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Design and Fabrication of an Internet of Things Level-4 Autonomous Smart Fan

Final year project proposal

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November 28, 2021

Declaration

We hereby declare that the work contained in this report is original; researched and documented by the undersigned students. It has not been used or presented elsewhere in any form for award of any academic qualification or otherwise. Any material obtained from other parties have been duly acknowledged. We have ensured that no violation of copyright or intellectual property rights have been committed.

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Contents

Declaration . . . . **I**

List of Figures . . . . **IV**

List of Tables . . . . **V**

List of Abbreviations . . . . **VI**

Abstract . . . . **VII**

1 Introduction **1**

1.1 Background 1

1.2 Problem statement 1

1.3 Objectives 2

1.3.1 Main objective 2

1.3.2 Specific objectives 2

1.4 Justification of the study 2

2 Literature Review **3**

2.1 Introduction 3

2.1.1 Overview on smart devices 3

2.1.2 Temperature control devices and energy usage 3

2.2 Related Works 5

2.3 System 6

2.3.1 Air Flow System 6

2.3.2 Fan Blade Design 6

2.3.3 Casing 7

2.3.4 Diffuser 8

2.3.5 Fan Laws 8

2.3.6 Specific Fan Power 10

2.4 Software 11

2.4.1 Communication 11

2.4.2 Mobile Application 12

2.4.3 Motor Control 12

3 Methodology 13

3.1 Interface module 14

3.2 Communication module 15

3.3 Software and Processors module 16

3.4 Measurement module 17

3.5 Actuation module 18

3.6 Assembly module 18

3.7 Environment module 19

4 Expected Outcomes 20

References 21

Appendices 24

List of Figures

Figure 2.1 Smart home system [1] 4
Figure 2.2 Axial Fan design [2] 7
Figure 3.1 Design architecture 13
Figure 3.2 Software Logic 17
Figure 4.1 Timeplan 24
Figure 4.2 Budget 24

List of Tables

Figure 2.1 Different fan designs 7

Figure 2.2 Influence of number of fan blades 8

Figure 2.3 Comparison of the Bluetooth Low Energy (BLE), Ultra Wide Band (UWB), ZigBee and Wireless Fidelity (Wi-Fi) protocols. 11

List of Abbreviations

IoT Internet of Things

KEBS Kenya Bureau Of Standards

DIY Do It Yourself

PWM Pulse Width Modulation

GPM Gallons per minute

rpm Revolutions per minute

SFP Specific Fan Power

BLE Bluetooth Low Energy

UWB Ultra Wide Band

iOS iPhone Operating System

Wi-Fi Wireless Fidelity

WLAN Wireless Local Area Network

WPAN Wireless Personal Area Network

IEEE Institute of Electrical and Electronics Engineers

DC Direct Current

UX User Experience

UI User Interface

UART Universal asynchronous receiver-transmitter

PVC Polyvinyl chloride

PCB Printed Circuit Board

3D Three Dimensional

Abstract

There is a rise in temperatures due to global warming and everyone is bestowed with the responsibility to reduce and possibly eradicate global warming. We too should take part in temperature regulations especially in Sub Saharan Africa so as to dampen the effect of global warming. Most common temperature regulation devices, air conditioners and fans are inefficient. Air conditioners use a lot of energy. On the other hand, most fans are manual and the smart ones are not smart enough to stop themselves in the absence of humans thereby using energy unsparingly.

This project, therefore, proposes an Internet of Things (IoT) level 4 autonomous fan system that would sense when the temperature is going up and sense the presence of people in the room and turn itself on. If the occupants leave it would automatically turn off. We intend to reduce the energy cost used in cooling houses thereby ensuring a sustainable energy consumption pattern while at large, building up sustainable cities.

This system would have sensor nodes positioned at different endpoints in the room that measure the temperature of the room. The fan will only start if there are people in the room and if the temperature increases above a normal preset temperature, the fan will start running. It will adjust its speed of rotation based on the temperature difference. This will be detected by a sensor on the smart fan main unit. If people walk out the fan will sense this and stop. Generally, the fan is specified to operate between a predefined working schedule by the homeowner.

This project intends to develop a smart fan product that will be applicable in society and apply for certification at the Kenya Bureau Of Standards (KEBS).

