Automated Wake-up Curtain
Design Document

ECE 445 Project #55

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1. Introduction

1.1 Objective

One of the most common struggles shared by people in modern society is getting up on time. The easy access to alarm clocks did not stop us from waking up later than intended and ruining our schedule. The traditional alarm clock fails because it does not engage people in the full process of waking up, but only a small part of it.

Opening eyes and exiting sleep is just the start of waking up. It takes more than that for full consciousness to kick in. If one's consciousness does not take over the brain faster than sleepiness, he will soon fall back to sleep again regardless of whether the alarm is working.

To expedite the process of waking up, which is crucial to one's productivity and health, we introduce the automated wake-up curtain. The user sets the time to wake up and a to-do list for the following day on an Android app. At the wake-up time, the curtain will open automatically and let sunshine into the room, and the speakers will play morning meditation music to wake the user up. According to a recent article, *Why you should ditch your alarm and wake up with light*, CNET editor Alina Bradford wrote, "If the lighting gradually gets brighter, like during a sunrise, our bodies are even more responsive and you'll feel much more refreshed"[1]. Therefore, incoming sunshine could help accelerate the process of recovering consciousness and melodic music will lighten the user's mood.

Also, there is a two step process the user has to go through in order to turn off the alarm. First, the user is asked to answer multiple choice questions about his to-do list on the Android app. After he passes the test, he will be able to deactivate the alarm via a physical switch that is only accessible off the bed. Answering the questions helps to stimulate the user's brain and at the same time prepares him for the events of the day. After getting off the bed and turning off the alarm, the user is guaranteed to be both physically and mentally ready to embrace the new day.

Besides the default Alarm Mode, the user can switch to Manual Mode via the App to simply control the curtain as a motorized curtain. There would be physical switches installed on the wall to open and close the curtain without the App as well.

1.2 Background

Original Project Description:
2015, Project 27

> As college students we all struggle to make it to class in the morning. There is no limit to the number of times we hit the snooze button. On top of all that we are expected to remember the huge list of things to do for the day. Our solution to this problem is the Smart Mat. This Smart Mat does not stop ringing until the person is awake and standing on the mat. Once awake , the person gets to hear his/her morning reminder that is set the previous night. This product would help any student get out of bed and kickstart the day.

The Smart Mat, although better than the traditional alarm, is also not enough to take the user throughout the process of waking up. In practice, even though the user is required to get off bed to stand on the mat to stop the alarm, the user can still crawl back to the bed and fall back to sleep easily. The Smart Mat does not place enough emphasis on the mental aspect of waking up. In the Automated Wake-up Curtain, we address this with the addition of sunshine and the wake-up quiz.

1.3 Differences

Overview:
Although the purpose that both the Automated Wake-up Curtain and the Smart Mat want to achieve is identical, and some of their functionality overlaps, they took different approaches in terms of physical design. Also, the Automated Wake-up Curtain has enhanced functionality regarding accelerating the process of waking up through facilitating consciousness in multiple dimensions.

The most significant difference between the two products is the physical design. The most unique feature of the Automated Wake-up Curtain is the automated curtain, whereas the Smart Mat is an enhanced mat. In comparison, the Automated Wake-up Curtain will be less mobile than the Smart Mat. However, it is also very unlikely for people to carry the Smart Mat around with them when traveling, both of the two advanced home products have low mobility. On the other hand, the Automated Wake-up Curtain provides more function than the Smart Mat. It serves as a motorized curtain when the alarm function is not in use, which alone is an upgraded smart home solution.

The second notable difference is the mechanism of deactivating the alarm. The alarm of the Smart Matt is turned off by the activation on the mat's pressure sensor. In the case of the Automated Wake-up Curtain, to turn off the alarm, the user needs the combination of both passing the quiz and the physical switch. In our product, no sensor is used, which means reduced risk of false activation, thus the reliability is improved.

Finally, the Automated Wake-up Curtain provides some additional features that can really make a difference in terms of effectiveness. Unlike the Smart Mat, which outputs audio display of the reminder set by the user, our product will actively engage the user into a hands-on wake-up quiz on their preset to-do list. This will activate the brain to a much deeper extent, which subsequently stimulates the restoration of consciousness.

Analysis:

The most significant improvement we implemented in the design of the Automated Wake-up Curtain is the feature of the "wake-up quiz". The essence of waking people up lies in getting their attention and maintaining their attention long enough to restore their consciousness. There exists a spectrum ranging from complete consciousness to deep sleep. Waking up the user means keeping introducing stimulation in him until the balance irreversibly tilts toward the side of complete consciousness. Otherwise, the balance will relapse into the side of deep sleep.

In the case of the Smart Mat, the user is required to stand on it for 20 seconds to deactivate the alarm. After 20 seconds, the Smart Mat will play audio reminders set by the user. In my opinion, although 20 seconds is not a short time, this alone will not be very effective. People often wake up at nights when they have to use the bathroom, and that interval is often longer than a minute, and usually they can fall back to sleep easily after that.

In the Automated Wake-up Curtain, there will be quiz questions testing the user on his daily to-do list. In the meantime, the curtain will automatically open and let the sunlight fill the room. Humans are naturally responsive to sunlight, so the influx of sunlight could greatly influence their brain activeness. Also, to answer the quiz, the user will have to unlock their phone. The artificial light and the notifications on the phone stimulates the user's brain activity, and then the process of reading through quiz problems will further enhance their level of consciousness. Finally, when the user gets out of bed and looks for the physical switch to turn off the alarm, he will be ready both physically and mentally.

