ECE 445 Senior Design Project Proposal

StoveSense

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Date: September 15, 2023

1. Introduction

PROBLEM:

In recent years, there has been a concerning rise in the number of house fires attributed to stoves being left unattended. Nearly 50% of house fires are caused by burners being left on and unattended. In addition, being able to control a stove away from the knobs allows for more control while cooking. As a result, there should be an easy solution where a user can remotely control and turn off any burner that is on.

SOLUTION:

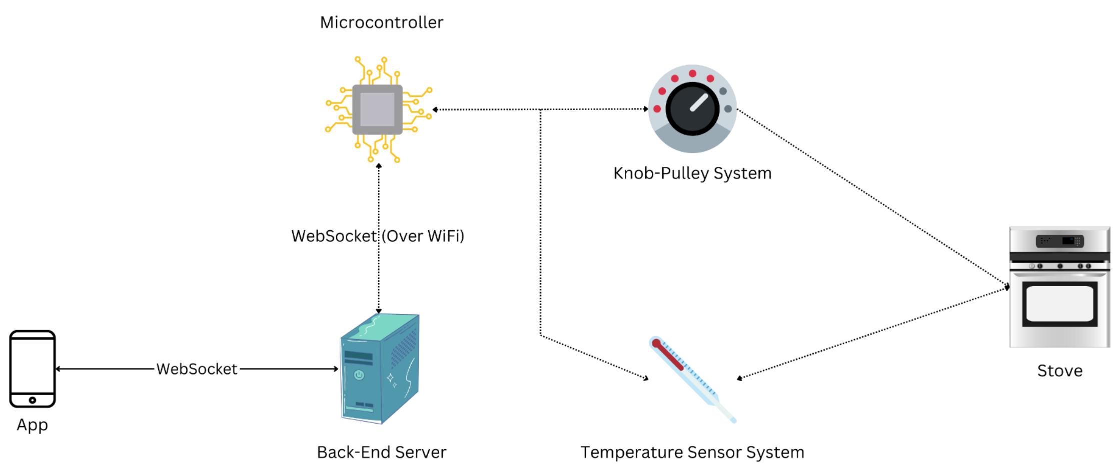
Our solution involves having heat sensors on each of the stoves to determine which burners are on and relay this information to the user via an app. The user will be able to see which stoves are on, and control each stove remotely.
Each stove knob will have a pulley system that will rotate the knob to the desired level. This will work by having a motor that will serve as a tensioner and tension a belt around the shaft of the knob. When the tensioner isn't activated the user will be able to freely rotate the knob. Through this design we will be able to automatically rotate the stove knob, while also allowing the user to control the knob without our mechanisms affecting them.

All communication between the app and the microprocessor will be done over a network connection. This microprocessor will let us control the knob turner remotely and with precision.

This solution will also have automated features. We plan to add a water-proof thermocouple the user can manually put in pots with soups or other liquids to add boil over protection. This device will monitor the temperature and automatically turn down the temperature of the stove once there is a risk of a boil over (temperature rising significantly above boiling point).

Our app will contain a visual interface which allows users to see which exact burner is on, and change the burner intensity to whatever is desired, including off. Additionally, we will add push notifications to notify the user if a burner is on or if boil over was detected and handled.

VISUAL AID:



PROJECT COMPONENTS:

- ESP-32: Processor to control the robotic knob turners' movements, send and receive signals from app, built-in wireless adapter
- Dual pulleys with belt: Comprises the pulley system, one pulley behind the knob, and one pulley attached to our stepper motor.
- Stepper Motor: Will be responsible for turning the pulleys, causing the knob to be turned
- Servo Motor: Will be responsible for tensioning the pulley
- App: Mobile app with front end to display which stove is on and allow users to close stove from app
- Thermistor: Temperature based resistor to detect if a stove is on or not
- LM35DZ: Sensor to check the temperature of liquid in pot, also waterproof

CRITERIA FOR SUCCESS:

Our main goal is making sure that a user is able to remotely turn off a stove. The system should be able display information regarding which stove is one and give the user the option to turn off the stove. All this communication between the system and user will be done through an app.

Our second goal is for boil over protection which should automatically detect when a liquid in a pot is being boiled for too long and either notify the user that their dish is about to boil over or remotely turn down the temperature of that specific burner to prevent the spill over before it occurs.

