AN INTELLIGENT INTERNET-OF-THINGS (IOT) SYSTEM TO DETECT AND PREDICT AMENITY USAGE

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ABSTRACT

As an act of disposing waste and maintaining homeostasis, humans have to use the restroom multiple times a day. One item that is consumed in the process is toilet paper; it often runs out easily in the most inconvenient times. One of the most fatal positions to be in is to be stuck without toilet paper. Since humans are not capable of a 100% resupply rate, we should give this task to a computer. The approach we selected was to use a pair of laser sensors to detect whether toilet paper was absent or not. Utilizing an ultrasound sensor, we would be able to detect whether a person was nearby and send a notification to a database. The online app, PaperSafe, takes the information stored and displays it onto a device for quick access. Once a sufficient amount of data is acquired, we can train a machine learning algorithm to predict the next supply date, optimized for the specific scenario.

KEYWORDS

Amenity, Homeostasis, Machine Learning, Mobile Application

1. INTRODUCTION

Homeostasis [1] is the state of steady internal conditions maintained by living things. This dynamic state of equilibrium is the condition of optimal functioning for the organism and includes many variables, such as body temperature and fluid balance, being kept within certain pre-set limits. Using the restroom [2] maintains it because humans urinate allowing fluid to rebalance. We should be able to detect toilet [3] paper insufficiency and predict its usage pattern. I chose this idea because of my own past experiences. Some of the components of the prototype included the various sensors and the raspberry pi. The laser sensors were situated opposite from each other, adjacent to the roll, so that when the roll empties, the laser will meet with the receiver. I also hooked up the ultrasound sensor, so that if any motion is detected within 5 feet then it will announce/display a message, informing you only if you are out of toilet paper. I thought this was too simple; so, I challenged myself to manipulate AI in my project. So, using python, I took some data and passed it through an algorithm to get a prediction. The user has his/her own database and can even check it on an app I developed called PaperSafe. Some similar purpose-fulfilling inventions were created by RollScout and Sollae Insider. Their devices detect toilet paper [4] in the same accuracy, but they don't have the main features listed in my video: A speaker, an app, and prediction. My device can be implemented in a number of facilities that have potential mishaps. People in hospitals don't have time to worry about supply insufficiency, so this eliminates that problem completely so that they will know when to replace it. Sometime down the road, I hope to make it compatible with Google home mini or amazon echo dot to automatically order insufficient supplies.

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Currently, most of the tasks are done manually, which tends to be tedious and inconsistent. Likewise, most hospitals resupply manually. Unfortunately, humans are not perfect, and inconsistencies happen, which could lead to bacteria and virus outbreaks. The question we are trying to answer is how we can automate the detection of supply usage, and accurately predict the usage in order to control an appropriate supply fulfillment without surfeit.

2. CHALLENGES

2.1. Installment

We would have to make sure these devices are placed strategically, so that motion could be detected. There is no way to entirely predict every single facility; different facilities come in various sizes and designs. The placement of these devices has to be convenient, safe, and usable. There shouldn't be any of them positioned behind doors or too high out of reach. Whether it's a private bathroom or a public restroom, the direction of all the sensors must be facing in a direction that would fulfill the use of the system as a whole.

2.2. Data

Obtaining data was not as easy, since there are not currently any predictors for toilet paper out there. This is something that cannot be avoided because everyone has to go through a "trial period" for the collection of data. Every facility will go under a certain time frame for about one month, where the main goal of the system will be tracking and sending information about usage. Without this data, the system cannot form a training set optimized for that device. In addition, no training set means no prediction.