1 Introduction

1.1 Background

The concept of a smart home is being adopted across the world. Smart homes involve introducing smartness into human dwellings to increase comfort and ease of living [3]. Another benefit is energy conservation, which is exemplified by incorporating a smart fan. Fans are used to lower temperatures in hot environments, but most often these fans have to be manually operated. This research project will provide a guide to developing an IoT level 4 autonomous smart fan that would fit nicely into a smart home [4].

1.2 Problem statement

The world is facing an unprecedented rise in temperatures in recent years due to the depletion of the ozone layer by greenhouse gases [5]. The United Nations has listed Climate action as one of its Sustainable Development Goals in an effort to combat this situation [6]. The high temperatures have necessitated communities to adopt climate control systems, which come down to air conditioners and fans. With the advent of smart devices and smart homes, the idea of smart air conditioners and smart fans that turn themselves on and off, and adjust their speed of rotation depending on temperature would be a welcome sight.

However, most of the technological advancements have been made on air conditioners but they are very expensive to run because they use up a lot of energy. The alternative, fans, remain mostly of manual control and those that have tried to bridge the gap are semi-autonomous. The problem with these kinds of fans is that people forget to turn them off which leads to a lot of energy wastage.

This, therefore, calls for the need to develop autonomous fan systems that bridges this gap. A need therefore arises to control the fan based on the temperature, position and number of occupants in a room.

1.3 Objectives

1.3.1 Main objective

To design and fabricate an IoT Level-4 Autonomous Smart Fan.

1.3.2 Specific objectives

1. To design and fabricate the fan blades, fan case, motor mount and stand of the smart fan.

2. To integrate a stepper motor and a brushless dc motor to the motor mount and fan blades.

3. To develop an algorithm to control the rotation of the fan blades based on the temperature, position and number of people in a room.

4. To submit a certification application at KEBS for our product.

1.4 Justification of the study

The apparent availability of cheap and accessible technologies that are bridging the gap between manual and level-4 autonomous control lead us to conduct this study. Autonomous control is very efficient, with the optimization of energy usage contributing to the reduction in burning fossil fuels around the world. Furthermore, developing a cheap user-friendly level-4 autonomous smart fan will help grow the field of IoT, especially in Sub Saharan Africa. This is where the world is headed, and it is only appropriate for us to try and head in the same direction.

2 Literature Review

2.1 Introduction

2.1.1 Overview on smart devices

Advances in communication and control technologies have led to the rise of internet controlled devices that change the way we live and work. An increase in computer processing power and energy-efficient sensors has made smart devices economically feasible. Smart devices comprise a physical component, a smart component and a connectivity component that allows the functions of the device to exist outside the physical component and connect with your smartphone. Smart components, such as sensors, microprocessors and software distinguish the conventional devices from smart devices as they allow a person to switch on the product just once and allow it to perform its functions without any more user input. The connectivity components such as antennae enable wireless connections with the product, allowing a user to control a device remotely. The control of the temperature of a room can now be accomplished using an internet-connected thermostat, allowing the user to monitor and control the heat settings of a room remotely on a smartphone while some systems are programmed to automatically lower or increase the temperature in a room [7]. The future of tomorrow is in smart homes such as the one shown in figure 2.1

2.1.2 Temperature control devices and energy usage

Climate control systems are required to keep the temperature and air quality within closed spaces such as houses in the desired and habitable range. The most common temperature control devices are the air conditioning units and generic fans. Fans blow air into a room which allows moisture to evaporate from an occupants skin thus providing that cooling effect. Air conditioners, on the other hand, pull air into a cooling and condensation mechanism, and once this cold air is radiated back into the room, a cooling effect occurs. Air conditioners are slightly more effective but use up considerably more energy to perform the same functions as a fan. To put this into context, you could have a fan running for 24 hours and it would use up as much energy as an air conditioner would use up in 15 minutes