1.4 Visual Aid

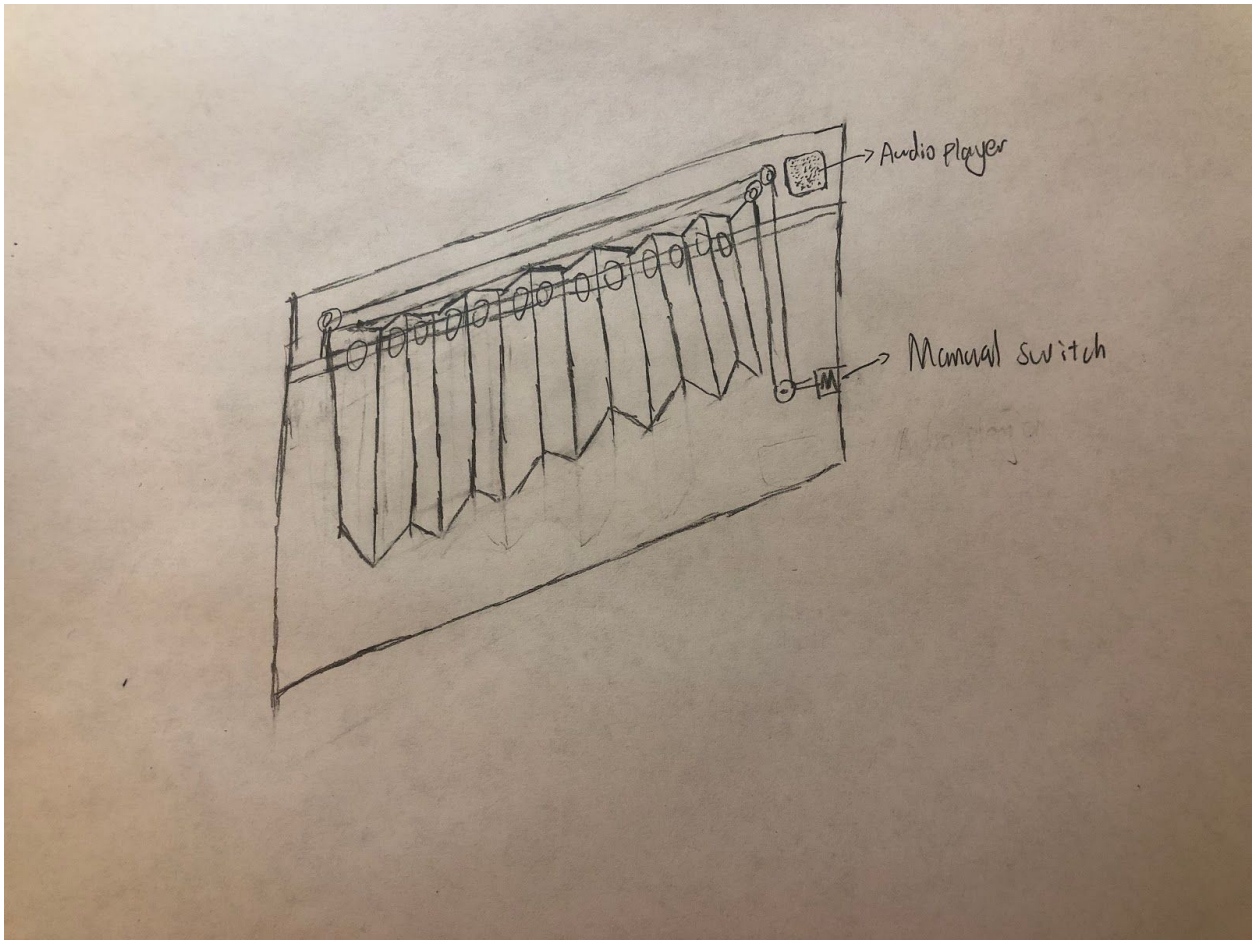

Fig.1 Visual aid

1.5 High-level requirements

- The curtain can automatically open at the preset wake-up time(+/-1 minute)
- The curtain can be opened/closed automatically by physical switches
- The app quiz will be generated at preset wake-up time, and passing the quiz will enable the user to turn off the alarm through physical switch

2. Design

The main features of the product includes:

- automatically open the curtain when the alarm is activated
- allow user to open/close the curtain via manual switch and phone app
- allow users to set wake-up time through phone app
- play melodic alarm music to wake up the user
- alarm can only be turned off with a manual switch that is not accessible on bed (to ensure that the user is off bed) (deactivate the alarm function via manual switch)

The entire system consists of 5 sub-systems: Motorized Curtain Module, User Interface Module, Sound Module, Control Module, and Power supply.

The curtain type fitting this project would be grommet style curtain, and the mechanical part of the project includes a pulley system, a motor system, and some extract components such as extruder gears and bearings. In order to drive the system, we used a 24V AC to DC adapter to power the Stepper motor driver and the Stepper motor.

We use Arduino as our microcontroller for this project, and it is responsible for processing the inputs and outputs from the User Interface Module and Bluetooth Module to set the alarm time, trigger it to go off, and controlling the curtain's movement.

A Bluetooth module (Bluefruit LE SPI Friend) is used to communicate between Arduino and Android Phone App to let the users set wake-up time and open/close the curtain.

The Arudino and other related components such as speakers, bluetooth modules will be powered by AC using a 12V AC to DC adapter.

