The TP Tracker

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ECE 445 Project Proposal - Spring 2018

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Introduction

1.1 Objective

Every two minutes, enough toilet paper is used to wrap around the Earth. The United States is a major contributor: per person, the United States uses fifty percent more toilet paper than Japan and multiple countries in Western Europe [1]. This has astronomical environmental impacts, especially since most of the paper used is not made from recycled material. The Environmental Protection Agency has long been pushing for the use of recycled toilet paper for its numerous benefits to the environment. If everyone swapped one roll for a recycled roll, 470,000 trees, 1.2 million feet of cubic landfill space, and 169 million gallons of water could be saved [2]. Unfortunately, most people still use paper made from cut trees due to the high cost of manufacturing recycled paper. However, if everyone simply used one less roll, the benefits could be even greater. Part of the problem is that most people simply don't realize how much toilet paper they are using.

We propose a electronically controlled toilet paper dispenser, similar to a paper towel dispenser in a public restroom, which will track toilet paper usage of individuals in a household or private restroom. The dispenser will inform users of their usage and promote more sustainable habits. Our product will allow a user to sign in with an RFID tag, wave their hand to dispense a serving of toilet paper, and then log out after a period of inactivity. The dispenser will track this usage for each user and display total usage since the last reset. Consenting roommates can allow other residents to compare against their own metrics, bringing awareness to toilet paper usage.

1.2 Background

Efforts have been made in a public restroom in China to limit toilet paper usage at the Temple of Heaven Park, one of Beijing's busiest tourist sites. The park has created a dispenser which uses facial recognition to dispense servings of toilet paper to patrons [3]. This is done for economic reasons as excess paper can be expensive overtime. However, this dispenser only limits usage; it does not track usage. At the time of writing, there is no widespread commercial product that tracks an individual's toilet paper usage. Furthermore, alternatives to toilet paper dispensers, such as bidets, have not taken hold in America. Therefore, there is a gap in the market for an electronic toilet paper dispenser and tracker.

In order for our dispenser to be a viable product, our design should be relatively cheap to allow for mass adoption by interested households and businesses. Initial investment in purchasing and installing a dispenser may be greater than purchasing a package of toilet paper, but over time the number of toilet paper rolls saved should be more than worth the cost. Our product must also be energy efficient, entering low power mode when no one is in the restroom such that its usage does not negate the positive impact of reduced paper use.

1.3 High Level Requirements

- Design will dispense a serving of toilet paper when prompted by user, then record this to the user's counter.
- Dispenser will warn when toilet paper roll needs replacing, and when there is only one roll left.
- The product will attempt to conserve energy by entering low power mode as much as possible when not in use, drawing ideally less than 20mA.

Design

Our design is broken into five components which must interoperate to successfully fulfill the requirements. The Control Unit is the “brain” of the product, controlling many core processes: reading and interpreting data from sensors, controlling the User Interface, and sending the order to dispense. The Mechanical Unit accurately dispenses the toilet paper using a motor (continuous servo, stepper, DC, etc.). The User Interface displays important information and handles user input. The Power Supply keeps the system powered from a wall outlet. The Power Saving Unit enables and disables low power mode, which will cut all but the necessary power for the microcontroller when entering sleep mode.