Stretch Goal: If time permits we would also like to add some sort of smoke detector sensor that would be able to detect if there's a fire on the pan or not. We would probably have to create our own module for this, and look into this further.

THREE HIGH LEVEL REQUIREMENTS:

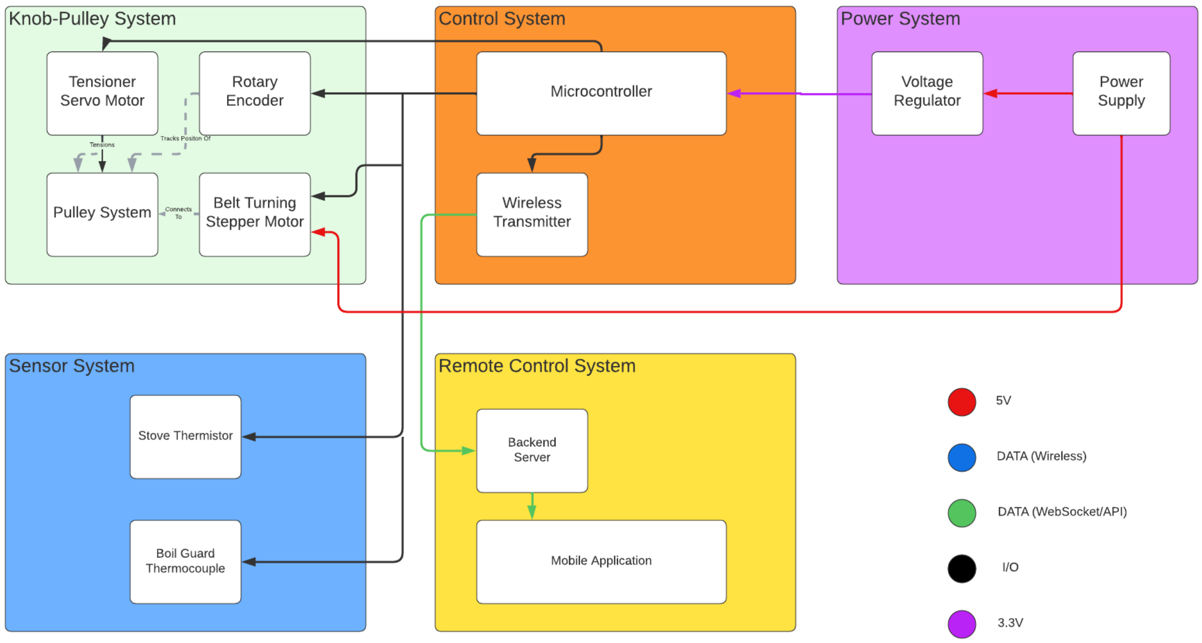
1. Product must be capable of maintaining water temperature at 100 degrees celsius, with a margin of error of 5%, to prevent over-boiling and spilling out of the pot. This will be made possible by constant monitoring of the data relayed by the LM35DZ in the pot of water. When the temperature surpasses 100 degrees celsius, the stove knob turner will slightly dial back the knob to lower the temperature back down.

2. Product must be able to turn the corresponding knob to the level desired by the user. This means the product must be able to turn the knob across the entire range of operation for the stove.

3. Users must be able to communicate with the microcontroller via the app with a latency of less than 1 second. The physical system should be able to complete the operation (e.g turn down stove, turn up stove) in less than 10 seconds. In total, end-to-end operation time should be 11 seconds or less.

2. Design

HIGH LEVEL BLOCK DIAGRAM:



SUBSYSTEMS:

1. Sensor Subsystems:

   Our sensor subsystem consists of three sensors, a thermistor, LM35 Temperature Sensor, and a Incremental Rotary Encoder. Our thermistors will be connected to the PCB and attached near each stove knob to check the status of the stove. The circuitry will be encased in a heat resistant material such as thermal pads while the ends of the thermistors will be open and exposed to the heat of the stove tops. We can get the temperature for the thermistor through calculating the rise or drop of its resistance. “The thermistor comes at a given resistance, we can use a voltage divider circuit with known resistance that is connected in series with a thermistor, and apply a voltage reference to one end of the resistor and connect the other end of the thermistor to ground, the voltage across the thermistor is read to determine the temperature based on the voltage reading” (Chueng, 2019).