And there are two modes available for the project:Manual Mode and Alarm Mode

- Alarm Mode: automatically open the curtain when the alarm is activated
- Manual Mode: open/close the curtain via App

2.1 Block Diagram

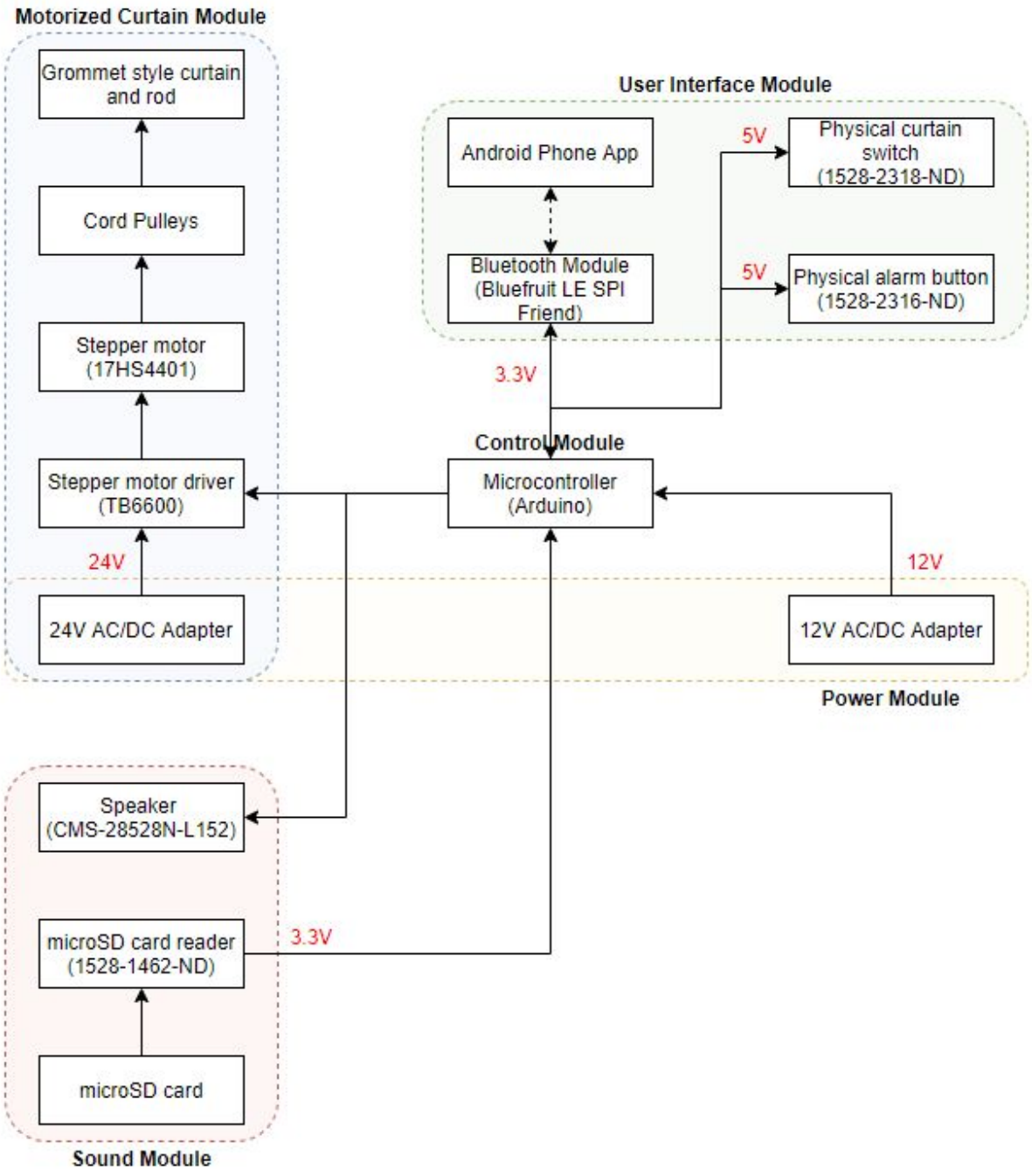

Fig.2 Block Diagram

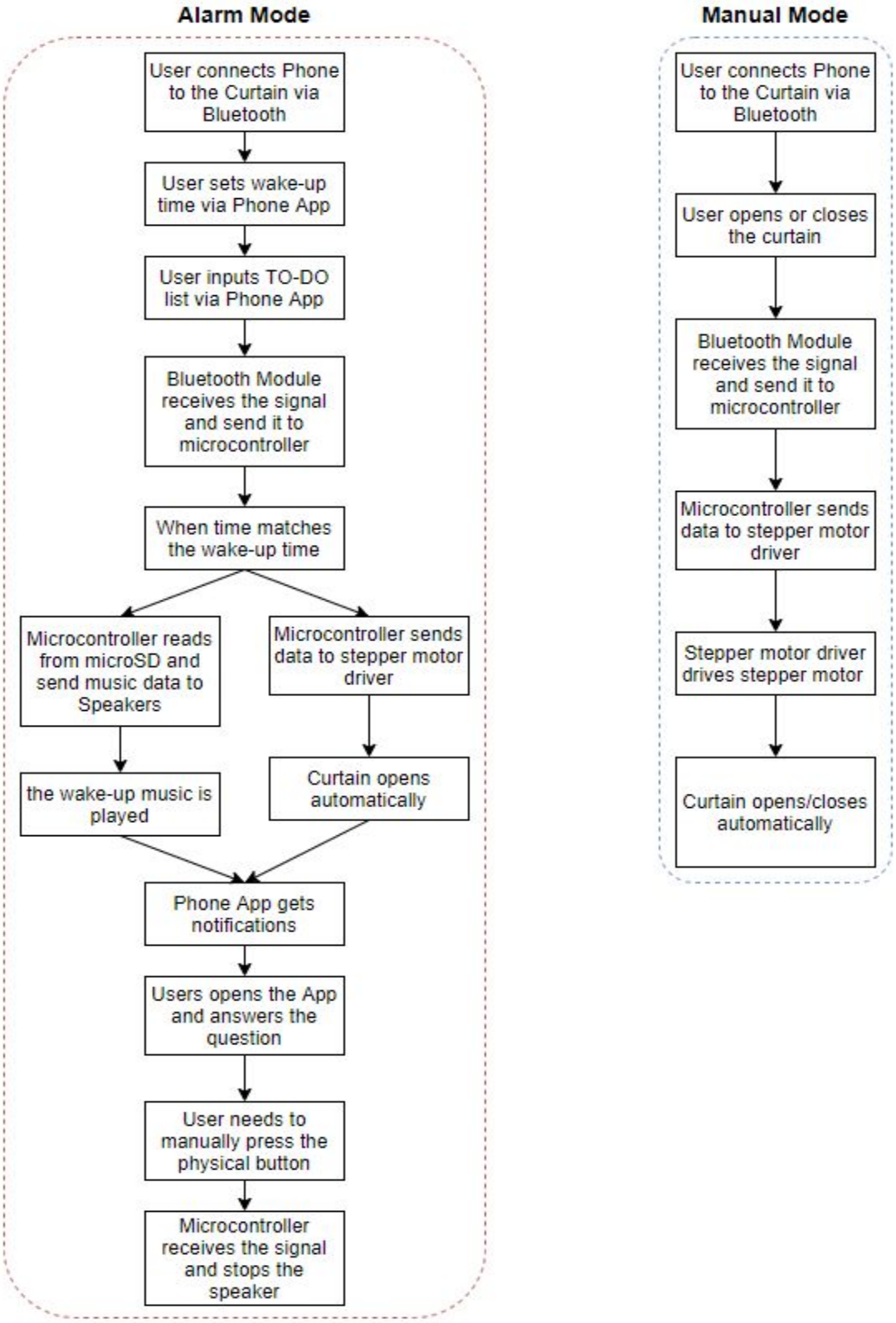

Fig.3 System flow chart

2.2 Physical Design

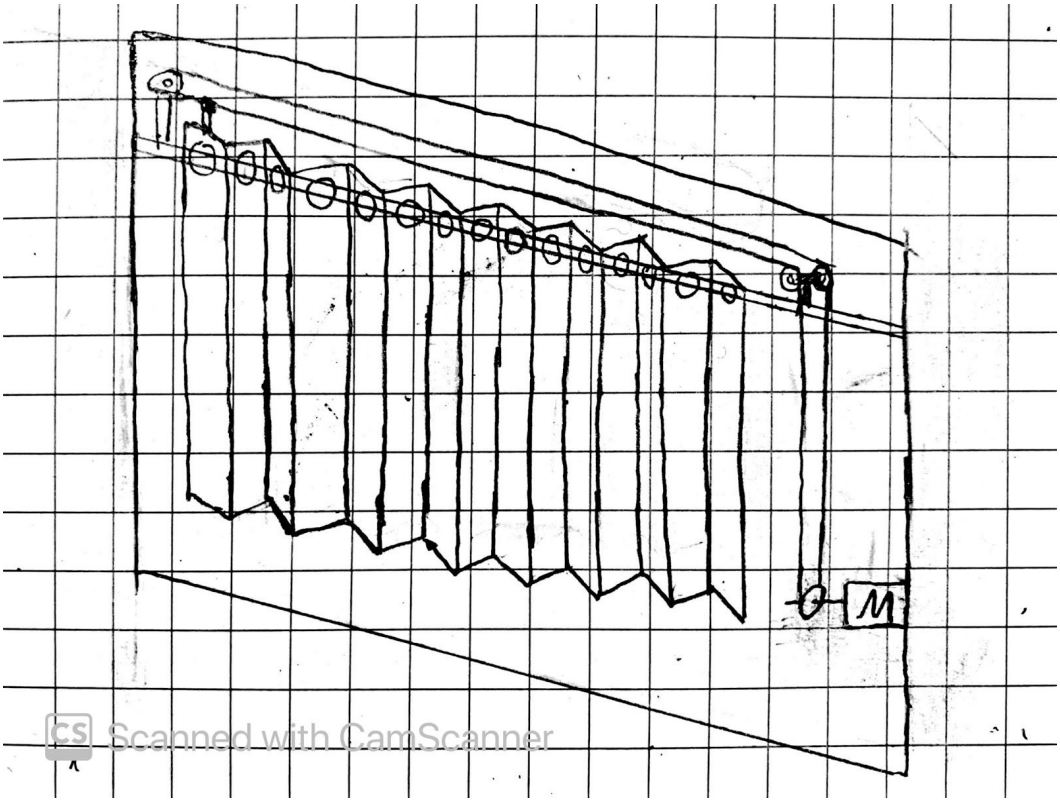

Fig.4 Curtain schematic diagram

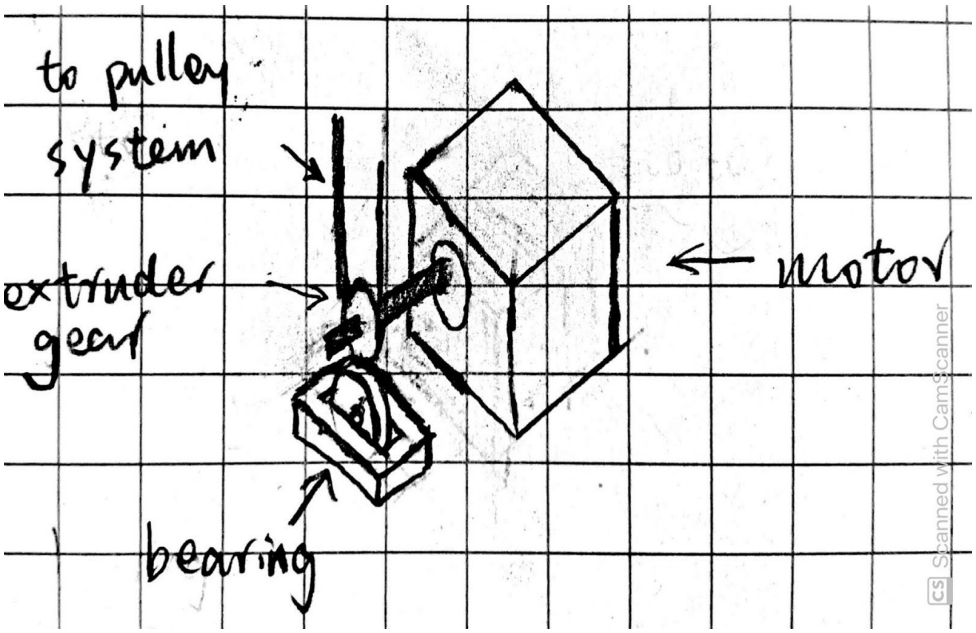

Fig.5 Motor schematic diagram

2.3 Motorized Curtain Module

2.3.1 Motorized Curtain

A Grommet style curtain and rod will be the main body of the curtain. In order to implement the automation feature of the curtain, we will use a Pulley system that folds and extends the curtain. More specifically, 3 pulleys will be used to move the leftmost part of the curtain to fully fold and unfold the entire curtain.

To drive the pulley system and the curtain, we will use the Stepper motor (17HS4401) and the Stepper motor driver (TB6600). Stepper motor driver is the interface between stepper motor and our microcontroller (Arduino).

Fig.6 Stepper motor

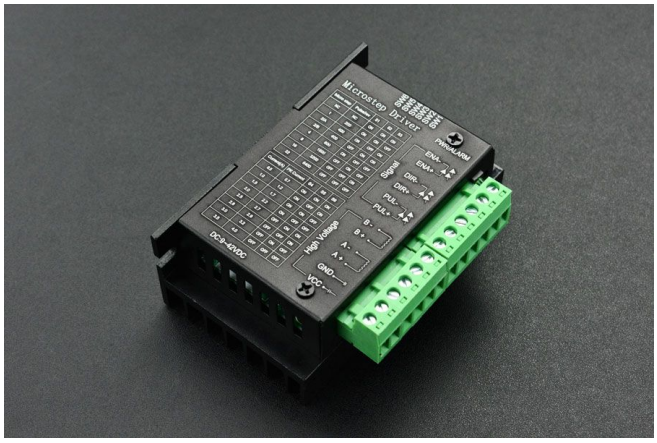

Fig.7 Stepper motor driver

The pin connections of integrating motor, motor driver and Arduino are:

1. Connect stepper motor wires to A+, A-, B+, B- pins on the motor driver
2. Common DIR-, PUL-, EN- pins of the motor driver, then connect them to the GND pin on Arduino.