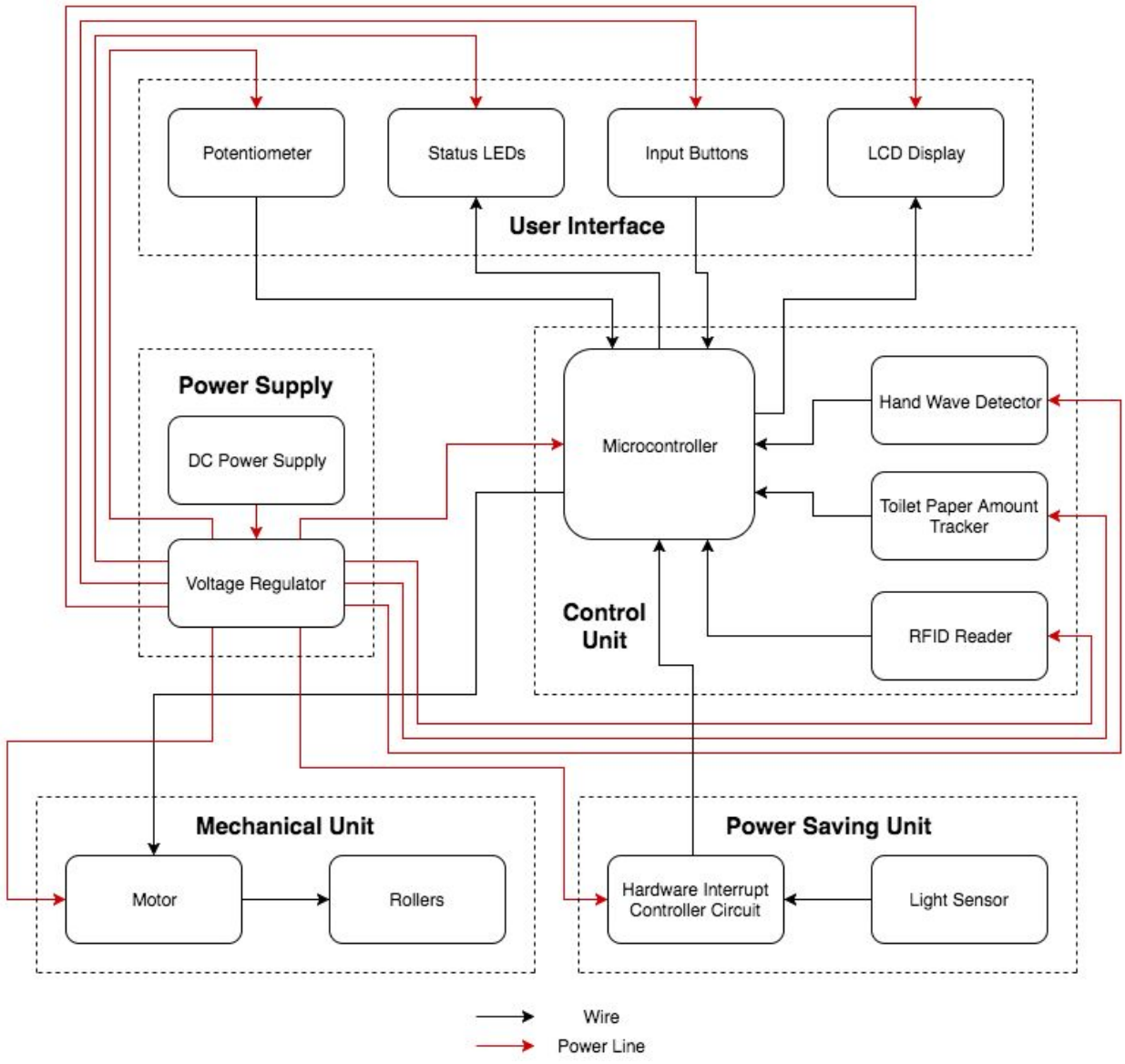

Figure 1: High level block diagram

These components will be arranged in an enclosure broken into three main compartments: extra roll storage, dispensing mechanism, and the pcb/circuitry housing. The side of the compartment will easily open so the rolls can be changed easily. The PCB compartment will not be accessible to the user.