$$\frac{V_{out}}{R_t} = \frac{V_s}{R_1 + R_t}$$

$$V_{out} = \frac{V_s \cdot R_t}{R_1 + R_t}$$

$$R_t = \frac{R_1 \cdot V_{out}}{V_s - V_{out}}$$

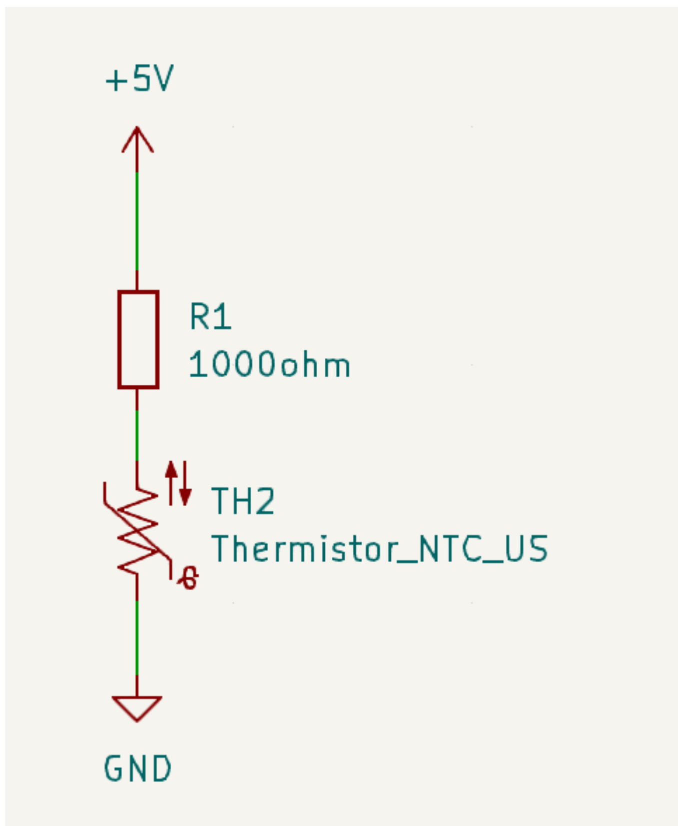


Figure 4: Formula to get R_T and schematic for Thermistor

Our LM35 Water Resistant Temperature will also be connected to the PCB and held in a pot of a liquid. Users will be able to manually put the LM35 in desired items (e.g soup, water). The LM35 will constantly relay its data to the microcontroller so that the stove knob turner can regulate the temperature of the desired liquid. We will use analog to digital converter software to convert the data voltage highs of lows from our LM35 to digital temperature values. See Figure 6 in the control subsystem to see it wired up to the ESP32 MCU.

The incremental rotary encoder will be used to determine the positioning of the stove knob. The incremental rotary encoder keeps track of relative position. For every movement counterclockwise or counterclockwise it'll send a signal high or low to the MCU and that can be used to determine how much the knob has moved. There are two outputs for the incremental rotary encoder A and B. On the rising edge of A, if B is high then the knob is being turned counterclockwise and if B is low then the knob is being turned clockwise. By knowing the initial position we can track the position of the stove knob through performing a series of calculations based on the signals received from A and B. We wish to measure every 18 degrees of rotation. This will give our rotary encoder's resolution as 360 / 18 = 20 degrees of pulses per rotation. This can be tracked by having a counter that increments by 1 for every 18 degrees of rotation and decreases by 1 for every 18 degrees of rotation.

2. Tensioner System

The tensioner subsystem consists of a servo motor that is being used to engage and disengage the pulley subsystem. The purpose of having a tensioner is to ensure that the user can turn their stove knob without any resistance when they are not using the assistance of StoveSense. The servo motor will have an extension from its shaft that will come in contact with the belt in the pulley subsystem. In order for the belt to be kept taught against the pulley when engaged, the servo motor must exert between 22.2 and 66.7 Newtons (5-15 pounds) of force on the belt. The tension on the belt needs to remain that high throughout the duration of the pulley subsystem's functioning. To make sure that this is the case, we will shut off the servo motor and lock it in place when it is maximally tensioning the belt and pulley system. After the stove knob has been autonomously adjusted, the servo will be reactivated and turned 180° to be fully disengaged. The servo motor we have selected is rated for anywhere between 4.8 - 6.0 volts of power, so we will be able to feed it 5V directly from our PCB.