2.3. Prediction

Usage is not always consistent and sometimes comes with exceptions such as vacations or remodelling, which will offset the training set. Unless this family goes on vacation at the same time every single month, this system will not work. Prediction is based on the training set, so each inconsistency in the "trial period" will reflect in its prediction. All in all, we need to determine a safe shutdown system for when

3. SOLUTION

3.1. Overview of the Solution

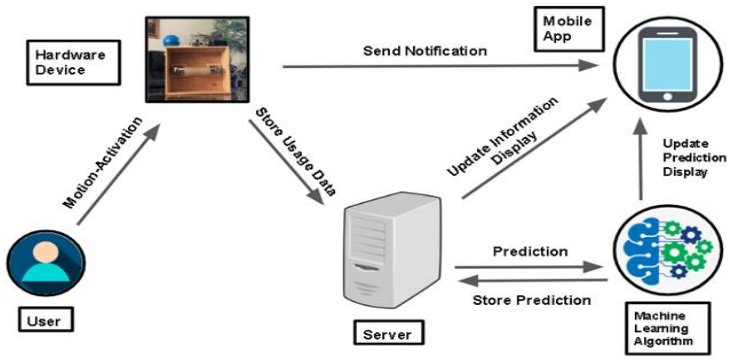

Figure 1: The Overview of the Solution

Users will use the restroom as usual and will deplete the amenity supply. Once the amenity runs low or out, then the system will send new data to the database, informing you of the

insufficiency. Then, a machine learning [5] model is utilized and manipulated to train the optimized set. The user can view the results and prediction date in real time.

3.2. Machine Learning Model and Feature Selection

In Figure 1, you can see the process of the data and how it is interpreted, manipulated, and displayed. For the feature selection we chose 2 things: Day to Start use and Day to be Replaced. Day to Start use is the day that the household starts depleting the supply. Day to be Replaced is the day that the toilet paper runs low or out and needs a resupply.

3.3. Training and Prediction

Using the standard machine learning library Scikit-learn [6], we trained the model. Some of their different machine learning procedures include classification, regression, and cluster dimensionality reduction. In order to analyze the best prediction, we compared 3 different types of algorithms: Linear Regression, Polynomial Regression, and Gaussian Regression. Linear Regression is a linear approach to modelling the relationship between a dependent variable and one or more independent variables. Polynomial Regression is a form of linear regression in which it has polynomial terms of features, offering a curve. Gaussian Regression is a collection of random variables indexed by time or space such that values are interpolated in between points using Gaussian process.

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3.4. Mobile Application

The mobile application, PaperSafe, was developed using MIT App Inventor. MIT App Inventor provides a tech-savvy array of tools to help develop Android applications. It establishes a user-friendly environment to encourage others in the creation of software applications.

The application only has one screen without any interactive options. The app only displays the status and distance. Status will either say "Normal" or "More" depending on whether you need a resupply or not. Later, there will be an adjustment where you get the prediction on the app too.

4. EXPERIMENTS

To begin our experiment, we needed more resources. In order to automate the detection or prediction of anything, we first needed to assemble a prototype, an IoT system. Of course, the machine will vary depending on the item being detected. For my project, I chose toilet paper to use as my amenity. As an example, I made a "toilet paper detector". I constructed a small device that fulfills the criteria with 4 aspects:

- The laser transmitter and receiver on each side of the roll will detect the empty roll and inform the system by displaying a message.
- If there is an empty roll, then the speaker will announce a message if a person is present within 5 feet.
- I also published an Android APP in Google Play called PaperSafe, to view the status in real-time. The APP will automatically send notifications to your cellular device if it detects no toilet paper.

- I also combined system data with AI to predict a usage pattern, optimized for the household. Then, the user can view his/her next replacement date in advance. I used Google Firebase to store the status of the toilet paper every time there is a change and published an app, called PaperSafe, to view this status in real-time.

There are some devices out there that already detect usage, but none of them stay one step ahead, using machine learning. Using python, I used machine learning algorithms such as linear regression, polynomial regression, and gaussian regression [8-11] to predict when the paper will run out, so that you will be prepared to replace it. The program uses the statuses sent from the machine for the input and output data, allowing the prediction to be optimized for the specific user/household. Once the prediction is created, it is sent back to the firebase, where the user can view his/her next replacement date. To verify the accuracy of our approach, we created a likely dataset for an average household with multiple people. We conducted these experiments to test the precision of the machine learning models and the original training set.

As mentioned before, I tested 3 different machine learning models and from Figure 2 Linear Regression had the best result.