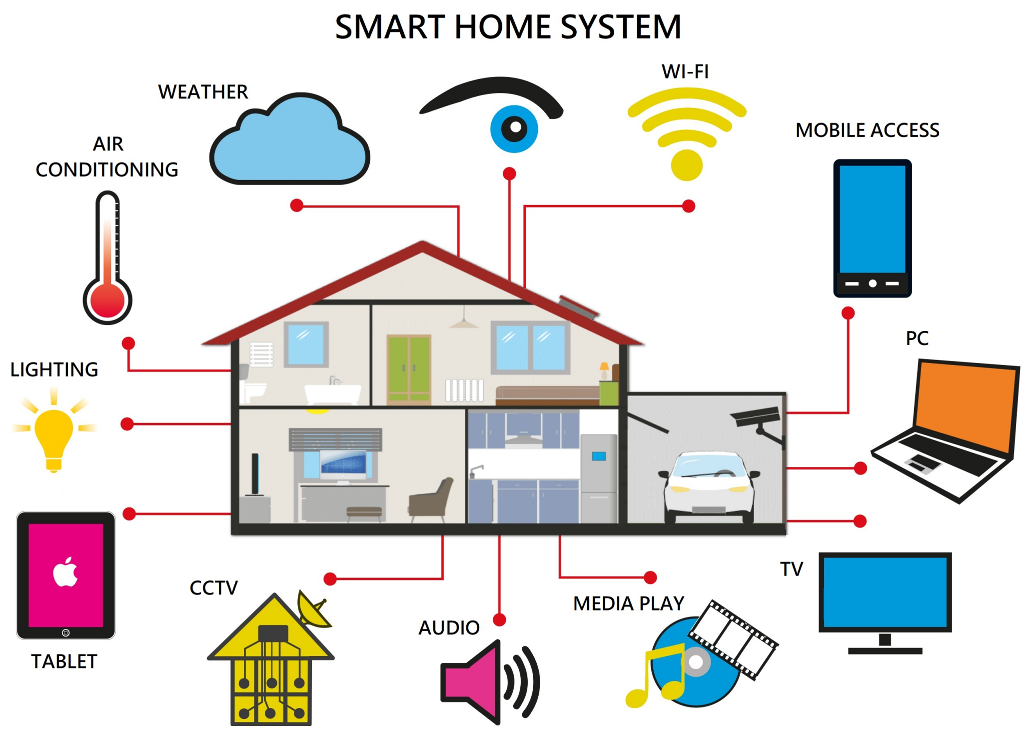

Figure 2.1: Smart home system [1]

[8]. Fans are not ideal for all situations, especially when it comes to heating up a room during the cold season. However, they can replace air conditioners during the hot summers thus cutting back on electricity usage significantly. Energy conservation helps domestic consumers save money while also conserving the environment by inadvertently subverting climate change. A 3% reduction in electricity demand would save the country about Shs.5 billion in generation capacity and Shs.1 billion in annual fuel costs [9]. According to research, buildings utilize more than 40% of the total energy produced globally, and a majority of this energy is consumed from running air conditioning units [10]. The use of fans enables sustainable energy management thus addressing the growing difficulties of rising energy consumption and limited energy supply due to Kenya becoming more industrialized [11].

As a result of rising average temperatures and extremely hot days brought on by climate change, people are anticipated to require more energy, primarily electricity for air conditioning. As a result, consumers would most likely have to spend more money on cooling due to the increased use of power [12].

2.2 Related Works

Related research has been done in the past and some products have also been developed. For instance, a group of researchers, including Emmeline Park and Joseph Fridlander conducted research on a smart fan that identified and tracked human movement using infrared sensors [11]. The basic premise was that fan movement and rotation would be determined by the movement of a person in a room. This research had its merits but implementation at the time was inhibited by technological deficiencies and as a result, the process stopped at the research stage.

Another research team from Chittagong University of Engineering and Technology tried to replicate the smart fan incorporating infrared sensors, but the inability to distinguish between human beings and other objects curtailed their work [11].

Vaibhav Bhatia from India and Mustafa Saad, Hossam Abdoalgader, and Muammar Mohamed have conducted similar research on temperature-controlled fans but it stopped at the research level [13]. The research proposes using Pulse Width Modulation (PWM) by varying the duty cycle using the room temperature and consequently varying the speed of the fan. Temperature data is acquired using a temperature sensor. The researchers focus on a ceiling fan, and while the research has merits that we can incorporate into ours, our focus rests on desk fans.

Zainal, Chelvam, Seman, and Othman Designed a Low-Cost Smart Fan System using Arduino Uno. This was only for Do It Yourself (DIY) projects [14]. In this project, a low-cost smart fan system is designed, in which the fan's speed is determined by the room temperature. A motion sensor, temperature sensor, and a short-distance communication network made up this smart fan system. If the ambient temperature rises above a predetermined level, the fan will switch on.