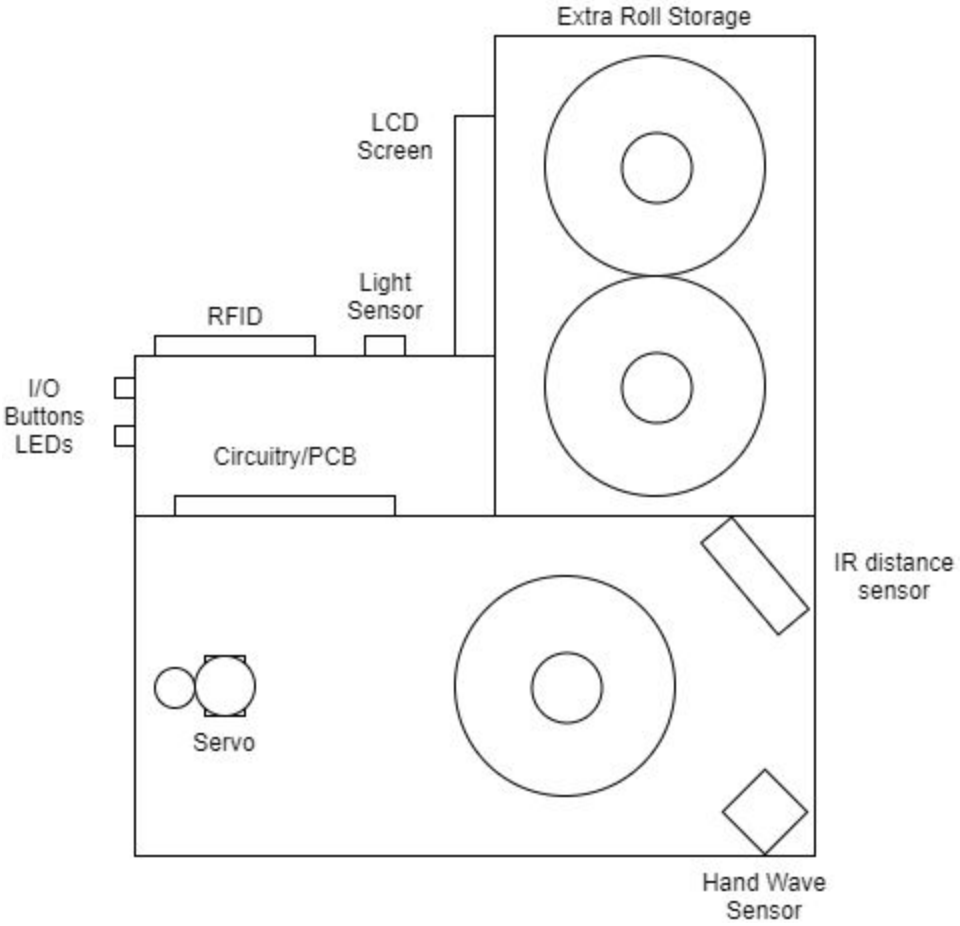

Figure 2: Physical layout of design

2.1 Control Unit

The control unit consists of a microcontroller to process data and various sensors to retrieve data. It also detects which user is signed in and tracks their consumption.

2.1.1 Microcontroller

We will use a microcontroller from the Atmel AVR ATMEGA series. The microcontroller processes data from the sensors on the product, sends commands for dispensing to the Mechanical Unit, and controls the User Interface.

Requirement 1: The controller must be able to read data from two distance sensors (IR, Ultrasound, etc.) from a minimum distance of 5cm, at least four input buttons, a trim potentiometer, and an RFID reader.

Requirement 2: The controller must be able to write data to an LCD Screen and at least one LED.
Requirement 3: The controller must be able to store 1 kB of writable memory to record consumption. This should not be erased upon power off.

2.1.2 Hand Wave Detector

This sensor detects a hand motion, which signals a request to dispense one serving of toilet paper. This will be either an IR or Ultrasonic sensor.

Requirement 1: The detector must recognize if a hand sized object is present at a distance of 4 to 8 cm.

2.1.3 Toilet Paper Amount Tracker

This distance sensor will be used to track the size of the toilet paper roll to determine when the roll is running low. This will be an IR, Ultrasonic sensor, or encoder on the motor/roller.

Requirement: This distance sensor must be able to detect a range of distance equivalent to the thickness/radius of a toilet paper roll, which is approximately a resolution/accuracy of a half centimeter at a distance of 4 cm. Alternatively, if using an encoder, the encoder must have an accuracy able to track at least 90 degrees of rotation increments at a time.

2.1.4 RFID Reader

The RFID reader is used to identify different users by allowing them to login with an RFID tag.

Requirement: This must be able to identify an RFID card/tag from a distance of 1 to 5 cm.

2.2 User Interface

The user interface displays information such as consumption of each resident, low paper warnings, and other important menus and metrics.

2.2.1 LCD Screen

The LCD screen will be used to display information to users.

Requirement: The display must be able to display at least 16 characters on at least two lines.

2.2.2 Input Buttons

These buttons will be used to allow the user to scroll between everyone’s stats.

Requirement: The buttons must be momentary pushbuttons.

2.2.3 Status LED(s)

The status LED(s) will light up when paper begins to get low, and blink when the roll has only 5 percent left.

Requirement: Must be an LED of any color, and be powered by microcontroller.

