Electronic Toilet Paper Tracker for Public Facilities

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Contents

1 Introduction

1.1 Problem Statement

In many public areas, keeping restrooms fully-stocked is usually very low on employees' priority list, behind other duties. This can render some bathroom stalls unfit for use for customers and people needing to use the facilities. We propose a toilet paper supply monitor and notification system and backup roll, so that employees can focus on other parts of their jobs and still maintain adequately-stocked restroom facilities.

1.2 Background and Alterations from Basis Project

Referencing two relatively recent telephone surveys by Harris Interactive, the website nearsay.com states that 94% of customers would never return to a business with a dirty restroom. Of those 94%, two out of three classify a restroom with a lack of toilet paper as dirty [1]. This provides substantial incentive for establishments to keep on top of restroom maintenance, including stocking toilet paper.

When addressing the issue of toilet paper shortage, the previous group placed their focus on a home environment, and who used the toilet paper within a particular household. We will instead focus on a public or commercial setting, where bathrooms are in practice cleaned and restocked on an as-needed basis. There is no widespread implementation of this kind of solution in any public restrooms that we have experienced. We also differentiate our solution with the previous project by adding a second sensor for stalls with multiple rolls, so that when the combined amount of toilet paper reaches a minimum threshold, the system will alert janitorial staff.

1.3 Alternatives

There is an application called Restroom Alert, which allows customers to notify staff about issues in restrooms, and also remind employees if a certain amount of time has passed between inspection [2]. However, this solution relies on the customer to discover the problems in the restroom, and does not contain the sensors or automation in our proposal. Based on the survey information supplied above, at that point, it might already be too late to save the business's reputation with that customer.

1.4 High-Level Requirement List

The following list details the high-level requirements for our project, and how we will evaluate and verify our compliance with these requirements.

- The toilet paper tracker must be able to sense whether the total amount of toilet paper between the rolls is below 10% of full supply (low).
- When the total toilet paper is low, the user should be informed before he/she sits down, for example with an LED indicator on the door.
- When the total toilet paper is detected to be low, the system must automatically inform the employee for replacement within one minute of detection.

2 Design

This section will detail our design considerations for the toilet paper tracker. Figure 1 shows the overview block diagram for our design. Figure 2 shows some concept illustrations.

2.1 Functional Overview

We now provide a functional overview of our project and its components.

2.1.1 Stall Module

1. Sensors
    - Distance sensor: Two distance sensors would be needed for each device (one for each roll of toilet paper, assuming two rolls in one container). They will be placed on the side of the container to measure the distance between themselves and the roll of toilet paper, to determine the amount of toilet paper still in the container overall.
2. Control unit and Indicator
    - Micro-controller: Each stall module requires a micro-controller to read sensors periodically and establish a connection to the collector receiver. This reading does not need to be particularly frequent, perhaps once every 10 seconds to a few minutes. The micro-controller will also perform a calculation based on pulse-width modulation (PWM) readings from the distance sensors to calculate the total amount of toilet paper supply between the two rolls. A message would be sent to the store staff several minutes through the WiFi capability after the toilet paper is lower than 10%, so the staff can restock the toilet paper after the customer has left the stall, ensuring the customer's privacy.
    - LED: A red LED light would activate if the toilet paper is lower than 10%, so customers would know there is not enough toilet paper before they use the stall, or to carefully arrange the usage of the rest if they are already on the stall. Otherwise, a green LED will declare that the stall is properly supplied.
3. Power Supply: We will utilize a wall plug-in for a stable power supply and convenience. We will attach an AC-to-DC converter to power the stall module at a safe, direct current voltage.
4. Toilet Paper Container: This may house one or two rolls of toilet paper, as well as the electronic components. Specific parts can be 3D printed to fit in the sensors and mechanisms. Our sensors could also be retro-fit onto existing consoles housing the toilet paper within stalls, to reduce the cost of installation of our product. This would require measurements and configuration.

2.1.2 Server Module

Control Server: The control server should be able to gather the data from each electronic toilet paper tracker stall module through WiFi and send the notification to employees when it is necessary. For demonstration purposes, we plan to use a laptop to host the server module.

2.1.3 Cellular Phone Application

Each employee will install a simple, streamlined app onto their personal device, through which they can toggle whether they are on-duty, and also receive notifications from the server. The security risks of such an app are very low, because it will only have access to give notifications, and the internet, but none of the user's personal data.