Woongseop Kim, Eunbi Ko, Hyebin Kim, and Eunyoung Lee, patented a Smart Fan with Face and Gesture Recognition Functions [15]. This smart fan automatically adjusts the fan's wind direction toward the recognized user's face direction while also providing operation control functions such as fan speed and power off based on the user's gesture. It is possible to control the fan even if the user does not carry the user's equipment.

Cheng Mang also patented an intelligent fan with voice control functionality [16], while another individual, Sewoong Lee, patented a smart fan with an automatic stop function. With this it was evident that most smart fans in the market are not fully autonomous as they require user input to control the fan. While the research area is showing promise, the smart fans havent reached the market and users cant enjoy their benefits.

2.3 System

2.3.1 Air Flow System

For extraction, air-conditioning, compression, and other purposes, fans are used to move gases from one location to another. They accomplish this by rotating a set of angled blades that pull air through a hole. There are many different types of fans: impeller, axial, centrifugal, Sirocco, and so on. Each has its own set of advantages, but they all shift gases at the same pace based on the input power. Because of certain design benefits that favour one attribute over another, differences in efficiency or flow rate arise in the kind of fan. Axial fans are a suitable design to use in this project as they have been previously used in normal fans, radiator fans and even ceiling fans. An axial fan can be depicted in figure 2.2.

2.3.2 Fan Blade Design

The shape of your blades and the direction they travel will define the performance characteristics of a fan. Table 2.1 shows the comparison between different fan designs based on how they are facing. The Backward facing design is the most suitable.

Fan calculations are based upon all the entrained air passing through the impeller with each rotation, which is normal practice for optimum blade configurations.

Figure 2.2: Axial Fan design [2]

Characteristic	Backward Facing	Straight	Forward Facing
Speed	High	Medium	Low
Noise	Medium	Low	High
Pressure	High	Low	Medium
Volume Flow	Medium	Low	High
Particulates	Good	Excellent	Poor
Efficiency	80%	70%	70%
Construction	Heavy	Medium	Light

Table 2.1: Different fan designs

However, too few blades, the air trailing each blade will be turbulent, reducing operational efficiency. Thus, your fan will not actually achieve the desired flow rate and pressure. Too many blades will also reduce fan efficiency through increased skin friction and impeller mass Table 2.2 Shows how different fan blades influence the workflow of the fan

2.3.3 Casing

A fan casing may be any shape or size as long as its inlet and outlet diffusers do not impede airflow beyond that intended by the designer. Fans do not consider the manufacturing quality of the impeller casing, nor does it consider internal bends or deformations affecting the flow path.

Number of blades	Description
1	Airflow will occur for about a third of the impeller volume, the rest of the air within the impeller will be turbulent making your fan extremely inefficient.
2	Significantly improved airflow characteristics than one blade design but still generates significant turbulence behind each blade. Blade balancing is easier to achieve than one blade designs.
3	Excellent for impellers with a small aspect ratio (e.g. axial fans) and much simpler to balance than 1 and 2-Blade designs.
4	Better airflow than the 3-Blade configuration but 33% greater skin friction. Airflow improvement more than offsets losses from skin friction.
5	Best configuration for all medium aspect ratio impellers.
6	Losses from increased skin friction and mass begin to exceed airflow gains.

Table 2.2: Influence of number of fan blades

2.3.4 Diffuser

The inlet area of a diffuser is the orifice nearest to the impeller. Unless the purpose of a fan is to generate suction, there is nothing to be gained by restricting inlet airflow. Therefore, the cross-sectional area of the inlet diffuser should be no less than that of the impeller blade inlet

The outlet area of a diffuser is the orifice furthest from the impeller. It is normal practice to design the diffuser outlet to minimise airflow restriction. In this case, the outlet area should be no less than that of the impeller blades.

2.3.5 Fan Laws

The exact relationship between speed, the diameter of the fan and efficiency is dependent on the particular design of a fan. Product testing and computational fluid dynamics are necessary to determine these design particulars. The affinity laws or fan laws express the relationships between multiple variables that determine fan performance.

These laws allow a designer to determine the air flow rate from a fan by varying either the speed or diameter of the fan.

Law 1. With fan diameter (D) held constant.

Flow is proportional to shaft speed as shown by equation 2.1:

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right) \tag{2.1}$$

Pressure is proportional to the square of shaft speed as show by equation 2.2:

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2 \tag{2.2}$$

Power is proportional to the cube of shaft speed as show by equation 2.3:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3 \tag{2.3}$$

Law 2. With shaft speed (N) held constant.