3. Connect PUL+, DIR+, EN+ to 3 separate pins on Arduino
4. Connect external DC power to VCC and GND pins of the motor driver.

The Stepper motor driver needs 9-42V DC to power so we will use a 24V AC to DC adapter to power the Stepper motor driver and the Stepper motor.

Requirements	Verification
1. The stepper motor should be able to generate a fixed amount of rotation under Arduino command in both direction, the lowest limit of precision should be ¼ rotation 2. The pulley system should be able to drive the curtain with a person operating manually 3. The stepper motor should be able to drive the curtain, fully folding/unfolding the curtain should take less than 10s	1. a. Connect the stepper motor, motor driver, Arduino and external DC source together. b. Wrap some tape around the axis of the motor to track the motor rotation c. Program the Arduino to rotate the motor in both direction, check if the minimal amount of rotation is less than 90° 2. a. Set up the pulley system and curtain, with the interface between the pulley system and the motor. b. Without turning the motor ON, check if one can manually fold/unfold the curtain by pulling the pulley rope 3. Turn on the motor, check if the curtain can fully fold/unfold within 10s

2.4 User Interface Module

2.4.1 Bluetooth Module

We will use Bluefruit LE SPI Friend as our Bluetooth module to communicate between our microcontroller (Arduino) and Android Phone App. The users can switch between Manual Mode and Alarm Mode, set the desired wake-up time, and remotely open/close the curtain through the App. All the data the user sends from the App will be transmitted via the Bluetooth module to the microcontroller.

Requirements	Verification
1. Able to connect to the Android Phone App 2. Able to receive data from the Android Phone App 3. Able to send data to the Android Phone App 4. Able to send and receive data to/from the microcontroller 5. Able to operate under 3.3V supply voltage	1. Write a testing Android program to see if the Bluetooth Module can connect to the App 2. Write a testing Android program to control the LEDs on the microcontroller to light them up 3. Write a testing program to send data from microcontroller via the Bluetooth module and display it on the App 4. Write a testing program to let the microcontroller turn on LEDs based on some Bluetooth module inputs, and write a testing program to let the Bluetooth module turn on LEDs based on some microcontroller inputs 5. Test if the Bluetooth Module works by connecting to a function generator outputting 3.3V in ECE 445 Lab

2.4.2 Physical Switches & Buttons

We will have two physical buttons(1528-2318-ND) installed on the wall acting as a physical switch used to manually control the curtain. One button opens the curtain, moving in one direction, while the other one closes the curtain, moving in the other direction. The two push buttons-switch are connected to the microcontroller, and the latency should be within 1s.