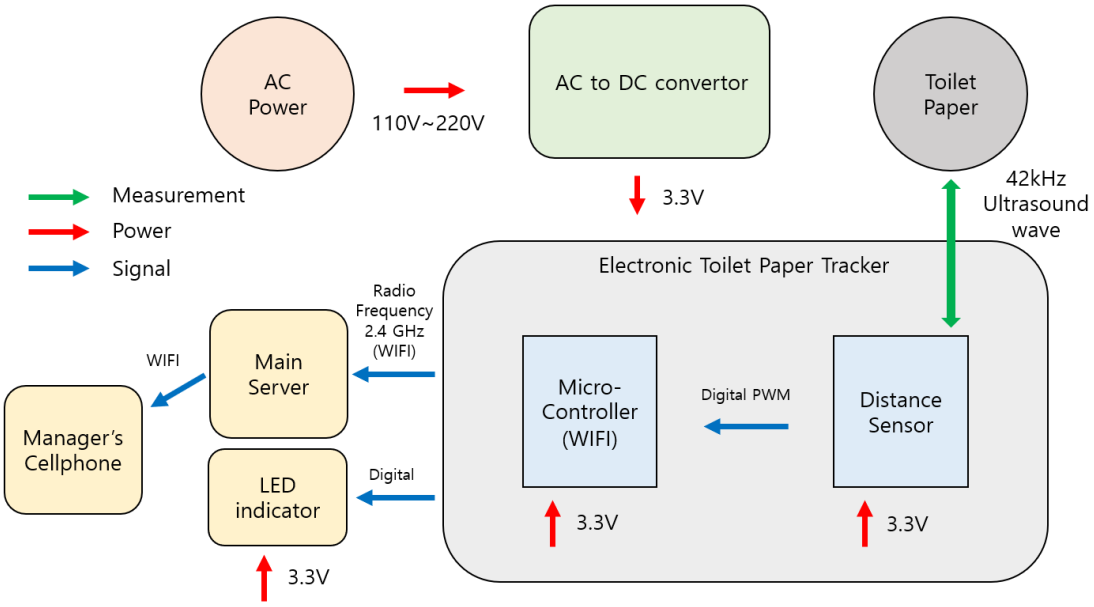

Figure 1: Block diagram for electronic toilet paper tracker

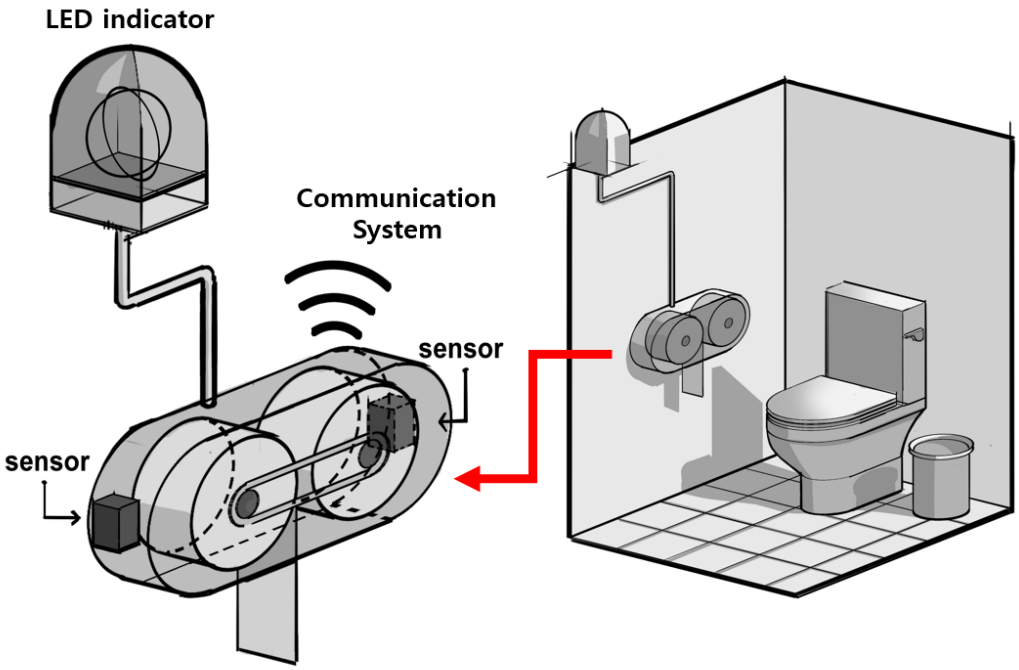

Figure 2: Concept art for electronic toilet paper tracker

2.2 Block Requirements

This section describes the functionality requirements of each major component of the toilet paper tracker system.

2.2.1 Control Unit and Indicator

The microcontroller must have WiFi capability, and accept and monitor the 2 distance sensor inputs:

- Digital PWM Inputs (2): One distance sensor per paper roll
- Make sense of readings and communicate when total amount of toilet paper is below 10% supply (via 2.4 GHz WiFi protocol)
- The controller must also control two LEDs (for example, red and green) to notify potential users whether a particular stall has enough toilet paper.
- The controller must operate on 3.3 ± 0.3 V DC power.

2.2.2 Distance Sensors

One distance sensors will need to discern its distance to the roll with fairly high accuracy, with two sensors in each stall module monitoring two rolls of paper. The distance sensors allow the microcontroller to compute the amount of toilet paper on each roll, and determine if it needs to notify staff.

- The sensors must be able to detect changes in 1 cm between the distances of 3-20 cm. Our sensor that we have in mind accomplishes this (see Appendix A).
- The sensors must be readable at least every five seconds.
- The sensors must operate on 3.3 ± 0.3 V DC power.
- The sensor uses 42 kHz Ultrasound wave.