2.2.4 Potentiometer
The potentiometer will be used to allow adjustment of the serving size by the user.

Requirement: The potentiometer must be adjustable by hand.

2.3 Mechanical Unit
This subsystem will handle dispensing the servings of toilet paper.

2.3.1 Motor
This will be mounted with a rotating wheel against a passive roller to push the toilet paper out.

Requirement 1: Motor must run at 5V or less.
Requirement 2: Motor must have adjustable speed.

2.3.2 Roller
This roller will be used in conjunction with the motor to ensure toilet paper is dispensed.

Requirement: This roller must be approximately 4 inches wide, or whatever length and girth that will safely be able to hold a roll of toilet paper.

2.4 Power Supply
Our dispenser will be powered from a wall outlet. The power supply must consist of an AC to DC converter and a voltage regulator to ensure the microcontroller and sensors receive the correct voltage.

2.4.1 AC/DC Converter
The converter will change the 120 Volt AC power to a useable DC voltage.

Requirement 1: The converter must output a voltage of 5-7 volts DC.
Requirement 2: The converter must be able to supply a peak current of 1.5 amps.

2.4.2 Voltage Regulator
In an effort to not waste power, we would like to implement an efficient voltage regulator. This regulator is required to ensure the correct voltage reaches the microcontroller and sensors.

Requirement: The regulator must output 5 VDC within a half volt, and 1 amp peak.

2.5 Power Saving Unit

The Power Saving Unit signals to the microcontroller when the lights in the bathroom are turned off, so that it may enter low power mode. It will also cut the power to all sensors and the motor to eliminate leaked power.

2.5.1 Light Sensor

The light sensor (photoresistor, etc.) measures the brightness of the room and will be set to signal when a threshold is met.

Requirement: Send a logical 1 signal when lights are turned on in the restroom, with 95% accuracy.

2.5.2 Hardware Interrupt Control Circuit

This will receive signals from the light sensor and microcontroller to interrupt power to various sensors, motors, and User Interface elements.

Requirement: Must disconnect power from sensors when signal is given from light sensor and microcontroller.

2.6 Risk Analysis

The Control Unit poses the highest risk to the success of the project, as it is the most complex part of the design. We would like the design to run with minimal inconvenience to the user. In its final form, the user should not have to wait for paper to dispense, the memory should not be randomly wiped, and all sensors will report accurately and quickly. We are aiming for a highly polished end product. Data storage on the ATMEGA series is new to us, as well as interfacing with an RFID reader and LCD screen. Most importantly, coordinating everything on a microcontroller with limited resources will be challenging, and we may have to be clever with our use of data pins.

Safety and Ethics

There are two main safety concerns we will have to worry about. First, we would like to avoid children getting their fingers stuck in the mechanism. For this reason we will use a low powered motor and will place a guard in the opening such that it is difficult to reach any moving parts. The second safety concern is that in a bathroom setting, there will likely be water splashed on the product. We will shield all connections as best as possible and only work with 9VDC or less within the enclosure. The entire enclosure will be sealed and as water resistant as possible.

Ethically, there is the issue of potential harm to others through disclosure of information [4]. We will include a visibility setting for each user so they may decide whether or not to display their consumption to other residents. However, we cannot control external pressure from roommates to share the said information; we can only provide the option of restricting visibility. This product

is designed such that everyone can become more aware of their own usage, not for purposes of spying or regulation. Participation should be voluntary.

References

[1] New Scientist, “Toilet Paper Use is a Growing Problem,” *New Scientist*, p. 5-5, April 24, 2010.[Online]

[2] Noelle Robbins, “Not a Square to Spare,” *Earth Island Journal*, vol. 25, no. 3, p. 57, 2010. [Accessed: 3-Feb-2018]

[3] Javier C. Hernandez, “China’s High Tech Tool to Fight Toilet Paper Bandits,” *The New York Times*, March 20, 2017. [Online] Available: https://www.nytimes.com/2017/03/20/world/asia/china-toilet-paper-theft.html. [Accessed: 5-Feb-2018]

[4] ACM.org, “ACM Code of Ethics and Professional Conduct,” 2018. [Online] Available: https://www.acm.org/about-acm/acm-code-of-ethics-and-professional-conduct. [Accessed: 5-Feb-2018]