We will have another physical button(1528-2316-ND) to let the user manually turn off the alarm since we want the user to get off the bed for the purpose of wake-up. We will place it at a location that cannot be easily accessed from bed to ensure the user can leave the bed. The button is connected to the microcontroller, and the latency should be within 1s.

Requirements	Verification
1. Able to send data to the microcontroller 2. The latency should be within 1s 3. Able to operate under 5V supply voltage 4. Buttons can be pressed	1. Connect the button with microcontroller and write a testing program to light LEDs when the button is pressed 2. Measure the time it takes to light LEDs after the button is pressed 3. Test if the button works by connecting to a function generator outputting 5V in ECE 445 Lab 4. Press the button

2.5 Sound Module

2.5.1 Speaker

We will use a speaker(CMS-28528N-L152) positioned at the upper part of the curtain on the wall to play the wake-up morning meditation music. Since it will be integrated into the curtain which will be positioned at the top of the window, we need it to sound loud and produce a sound level of 80dB at about 5ft.

Requirements	Verification
1. Speaker is able to receive data from microcontroller and play audio output accordingly 2. Can produce a sound level of 80dB at about 5ft	1. Connect the speaker with the microcontroller and send the music data to the speaker. Check if the sound produced by the speaker is correct 2. Use a decibel meter to measure at 5ft

2.5.2 MicroSD card & reader

We will use a MicroSDcard reader (MicroSD card breakout board) to read the MicroSDcard that we will use to store the music file. It is connected with the microcontroller so the microcontroller can read the file containing music and send it to the speaker to be played. For the purpose of this project, 8 GB storage would be sufficient, and it should be able to store plenty of music.

Requirements	Verification
1. Microcontroller can access the data store in the MicroSD card 2. Able to operate under 3.3V supply voltage 3. MicroSDcard is not defective	1. Connect the MicroSD card reader with the microcontroller and plug in the SD card. Write a testing program to see if the data inside it can be accessed and print out 2. Test if the card reader works by connecting to a function generator outputting 3.3V in ECE 445 Lab

	3. Store music files via laptop/desktop to the MicroSDcard

2.6 Control Module

2.6.1 Microcontroller

We would use Arduino as our microcontroller for this project. Microcontroller is responsible for processing the input and output from the User Interface Module and Bluetooth Module to set the alarm time, trigger it to go off, control the curtain's movement, and send music data to the Sound Module.

- Input Signals: alarm time, mode selections, physical buttons
- Output Signals: alarm activation, motion control of curtain, music data to speaker

When the user is giving certain instructions using the Phone App, the Bluetooth module will pick up the signals and send them to the microcontroller. Microcontroller will then based on the input signals to decide what action the system should take. If the user wants to set a time, the microcontroller will set an alarm time using its external real time clock module, and the time arrives, it will trigger the alarm and load the music data file from the microSD card to the speaker to play the morning music.

To control the curtain, the open/close signal received by the microcontroller will control the step motor driver connecting to the motor to change the direction of the movement of the curtain.

Requirements	Verification
1. Able to get time from external real time clock module 2. Able to obtain data physical buttons 3. Able to send and receive data to/from the Bluetooth Module 4. Able to send data to the Stepper motor driver 5. Able to send signals out through I/O Pins 6. Able to operate under 12 V +/- 5% supply voltage	1. Write a testing program to let the microcontroller turn on LEDs based on the real time clock signals 2. Connect the buttons with microcontroller and write a testing program to light LEDs when the button is pressed 3. Write a testing program to let the microcontroller turn on LEDs based on some Bluetooth module inputs, and write a testing program to let the Bluetooth module turn on LEDs based on some microcontroller inputs 4. Connect the microcontroller to Stepper motor driver and write a testing program to let the microcontroller turn on the motor and adjust its speed 5. Connect the microcontroller to LEDs via I/O Pins and write a testing program to see if the microcontroller can produce output signals to different LEDs. 6. Arduino has a built-in regulator, and the manufacturer recommended to use 7-12V as input power supply. Connect the microcontroller to a 12V AC to DC adapter and see if the microcontroller can be turned on.

2.6.2 Real Time Clock Module

The DS3231 is a low-cost, highly accurate Real Time Clock used to keep track of real time and send its time data to the microcontroller. It has its own battery slot for a 3V battery. The module uses the I2C Communication Protocol to connect to our microcontroller.

Requirements	Verification
1. Real Time Clock Module can obtain correct real time 2. Able to operate under 3V supply voltage (battery) 3. Able to send data to microcontroller via I2C Communication	1. Verify if the current time of Real Time Clock is the same as real time after setting initial time for RTC 2. Install the battery and see if RTC can keep track of the time 3. Write a testing program to print out the time information received from RTC

2.7 Power Supply

We will use a 24V AC to DC adapter to power the Stepper motor driver and the Stepper motor, and a 12V AC to DC adapter to power the Microcontroller (Arduino).
Since the Arduino has 3.3V and 5V outputs, it will power the rest of the circuit components such as the Bluetooth Module and physical buttons.

- 24V AC to DC adapter to power the Stepper motor driver and the Stepper motor.
- 12V AC to DC adapter to power the Microcontroller (Arduino)
- Microcontroller (Arduino) will power the Sound Module and the User Interface Module

Requirements	Verification
1. Provides 12V +/- 5% from the 12V AC to DC adapter	1. Using an oscilloscope to measure the voltage, and make sure it's within the 5% range of the specified output.

2. Provides 24V +/- 5% from the 24V AC to DC adapter	2. Using an oscilloscope to measure the voltage, and make sure it's within the 5% range of the specified output.