2.2.3 Stall Module Power Supply

The supply will include an AC-to-DC converter from 220/110 V AC power to 3.3 ± 0.3 V DC power. This is critical because our microcontroller cannot handle voltages higher than 3.6 V. We also want to keep voltages at a safe level in a restroom environment, where there is water involved.

2.2.4 Control Server

A server will be built to gather the signals from each of the WiFi modules and send them to the managers or employees for notification.

- The server needs to accept a connection from the stall module (minimum one for demo purposes).
- The server needs to track which employee(s) is/are on-duty and notify them when the restroom needs to be restocked.

2.2.5 Cellular Phone Application

The employee's personal device will be the receiving endpoint for our notification system. The application must be able to:

- Communicate with the control server over WiFi
- Receive and display push notifications within one minute of them being sent by the server.
- Distinguish to the server whether the employee is on-duty or off-duty, via a toggle at the control of the user. This should also have a maximum update delay of one minute.

2.3 Risk Analysis

We believe that the most difficult component will be wireless communication between our various modules. We plan to use WiFi in our design project, but we also considered using Bluetooth. While WiFi could prove slightly more costly and power-consuming, we determined that its superior wireless range and socket-based networking compensated for potential increases in the complexity of each stall module. Bluetooth also carried with it the difficulty of connecting multiple stall modules to a single receiver device, without a proportional number of chips. This could have become a significant issue for scalability to larger restrooms.

For WiFi, every stall module will require a constant full-powered connection to the LAN. However, this will reduce potential complexity on a central receiver, by simply requiring the receiver to run a server on a LAN. This would have been required anyway to send push notifications to employees, and so consolidation into an all WiFi design would make sense.

Both options will require venturing into new design territory for our group, as none of us have had prior experience working with wireless connections. After group discussion, we have decided to use WiFi. We expect there to be substantial documentation on the internet to guide our understanding. This portion of our project will be the most challenging and the riskiest, because it will require reliance on a network over which we will likely not have control. Wireless communication is critical to the service-oriented focus of our project. For these reasons, we have elected to use a very simple server-client design, with one variety of client (the stall module) providing only input, and the other variety (the employee's smartphone) requiring both input and output.

If we do not execute the WiFi communication portion of our design, then we will simply have three disconnected products, and the goals of our project will not be satisfied. The stall module will still be able to deter customers from using inadequately-stocked stalls, but will be unable to call for attention from staff. These risks illustrate why this component of our design warrants special consideration

3 Conclusion

3.1 Ethical Considerations

- People need privacy while using the restroom, so they probably do not want other people to know that they are short on toilet paper. The reminding module would use an LED light to tell the user that the toilet paper is low, without making any sound to allow others hearing it. Very loosely, this corresponds to the guidelines of IEEE Policy 7.8.9 [3].
- We would not want customers' privacy to be invaded, so shop staff should not receive the message and try to refill the toilet paper while the customer is still sitting on the stall. We can ensure this by reminding the employee to go change the toilet paper several minutes later in the notification text, so employees would arrive after the customer has already left. (IEEE Policy 7.8.9)[3].

3.2 Safety Considerations

- The devices would be plugged in, so the plugin and the device should be tightly sealed to protect the users from getting shocked. Following IEEE Policy 7.8.1 [3], we will make sure the wires and plugin are inaccessible from the customers, by adding a layer of protection to the wires and making the plugin out of reach.
- The opening of the device should be designed so kids cannot put their hands inside and get stuck. We will make sure the only opening of the toilet paper container is small enough so hands cannot reach in, following IEEE Policy 7.8.1 [3].
- The device should be firm enough to handle some physical damage, so it does not break and harm the users. We will use hard plastic for the container, which is both hard to break and does not shatter when broken. (IEEE Policy 7.8.9)[3].
- The electronic parts need to be somewhat waterproof, to work safely in the humid environment in the bathroom. We will make sure the plastic container has no holes besides at the bottom, so water cannot leak in. The electronic components would be protected by plastic or rubber container, so it endures the humid environment. (IEEE Policy 7.8.9)[3].

References

[1] L. Hobbs, "Just how high is the roi on clean bathrooms? - a-1 pro steam, inc. - hobbs," nearsay.com, 03 2018. [Online]. Available: https://nearsay.com/c/445849/324513/just-how-high-is-the-roi-on-clean-bathrooms

[2] "Restroom management system," Restroom Management System, 06 2012. [Online]. Available: https://www.restroomalert.com/

[3] I. of Electrical and E. Engineers, "Ieee code of ethics," @IEEEorg, 2018. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

Appendix A Sensors We Have in Mind

This section provides a few links to sensors we are thinking of using in our project.

- Microcontroller: ESP32-WROOM-32 – https://www.digikey.com/short/zj0d9d
- Distance Sensor: Distance Sensor Development Tool Grove - Ultrasonic Distance Sensor 101020010 – https://www.mouser.com/ProductDetail/Seeed-Studio/101020010?qs=1%252B9yuXKSi8D6aN06jq6dCQ%3D%3D&gclid=EAIaIQobChMIOo_P_6XK6AIVAo9bCh2D5wg7EAQYAiABEgKjivD_BwE
  - NOTE: this will give PWM