3. Control System

Our control system will primarily be run through a microcontroller. We decided to go with an ESP32 microcontroller unit with Wi-Fi enabled communication. The primary communication protocol that we decided to go with is a web socket connection between the board and our app. By establishing a web socket connection we can ensure bidirectional communication between our app and the microcontroller. The microcontroller will be relaying information regarding whether the stove is on or not and the temperature of the liquid on the stove to the app. Additionally, the microcontroller will be responsible for handling user inputs and sending the signals to the knob-turner system if the user wishes to rotate the knob.

4. Remote Control System

Our mobile application will be primarily controlled through a backend server. The backend server will be responsible for facilitating communication between the ESP32 MCU and the app itself. The backend server should be able to properly take in user's input and relay them to the app. We envision the app to display each knob on the stove that is supposed to mirror each of the knobs on the stove. Additionally, there should be a temperature associated with each stove to indicate whether it is on or not and also how hot the stove currently is. Finally, if the LM35 is in use the app should display the temperature of the liquid that is currently on the stove. The primary input that our app should take is allowing the user to rotate any specific knob to any degree that it desires. The user will not be able to turn on the stove remotely, but will be able to decrease and turn off the stove via the app. We envision the user rotating a virtual knob on our app that will correspond to the knob on the stove.

5. Power System

Our power system will simply consist of a power supply. This power supply will deliver power from an outlet to a microcontroller. It is imperative that we do not deliver too much power as the maximum amount of input voltage for an ESP32 MCU is over 3.6V.

6. Knob-Pulley System

The pulley subsystem is responsible for the actual rotation of the stove knob. This system will function with the use of a belt, pulley, and a stepper motor.

The pulley subsystem is only active when the tensioner subsystem has removed all slack between the pulley and the belt, and when the user initiates the stepper motor via control on the mobile application. When the belt is taught and the user has specified the stove setting they wish to adjust to, the stepper motor will begin to drive the belt along the pulley, which is attached directly to the shaft that the stove knob is on. As the pulley begins to rotate, the shaft will as well, which in turn causes the stove knob to turn to the user's desired position. The adjustment period should be relatively brief, taking roughly 5, +/- 1 second to reach the desired position. After the knob has been rotated accordingly, the stepper motor stops driving the belt along the pulley and the tensioner subsystem disengages the belt from the pulley until notified otherwise by the user. The stepper motor we have selected is rated for 3 volts of power, so we will use a voltage transformer to convert 5V of power to 3V to power the motor.

Subsystem Requirements

1. Sensor Subsystems
    a. The sensor subsystems are responsible for measuring the temperature of the stove and if there's a pot of liquid on the stove measuring the liquid temperature. The sensor subsystems will then convey this information to the ESP32 microcontroller. The sensor subsystems consist of a thermistor and LM35 waterproof sensor.
    b. The thermistor will be used to tell if the stove is on. It should be able to detect heat from the stove and operate up to 150 degrees celsius.
    c. The LM35 waterproof sensor will be used to measure the temperature of the liquid in a pot. It should be able to detect the temperature of liquid up to 120 degrees celsius.
2. Knob-Pulley Subsystem
    a. Stove knob should be able to reach the desired position in 5, +/- 1 second(s).
    b. Stepper motor should be getting at least 3 volts of power throughout the duration of a knob adjustment.
3. Control System
    a. The control system will be responsible for communicating with all the peripherals. It should be able to send and receive information via websocket connection to an app. It should be able to take in and understand information from the sensor. It should also be able to relay information to the knob-turnery subsystem regarding the position a specific knob should turn to.

   b. The microcontroller should be able to communicate with all peripherals within 5sec +/- 1sec.
4. Remote Control System
   a. The remote control system should be able to display information regarding the state of the stove and how far the knobs are turned which it will receive from the control system. Additionally, it should send user inputs regarding how much they want to turn the knobs.
   b. The remote control subsystem should be able to send user input data within 1 +/- 0.5 seconds to the remote control systems.
5. Power Supply System
   a. The power supply subsystem is responsible for delivering voltage and current to the ESP32 microcontroller.
   b. The power supply should send 3.3V to the microcontroller. It should also deliver 20mA to the microcontroller.
6. Tensioner System
   a. The servo motor must be able to exert 22.2 - 66.7 Newtons of force against the belt throughout the duration of the pulley subsystem's functioning time.
   b. The servo motor must keep the belt engaged with the pulley for 5 +/- 1 second.
   c. The servo motor should be receiving between 4.8 and 6.0 volts of power while activated.