2.8 Software Module

2.8.1 Android Application

We will design an Android Application to communicate with the system via Bluetooth Module and let the users set his/her wake-up times as well as the TO-DO list which would be used for questions that he/she needs to answer correctly the next day in order to shut the alarm down. When the user opens the App, it will ask the user to set a time, input TO-DO list, or modify the time set previously. The user needs to type at least 3 things as a TO-DO list, and the data would be stored in the Phone's internal memory. We would pre-set a certain TO-DO list as the database to generate questions such as *go to walmart* or *go to the gym*. When the Wake-up time arrives the next day, the App will send a notification, and once the user opens the app, he/she will need to answer a multiple choice question with 4 choices and 1 being the correct TO-DO item. For example, if the user inputs *go to ECE 445*, *have dinner with Danny*, *go to County Market*, then in the next morning, the App will generate one correct TO-DO item form the input and generate three incorrect TO-DO items from the database to let the user choose. The user may choose from the following options: *go to the gym*, *go to ECE 498*, *go to Panda Express*, and *go to ECE 445*. Only if the user picks the correct TO-DO items for the day, he/she may then turn off the alarm using the manual button on the wall. Otherwise, the button will not work, and the user needs to keep answering until he/she gets right.

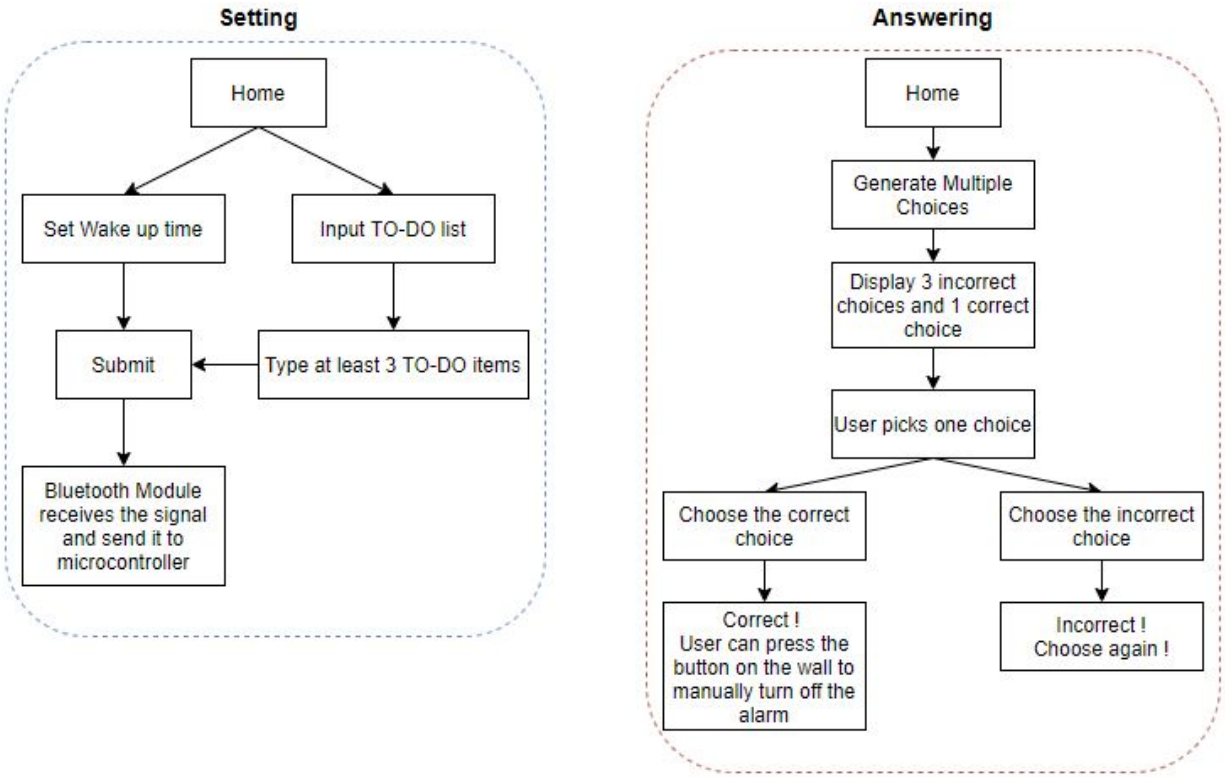

Fig.8 Software Flow

Requirements	Verification
1. Android app is able to connect to Bluetooth 2. Able to send and receive data to/from the microcontroller	1. Write a testing Android program to see if the Bluetooth Module can connect to the App 2. Write a testing program to let the microcontroller turn on LEDs based on some user inputs, and write a testing program to let the Bluetooth module turn on LEDs based on some microcontroller inputs

2.9 Tolerance Analysis

In this project, the link that puts the tightest requirement on the system is the motorized curtain module. It is critical to ensure that the power from the motor will be able to drive the curtain with reasonable speed.

The assumption in the tolerance analysis is summarized as follows:

1. The curtain has a full span of 1.5m, and weighs 6kg
2. Friction between rope and pulley is ignored
3. Friction between rope, bearing and extruder gear is ignored
4. The rope is made of nylon
5. The curtain rod and the rings on the curtain are made of plastic

Step 1: Calculate the maximum power needed to move the curtain on the curtain rod

To make the curtain start moving, the pulley system has to overcome the total static friction force between the curtain rings and the curtain rod. We should also assume that the motor should be able to move the curtain when it is fully unfolded.

