the tank and gives the user an indication on water level. A simple temperature sensor is also placed in close proximity to the plants to monitor their health.

4.3 Automatic window blinds control

The automatic window blinds control was split into two different devices. The first blinds control swivels the angle of the blinds, to let more or less light in. The angle is adjusted by turning the already existing blinds angle adjuster (BAA) by using both a small stepper motor (BYJ48). To make the blinds turn pointing upwards to pointing downwards the axis was to be turned 210 degrees. Since the stepper motors rotary angle isn’t determined directly by angle a conversion had to be made in order to know how many steps there were in 210 degrees.

$$\alpha = \frac{5.625}{64} \text{ deg/step} \rightarrow \alpha = 210 \rightarrow \frac{64 \times 210}{5.625} = 2190 \text{ steps}$$

The BYJ48 has stride length of 5.625 degrees and a gear transmission ratio of \(\frac{1}{64}\), therefore one step is equal to \(\frac{5.625}{64} = 0.088\) deg. When these calculations were done, they were programmed onto the Arduino, and the 3D-printed parts where attached. The device was programmed to accommodate three different positions, pointing upwards, downwards and straight out.

A version of the blinds angle adjuster was also constructed using a servo motor, which was smaller but had similar torque to the BYJ48, this was what was later used in the final product.

The second blinds controller pulls up and lowers the whole blinds, to shut out or let in as much light as possible. Since a larger force is needed to lift the entire blinds a bigger stepper motor (HY200) had to be used. This stepper motor was attached to the 3D-printed holder along with the driver board and Arduino Nano. The stepper motor rotated on commands and retracted the blinds wire onto a coil, taking 10 revolutions to pull the entire blinds to the top.

4.4 Wireless coffeemaker

In order to make the coffeemaker wireless a 230 volt relay was added on the main input voltage inside the coffeemaker. The relay could then be controlled by a Arduino Nano with a signal-receiver.
Chapter 5

Discussion

5.1 HUB and control unit

Since the HUB or control unit is a vital part of the communication between devices the utilization of a slightly more expensive Arduino Uno was chosen. However the Arduino Nano is still sufficient though as the Uno is more widely used one could argue that troubleshooting can be made easier by the choice of using an UNO.

Blynk is one of dozens of smartphone to Arduino communication protocols. However due to it’s fast start and the fact that is was among the first encounter during the projects planning phase made it an obvious choice. Blynk also offers a variety of custom "get started" scripts depending on platform used. once the script is downloaded its just compile and run.

5.2 Automatic irrigation system

The system works as intended one could be skeptical to the slow rate of water dispensed by the pump, however since the system is automated the flowers won’t take notice if it takes the pump five minutes or a whole hour to water them, so it does not matter. This system could as well be enhanced by a Ultra violet lamp placed above the plants in case they if sunlight is not sufficient enough. However due to time limitations this part was cut for this project. This is also a very small model but in general this system could be scaled to a much larger to cover a backyard greenhouse or even an entire farm.

5.3 Design and Material Choices

The majority of the the objects constructed are 3D-printed since one can easily design items after their own specification. It is nearly impossible to get such specific items as those used in this project on the commercial market. Furthermore this does not come with its own flaws as many parts can be deformed in construction and larger prints have a tendency to be somewhat unreliable.

PLA plastic have been the dominant use of building material. This is due to the price, PLA is very cheap in comparison to its durability, hence it is the optimal choice of material.

5.4 Wireless coffemake

The system built in this project is very simple due to fact that it was implemented on a regular coffee machine with just an on/off button. However it is possible to widen the scope of this device and implement
this wireless communication on a more advanced machine. Many modern coffee machines have the ability
to brew different types of coffee, espresso and so on. In theory it is possible to connect the arduino nano to
the electronics in these machines and thereby make it controllable from mobile applications. However due
to budget this product modification was never made as one device would blow the entire project miles over
budget.

5.5 Motor types

When picking the different kinds of motors for our different smart devices there where a number of different
sorts to choose from. All of the following motor types have advantages and disadvantages.

**Servo Motors**

The servo motor is a very precise motor with position feedback. These motors have a tendency to be
loud and does usually have a turn radius of 180 degrees. It makes up for its shortcomings by usually
having a high torque to size ratio.

**Stepper Motors**

As the servo motor above, the stepper motor is also precise in its motion, with a typical stride length
of 1.8 degrees. The stepper motor doesn’t normally have position feedback nor high rotation speed.

**DC Motors**

The DC-motor is as its name implies fed by direct current (DC). The direction of the current
is most often changed with a mechanical contraption of some sorts. The DC-motor can rotate fast,
but accurate position control is non-existents on traditional DC-motors.

An application was found for all of the motors above, since all of the different devices that were constructed
needed a specific kind of mechanical movement. Both of the two blind control devices where in need of
high precision movement. Where as the blinds angle adjuster needed an angular rotation of 180-210 degrees,
where both a servo motor and a stepper motor could be used. In the final version a servo motor was used,
since its higher torque to size ratio.

A larger stepper motor was used to raise the entire blinds, since several full rotations where needed to wind
up the entire binds.

The DC-motor was only used in one application, the Automatic irrigation device, in the water pump.
Chapter 6

Conclusion

Our IoT devices work as expected and provides the user with automation and wireless convenience in the everyday life. The devices could definitely be improved with more time and experience in the subject. The biggest area of improvement would be to give the devices more functions, and to make a better user interface. For example could the irrigation system include more sensors to monitor more vital values and give the user the ability to select pre-determined operating patterns for certain plants, giving them the optimal amount of water, light etc.

6.1 Acknowledgements

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