Tolerance Analysis:

Required Torque for Motor in Pulley System:

Stove knobs are designed to provide mechanical advantage, which makes them easier to turn, opposed to directly rotating the shaft. We can also achieve a mechanical advantage with our pulley system. In our case, we have two fixed pulleys having force exerted on them via a stepper motor. This would allow us to have a mechanical advantage of 2 [6]. Essentially, we can use half the force necessary to turn the shaft compared to a knob of a similar size. The problem is, how do we estimate the amount of torque needed to rotate the shaft? An average plastic stove knob is between 1-3 oz. Assuming the higher end, to rotate a 3 oz knob with a 1 inch diameter we will need roughly 3oz-in of torque. Using our pulley system we only need 1.5oz-in of torque due to the mechanical advantage. The stepper motor we are utilizing has a holding torque of 67.97 oz-in and detent torque of 3.11 oz-in accordance with the datasheet [7]. To calculate the torque at low speeds, we can use this equation [8]:

$$Holding\,Torque \;-\; 2(Detent\,Torque) \;=\; Available\,Torque$$

This gives us an available torque of 61.742 oz-in, which is significantly more than the force to turn the knob, leaving us with ample torque to overcome friction.

4. Ethics and Safety:

The main safety risk associated with this project is a potential malfunction of the stove knob turner. If this component were to malfunction and turn the heat up too high it could potentially cause a fire. Additionally, having remote control of the stove's level could pose a risk to safety as the user might accidentally turn the stove up too high or even have someone steal their device and turn it up on purpose. One way to remedy this problem is to require the user's face ID or fingerprint ID on their mobile device to confirm that they want to operate the stove. This would make it difficult for someone to forcibly mess with the stove and also for the user to accidentally interfere when they don't mean to. An issue that could arise during the development of this project is if the boil-over protection feature were to fail and cause liquid from the boiling pot to spill across the stove top. We can easily remedy this by keeping a close watch on the pot while testing this feature and ensuring that it never reaches this critical point. Section 1.2 of the ACM Code of Ethics states that unjustified damage to property should be avoided. This is an ethical issue that we must also take into account, as our product has the capability to severely damage property if misused or malfunctioned. This ethical breach can be mitigated by holding the leaders accountable for knowing when to "pull the plug" on the operation. "If leaders do not act to curtail or mitigate such risks, it may be necessary to "blow the whistle" to reduce potential harm" [5]. Section 1.5 of the ACM Code of Ethics states to "Respect the work required to produce new ideas, inventions, creative works, and computing artifacts." Smart stove knobs already exist as a product and we will respect this invention by crediting the creators and also identifying how our product differs from the existing ones.

References:

[1] “ESP32 Wireless Communication Protocols | Random Nerd Tutorials,” Oct. 28, 2022. https://randomnerdtutorials.com/esp32-wireless-communication-protocols/#wifi

[2] “CALLIOPE | Measuring the temperature of liquids,” *calliope.cc*. https://calliope.cc/en/examples/temperatur-von-fluessigkeiten-messen (accessed Sep. 15, 2023).

[3] “Torque Calculator,” *www.omnicalculator.com*. https://www.omnicalculator.com/physics/torque#:~:text=Measure%20the%20distance%2C%20r%20%2C%20between

[4] IEEE, “IEEE Code of Ethics,” *ieee.org*, 2020. https://www.ieee.org/about/corporate/governance/p7-8.html

[5] ACM, “ACM Code of Ethics and Professional Conduct,” *Association for Computing Machinery*, Jun. 22, 2018. https://www.acm.org/code-of-ethics

[6] “Powerful Pulleys - Lesson,” *TeachEngineering.org*, Jun. 30, 2019. https://www.teachengineering.org/lessons/view/cub_simple_lesson05

[7] “Stepper Motor - 68 oz.in (400 steps/rev) - ROB-10846 - SparkFun Electronics,” *www.sparkfun.com*. https://www.sparkfun.com/products/10846 (accessed Sep. 27, 2023).

[8] “What’s the holding torque and detent torque of the stepper motor? – AKT Motor and Drive.” https://aktmotor.com/whats-the-holding-torque-and-detent-torque-of-the-stepper-motor/