Flow is proportional to the cube of fan diameter as show by equation 2.4:

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right) \tag{2.4}$$

Pressure is proportional to the square of fan diameter as show by equation 2.5:

$$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2 \tag{2.5}$$

Power is proportional to the fifth power of fan diameter as show by equation 2.6:

$$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^5 \tag{2.6}$$

where:

- Q is the volumetric flow rate (e.g. in Gallons per minute (GPM) or L/s)
- D is the impeller diameter (e.g. in or mm)
- N is the shaft rotational speed (e.g. Revolutions per minute (rpm))
- H is the pressure or head developed by the fan/pump (e.g. psi or Pascal)
- P is the shaft power (e.g. W).

2.3.6 Specific Fan Power

This parameter determines the amount of electric power needed to drive a fan depending on the amount of air that is circulated through the fans. It is therefore proportional to the rate of air flow as show by equation 2.7. A designer will be able to quantify the energy efficiency of a fan by determining the specific fan power.

$$SFP = \frac{\sum P}{q_v} \tag{2.7}$$

where:

- $\sum P$ is the electrical power used by the fan (or sum of all fans in the ventilation system) [kW]
- q_v is the gross amount of air circulated through the fan (or ventilation system) [m3/s]

The relationship between Specific Fan Power (SFP), fan pressure rise, and fan system efficiency as show by equation 2.8:

$$\eta_{tot} \cdot \mathrm{SFP} = \Delta P_t \tag{2.8}$$

where:

- η_{tot} is the electrical power used by the fan (or sum of all fans in the ventilation system) [kW]
- ΔP_t is the gross amount of air circulated through the fan (or ventilation system) [m3/s]

The efficiency is a function of aerodynamic losses, friction losses and other types of losses and is often in the range of 0-60%

2.4 Software

2.4.1 Communication

To implement this design, communication between devices is constrained to wireless low energy. BLE , UWB, ZigBee, and Wi-Fi are four protocol standards for short-range wireless communications with low power consumption. They are based Institute of Electrical and Electronics Engineers (IEEE) standards. In general, BLE, UWB, and ZigBee are intended for Wireless Personal Area Network (WPAN) communication (about 10m), while Wi-Fi is oriented to Wireless Local Area Network (WLAN), about 100m. However, ZigBee can also reach 100m in some applications. Lee, Su, and Shen did a comparative study of wireless protocols: BLE, UWB, ZigBee, and Wi-Fi and what they found out will help make an informed decision of which technology to use [17].

Standard	BLE	UWB	ZigBee	Wi-Fi
IEEE spec	802.15.1	802.15.3a	802.15.4	802.11a/b/g
Frequency band	2.4GHz	3.1-10.6GHz	915MHz;2.4GHz	2.4GHz;5GHz
Max Signal rate	1 Mb/s	110 Mb/s	250 Kb/s	54 Mb/s
Number of RF channels	79	1-15	16	14(2.4GHz)
Nominal Range	10m	10m	10-100m	100m
Nominal Tx power	0-10 dBm	-41.3 dBm/MHz	-25-0 dBm	15 - 20 dBm
Channel bandwith	1MHz	500MHz - 7.5GHz	2MHz	22MHz
Max number of cell nodes	8	8	65000	2007

Table 2.3: Comparison of the BLE, UWB, ZigBee and Wi-Fi protocols.

BLE is a significant protocol for IoT applications as demonstrated by Table 2.3. Its designed and enhanced for short-range, low bandwidth, and low latency for IoT applications. The advantages of BLE classic Bluetooth include lower power consumption, lower setup time, and supporting star network topology with an unlimited number of nodes [18].

Even on the basis of power consumption, BLE uses less power. This is useful in developing sensor nodes. Since it will be powered by a battery it will be wise to use the lowest energy-consuming technology.

2.4.2 Mobile Application

Flutter apps are written in Dart, an object-oriented programming language that resembles C. Dart is a programming language as well as a mobile app development platform. It's used to create almost anything on the web, including servers, desktops, and, of course, mobile apps. When Dart is used in a web application, it is converted to JavaScript so that it may run in any browser. Dart also has a Virtual Machine that allows you to run .dart files from a command-line interface. Flutter apps' Dart files are built and packed into a binary file before being uploaded to app stores. By working with Flutter for iPhone Operating System (iOS) and Android at the same time, you can reach a larger audience from the start, without losing features, quality, or performance. It is used in this product because it can help with developing the application quickly instead of using the Native Android development platform [19].