The static friction coefficient between two plastic materials:

$$\mu_{static} = 0.35$$

The maximum static friction is

$$F_{static} = \mu_{static} \times m_{curtain} \times g = 0.35 \times 6kg \times 9.8N/kg = 20.6N$$

Given that the curtain should be able to fully unfold within 10 seconds, the maximum power needed from the motor will be

$$P_{max} = F_{static} \times distance/time = 20.6N \times 1.5m/10s = 3.1W$$

Step 2: Calculate the power output from the stepper motor

The stepper motor's power input takes DC voltage from 9-42V. It produces discrete output current from 0.5-3.5A, with an increment of 0.5A. Since there is no information about the exact power output available, we will calculate power output from the motor using the basic formula:

$$P = V \times I$$

The lower limit of theoretical power output from the motor will be

$$P_{min} = V_{min} \times I_{min} = 9V \times 0.5A = 4.5W$$

The upper limit of theoretical power output from the motor will be

$$P_{max} = V_{max} \times I_{max} = 42V \times 3.5A = 147W$$

Conclusion:
Even the minimal output power from the stepper motor is slightly greater than the maximum amount of power needed to drive the curtain at a reasonable speed. Therefore, our motorized curtain module will be able to meet the high level requirement.

3. Cost and Schedule

3.1 Cost Analysis

Part	Cost ($ per unit)
Arduino Uno Rev3	18.00
Grommet style curtain (example)	29.99
Stepper Motor (17HS4401) & Stepper Motor Driver (TB6600) Package	23.99
Cord Pulleys	24.90
Curtain Rope	16.99
Extruder Gear	8.89
Bearings	6.99
24V AC to DC Adapter	14.99
Bluetooth Module (Bluefruit LE SPI Friend, Adafruit Industries LLC)	17.50
Speakers (CMS-28528N-L152, CUI Devices)	3.59
Real Time Clock (DS3231, Adafruit Industries LLC))	13.95
12V AC to DC Adapter	11.99
Physical Buttons (1528-2318-ND, Digi-Key) × 2	2.5
Physical Buttons (1528-2316-ND, Digi-Key)	2.5
Total	199.27

3.2 Schedule

Week / member	Jianzhi Long	Yunhan Wang	Ziwei Qiu
Week 1	Order components		
Week 2	Assemble the curtain Assemble the pulley system Manual test of pulley system	Test physical buttons and make a switch Write code for buttons and switches Set up power supply for motorized curtain module and control module	UX and UI design of Android App. Build chain of actions which will be required to complete the tasks. Conduct attractive visual/audio design of the app. Determine the color/texture/shape/animations of the App.
Week 3	Write Arduino code for driving the stepper motor Assemble stepper motor circuit Test the function of stepper motor	Write code for sound module, and test speakers Test microSD card and test reading data from it	Build database and the App server. Make sure the dynamic application requires data synchronization and storage ability.
Week 4	Assemble the motorized curtain module Test the motorized curtain module and make necessary modification	Test Bluetooth Module Test real time clock module and make sure time is accurate	Write codes to implement the main functionalities of the App with the help of Graphics design built on week2.
Week 5	Test the motorized curtain module and make necessary modification	Test Bluetooth activation of sound module and load preset music Test Bluetooth activation of motor	Test the main functionality of the App.

Week 6	Integrate motorized curtain module with other modules	System integration; check the data transmission of the system	Test the functionality of the App with integrated hardware system
Week 7	Full system test		
Week 8	Set up testing procedures for Mock Demo Mock Demo		
Week 9	Demo Final Presentation		
Week 10	Final report		

4. Ethics and Safety

We fully considered the safety issues in our design of Automatic Curtain. As a product to be used frequently in people's daily lives, the Automatic Curtain must be completely safe and comfortable to use. Since we are using a power module with more than 24V, users should use the Automatic Curtain as carefully as using other electronic devices that may cause electric shock. In addition, our design must make sure that there are as least as possible sharp angles in the physical design of the Automatic Curtain. Such concern is due to the fact that users are very sleepy and careless when they just wake up, and they may be hurt by the sharp angles in the external physical design of the Automatic Curtain when trying to approach and close the curtain. Children are another reason for us to avoid sharp physical design. It is very dangerous to place an electronic device with sharp design in bedrooms where children can get hurt easily. Such design follows #9 of IEEE Code of Ethics "to avoid injuring others, their property, reputation, or employment by false or malicious action"[2].

We are also responsible for the ethics of the Automated Curtain. As we know, traditional alarm clocks and even cell phones will produce very loud noise which may annoy the user's roommates or other people. We understand that it is embarrassing and unsuitable to disturb the sleep of others. Our design will try to reduce such problems by adapting melodic music instead of annoying alarms to wake up the user, and the opening of the Automatic Curtain will allow the sunshine to come in so that the user can wake up more quickly without disturbing others. Unfortunately, we are unable to solve this problem completely because the type and volume of the wake-up music are chosen by the users.

In this project we divide the workload by parts and distribute the workloads to each of our teammates so that "objectives are established and the results measured"[3]. We also made a weekly schedule to arrange these individual work so that all of us can track the completion of this project. We believe that making a schedule and divide the total workload can effectively "acknowledge and correct errors" and "credit properly the contribution of others"[2].

In conclusion, we believe that the design of Automatic Curtain is a nice try to combine a traditional alarm clock with a curtain and a product to wake up the users in the most tender and soft way while reducing the adverse effect on others as much as possible.

5. References

[1] Bradford, Alina. “Why I Ditched My Alarm and You Should Too.” *CNET*, CNET, 10 Mar. 2019, www.cnet.com/how-to/light-alarm-clock-wake-up-to-light/.

[2] Ieee org, “IEEE IEEE Code of Ethics”, 2016.[Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed: 27/2/2020.

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