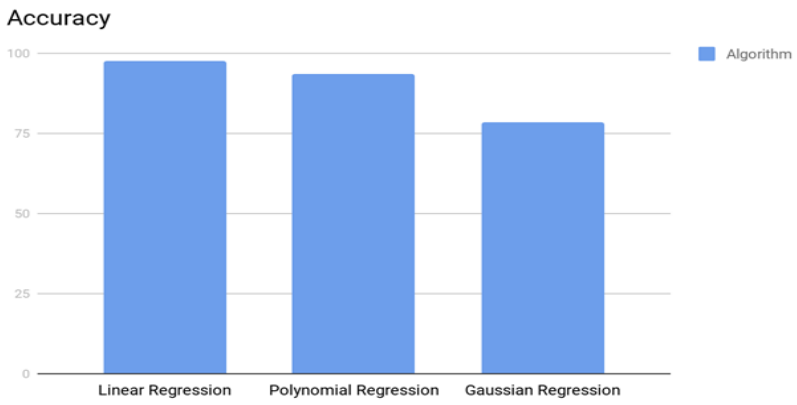

Figure 2: Machine Learning Models

5. RELATED WORK

Sollae Insider, for example, introduced their toilet paper solution that will "essentially remind you anytime you need a new roll"(Mix 1). They used a PHPoC Blue Programmable IoT board as well as an HC-SR04 ultrasonic sensor, constructed into the toilet paper holder. The monitor measures the distance between the sensor to the surface of the roll. Once the distance reaches a “maximum distance”, it indicates that the roll is empty and needs to be replaced. Another example is made by RollScout, they used "a modern, sleek, wall-mounted toilet [12-15] paper holder"(Kooser 1), concealing an infrared laser transmitter and receiver. When the roll empties down enough, it allows the laser to be tangent with the empty toilet paper roll and connect to the receiver. Once it connects, the device triggers a red light to alert others of the lack of paper. Both of these devices accomplish the same thing, but my innovation has more to offer. Similarly, I used an ultrasonic sensor to detect human motion and a laser to detect the toilet paper usage, but on top of that, I also implemented a speaker, an app, and a prediction element to my prototype. When there is a low source of an amenity, the speaker will communicate a message that will warn others of the lack of paper. Every day, we use our smartphones to our advantage. For my device, I developed an app that identifies when there is no more paper in real-time. As humans, we can fix things once they already happened, but to maximize efficiency; what if you predicted when an amenity would run out? In my invention, I used

machine learning to predict when something would run out proportional to a dynamic dataset optimized for the user in any adaptation [7].

6. CONCLUSION AND FUTURE WORK

Let's start from the beginning: I designed a physical prototype and an internal IoT system to detect amenity usage, then sent the data to the firebase, ran it through an algorithm to predict the next replacement and then sent it back. By analyzing our results, I determined that the best technique to use would be a linear model to assess the item usage. So, based on the results, how can we automate the detection of supply usage, and accurately predict the usage in order to control an appropriate supply fulfillment without oversupply? Likewise, in my experiment, we should develop devices for each specific amenity and then replace all of the containers with its own individual IoT system. I think that this would serve as a consummate solution to the question because we could recycle plastic for the physical system and everything else is online and can be withdrawn for usage. My experiment does not apply to everyone since some people might have diseases or other habits, but in a real-life scenario the prediction would be optimized for the specific household, so there really aren't any limitations on the prediction. I think my device is ideal because it is eco-friendly and cost-efficient.

Using cross validation score, I was able to check the accuracy of my prediction, as seen in the results. I think that my invention would affect the world in a number of ways: healthcare sources/work places would decrease in potential accidents and even the common household would just save time and energy that could otherwise be put into something that requires manual-completion. Many questions have emerged through the process of decision-making and problem-fixing: Are laser-sensors the most effective detection method? Does the system need a manual startup each time? Working on the project, I realized that the point of the science fair is to stretch your creativity a little bit and to discover new solutions to things that are inevitably going to happen.

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