2.4.3 Motor Control

PWM signal output is supported by traditional embedded systems such as Arduino. Take, for example, when the PWM signal is always 0V (i.e., 0% Duty Cycle), the motor is stopped from spinning. If the 5V output adds 25% to the cycle time (i.e., 25% Duty Cycle), the motor runs at a fourth (1/4) of its full speed. The motor spins as quickly as it can if the signal maintains a 5V output (i.e., 100% Duty Cycle).

3 Methodology

The design considerations will be explored in this section. There will also be a full description of how the smart fan system will be implemented. Figure 3.1 shows the basic architecture of the system. Because it is part of a larger modular system, its integration should be seamless. There are basically two modules:

- The smart fan
- The sensor node

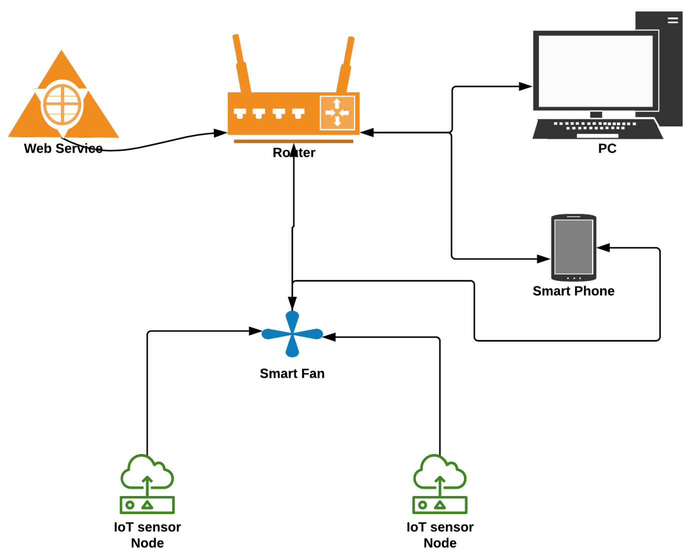

Figure 3.1: Design architecture

The sensor nodes measure the temperature of the room and send it to the smart fan main controller. The sensor nodes are positioned far from the smart fan but in the same room to measure the temperature endpoint after the air has travelled from the smart fan.

The smart fan has the main controller. This controller controls the stepper motor which controls the position of the fan. It also controls the brushless Direct Current (DC) motor which controls the spinning of the fan. The main controller communicates with sensor nodes via BLE then communicates with your device through the Wi-Fi router in your home or you can connect to its Wi-Fi network.

The following modules break down the design problem:

3.1 Interface module

The interface module is responsible for the following:

- Human-machine interface.
- Manual overriding of settings and configurations.
- Creating a visual appeal of the product.

The following considerations were made during the design of the interface of the mechanism:

- Fulfilling the function to control the smart fan remotely.
- Unlocking the full functionality of the smart fan
- Ease of use of the interface.
- Ease of integration with third-party mobile IoT applications.
- Availability on both Android and Web platforms.

The interface for this design is intended to be a web and android based application to be installed on the device of the home user. In tandem, it will provide a few buttons to start and stop. This will be crucial to our development as we will provide the user with the ultimate user experience for both advanced and novel users. The User Experience (UX) is a phrase that is strongly related to the User Interface (UI). The distinction between the two is that UI is concerned with what a user sees and interacts with, whereas UX is concerned with the total experience a user has with a product. It comprises the website, application, hardware packing, and installation, among other things.

The user can receive automatic notifications if they have a web or Android application. In IoT applications, the most common scenario is that we want to be notified or alerted if something strange occurs. The user will also be able to keep a proactive eye on the data. The user will undoubtedly be able to control the system remotely as a result of this. This might also be done automatically by the application, based on the instructions provided.

3.2 Communication module

The communication module is responsible for the following:

- Transmitting data from our sensor nodes to the smart fan.
- Transmitting data from our smart fan to the mobile phone and vice versa.
- Sending analytics data back to our backend server.

The following considerations were made during the design of the interface of the mechanism:

- Communication must be done over low energy.
- Communication must be secured with encryption.
- Communication must be done wirelessly either through BLE or Wi-Fi.

The four most prevalent wireless technologies, BLE, UWB, ZigBee, and Wi-Fi, will be evaluated quantitatively in terms of transmission time, data coding efficiency, protocol complexity, and power consumption in this paper. Network protocol appropriateness is heavily influenced by practical applications but based on existing data, the best technology to be used will be BLE Low Energy based on its low consumption power, availability and low overhead.

For communication with the mobile device, Wi-Fi will be the appropriate medium. This is based on research that most home users use Wi-Fi within their homes and also most of them keep their Wi-Fi on connect compared to BLE [19].

Universal asynchronous receiver-transmitter (UART) communication will be used for communication with the BLE module. A UART provides a bi-directional byte stream so that both ends of a connection can transmit and receive bytes with each other [20].

3.3 Software and Processors module

The software and processing module is responsible for the following:

- Process information from the interface to actuate it.
- Control the smart fan.
- Transmit data to the backend server.
- Receive data from the sensor nodes.
- Be able to utilize deep sleep
- Minimum of 1 PWM and UART communication pins
- Wi-Fi and BLE enabled

The following considerations were made during the design of the software and processing module of the mechanism:

- Computationally less intensive method
- Secure all communications
- Low cost of the processors module with Wi-Fi and BLE modules

Figure 3.2 shows the basic software logic of how the smart fan control module will operate.

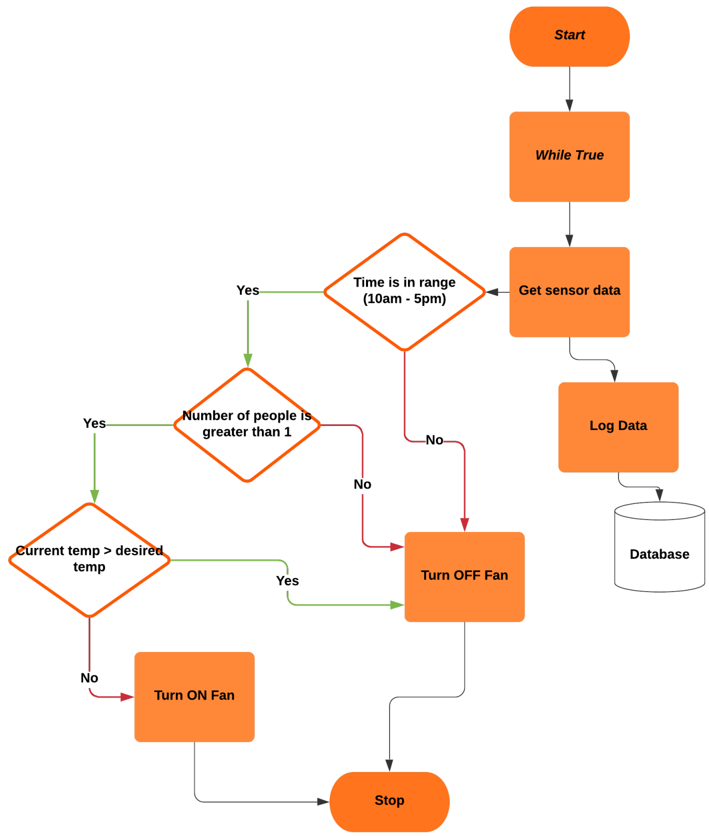

Figure 3.2: Software Logic

3.4 Measurement module

The interface module is responsible for the following:

- Measure temperature and humidity.
- Identify the occupants in the house.

The following considerations were made during the design of the measurement module of the mechanism:

- Fulfilling the function to control the smart fan remotely.
- Unlocking the full functionality of the smart fan.
- Ease of use of the interface.

3.5 Actuation module

The actuation module is responsible for the following:

- Rotating the Brushless DC motor.
- Rotating the Stepper Motor.

3.6 Assembly module

The assembly module is responsible for the following:

- Synergistic integration of the motor and fan blades.
- Full working of the sensor nodes.
- Hold the fan up high and maintain its weight.

The following considerations were made during the design of the assembly of the mechanism:

- Use as many modular parts as possible.
- Using easily available material from the workshops.
- Must hold the frame so as not to fall.

The fan will be assembled by mountain the fan blades on the motor shaft. The fan casing will be added onto the fan blades, while the motor is added into the motor casing. This will be assembled to the stand so as to hold it above. The stand will have an aluminium tube and a base plate to increase stability.
The fan blades will be constructed from a Polyvinyl chloride (PVC) tube. The tube will be cut and straightened out after which the blades with equal dimensions will be cut out and rolled to have a curvature. This is to reduce the air resistance as the fan is moving. The blades will be attached to the centre case which will be attached to the motor shaft.

The fan case will be made from small steel wires welded together. It will be moulded into a punched shape and mounted to the motor mount as the fan will be inside the case.

The stand, made from a steel tube, will be joined to the motor mount, hence holding the fan in position.

For the sensor node, the Printed Circuit Board (PCB) circuitry will be assembled inside the sensor box which will be Three Dimensional (3D) printed. A battery will be added to provide power to the sensor node.

3.7 Environment module

The environment module is responsible for the following:

- Interaction with the environment.
- Blow maximum air through the inlet diffuser

The following considerations were made during the design of the environment module of the mechanism:

- To minimise noise produced by the fan as it moves.
- Not to interfere with most of the users space
- Ultimately reduce energy consumption hence helping reduce climate change at large.

For the design, the motor should produce the minimum noise possible while rotating. Its aesthetics will be improved by applying paint which will increase the product appeal to the user. The sensor nodes will also interact with the environment, getting temperature readings from it. The sensor node will be as small as possible and not interfere with the aesthetics of the room.

4 Expected Outcomes

1. Fabricated fan blades, fan case, motor mount and stand of the smart fan.

2. Synergistic Integration of a stepper motor and a brushless dc motor to the motor mount and fan blades.

3. An algorithm to control the rotation of the fan blades based on the temperature, position and number of people in a room.

4. An application receipt to KEBS for our product.

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Appendix A: Time plan

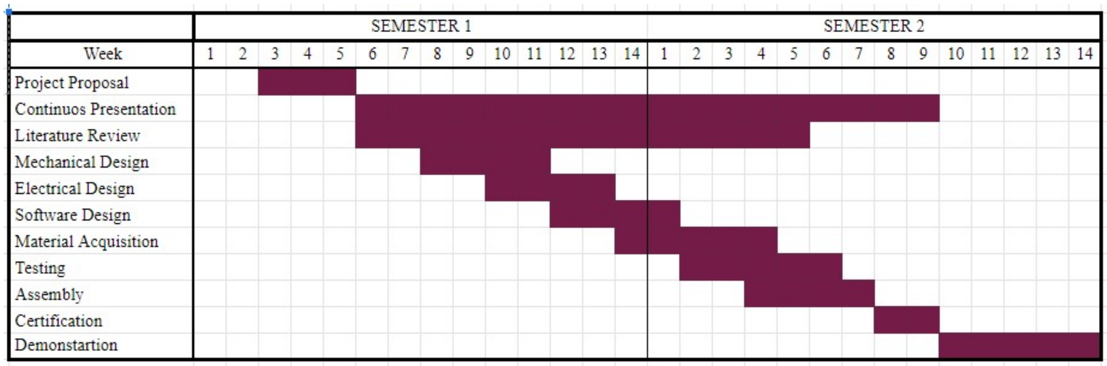

Figure 4.1: Timeplan

Appendix B: Budget

No.	Item	Description	Quantity	Supplier	Unit Cost	Total cost
1	DC motor	920KV, 12V, 30A	1	Pixel Electric	1800	1800
2	Stepper motor	1.26Nm, 2.5V, 2.8A	1	Pixel Electric	3200	3200
3	ESP32s	Wifi and Bluetooth enabled	1	Pixel Electric	600	600
4	nRF51822	Bluetooth enabled	2	Pixel Electric	500	1000
5	DHT11	Temperature Sensor	2	Pixel Electric	300	600
6	HC-SR501	PIR Motion sensor	1	Pixel Electric	150	150
7	Battery	1.5V	1	Pixel Electric	150	150
8	AC to DC converter	12v output	1	Pixel Electric	500	500
9	PVC pipe	1m	1	Hardware	60	60
10	Steel tube	1.5m	1	Hardware	250	250
11	Steel wires	1 metre each	5	Hardware	60	300
12	Paint	500ml	1	Hardware	300	300
13	Miscalleneous		1		1000	1000
						9910

Figure 4.2: Budget