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ENGO 500: GIS & Land Tenure #2

Literature Review

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Introduction

Purpose

Information relating to customer frequency, interest, and product popularity is essential to many grocery store owners [1]. Analytics of this kind are useful to store owners as they make strategic marketing decisions, provided data is collected in an efficient and understandable manner. Issues that must be addressed comprise how many people come and go every day, their purchase decisions and history, and which products are sold at different times of year. Much of this data can be gathered by observing the areas of high and low customer traffic within the store, and correlating that information with product locations throughout the store, and to the objects which have been purchased. By gathering this data effectively, retail management can potentially arrange and analyze the store configuration over time, which can be an effective tool in maximizing profit and customer satisfaction [1].

In addition to knowing traffic patterns, store owners also value a well-stocked and orderly appearance. To satisfy this condition, grocery store owners will often ask their employees to *face* (or *block*) the shelves in their store's aisles. Facing a shelf involves moving all products on the shelf towards the front of the shelf (known as the face) and arranging them in a neat and orderly fashion. This allows the customers to easily see all available products and allows them to reach them without trouble as well. Therefore, keeping shelves faced is also important for grocery stores who wish to maintain their image.

This project will focus on consolidating the two above problems in the form of a “smart shelf” solution which can both track customer locations within the store, and likewise provide a means to report on the status of an item's stock (faced or not faced). Therefore, the purpose of this literature review is to not only understand the perspectives and needs of store managers, but also to study the current models which are being created to address the similar challenges. Upon understanding these methods and challenges, a specification for a “smart shelf” system is proposed. The proposed system will be designed to empower non-expert users from general grocers who stock shelves, to upper management, to understand the needs of individual retail chains as well as develop models and data that can be applied to both the store layout, and likewise to marketing tactics in order to maximize their profit and customer's satisfaction.

Background Information

The issues stated in the above section have been addressed before, by many different parties and in many different ways. All of them sit within the field known as the Internet of Things. The Internet of Things is defined as a relationship between tangible objects and their virtual counterparts, achieved by equipping objects with sensors. This provides them with the ability to communicate with the web without human interaction.

Internet of Things

While there is a broad spectrum of IoT applications (many of which are proprietary), to a user, each thing must be controlled by its respective application individually. This will eventually become cumbersome as the number of thing one might use increases. There are two very general ways to approaching this problem: one way is to create standards which are widely accepted and can be considered as IoT protocol, and the other way is to create many different libraries which accommodate for the diverse number of applications (written in various languages, each with their own API, etc.). This second approach has been adopted by an open source community called OpenRemote, which is designed to work with a variety of existing sensors already on the market.

The idea is that users can design their own interface and integrate whichever sensors they want, regardless of that sensor's own protocol. Currently, OpenRemote support protocols from more than 25 different applications, such as PhilipsHue, FreeBox and Samsung Smart TV [2].

Existing Smart Shelves

When considering the problems stated previously, our team began by researching existing products that address the same issues we are trying to solve. Due to the requirements of our project scope and the limitations in budget and knowledge that comes with being students, our final product will certainly be designed differently from the existing products studied below. Nevertheless, they provided insight and guidance in laying out the concept side of our design if not the hardware and software side of it.

One of the concepts researched by our team was a shelf that is heavily reliant on an RFID sensor, as discussed by the RFID Arena Smart Shelf article [3]. Since this field of Internet of Things is so modern, there are hardly any academic articles/journals written on this topic as of yet. The article referenced above is an online document written by Sini Syrjala for the RFID Arena website, which seems to be considered an important source for RFID information in the modern playing field, and equivalent in this sense to an academic document had this subject been allowed more time to mature.

The RFID Arena Smart Shelf article discussed the ability of a shelf, when equipped with RFID sensors, to provide information to the store owners about the products which are placed on it. By scanning the product, the shelf is able to identify when an item is picked up or put down. In this manner it may also track an item through the store by recording which shelf it is placed upon. The RFID scan also provides data such as the expiry date, which the shelf can store and set up a notification if the product has not been bought before that date.

Most interestingly, by tracking the item around the shelves, the owners may also track the item to the cashier. This way they can even gauge customer interest in a product by noting if, after it is picked up, it is put back onto the self or scanned through the check out. Finally, and perhaps most simplistically is the ability of the shelf to automatically alert the employees of a shelf that is empty.

RFID, or radio frequency identification, is a form of automatic identification that falls under the same category as barcode scanning and voice recognition. RFID is a general term for systems that use radio waves to automatically identify objects. The most common method involves storing a serial number on a microchip which can then transmit this number to an automatic reader via an antenna. The reader can then convert the radio waves into digital information [4]. In this way, the reader is able to gather information that is unique to each separate item that has been tagged.

RFID has been in use since the 1970s [5], but it has not been widely used until recently due to its high cost. Tags are now cheaper to produce, but an application such as ours would require a tag on every item that was to be placed on the shelf. Some companies may be able to fund this, such as in the application mentioned above (RFID Arena Smart Shelf), and in return have access to interesting, product specific information, but as students we do not have the means for such a large scale operation.

Furthermore, unlike our design, this item it does not concern itself with facing of the shelves and it does not have an open source website component. However it could easily provide data relating to customer density and flow, although not entirely accurately, by tracking the RFID tagged items among the shelves.

Another existing smart shelf is the NeWave Sensor [6]. This item is also created to be used mainly by store owners, however it does not focus on the improvement of customer satisfaction, but rather on security and monitoring of items. The technology involves an antenna that can detect change within a certain area, and in this way it is able to indirectly track the items placed within that area / on the shelf. Since it relies only on a sensory antenna, it can not tag items like the RFID can. It's functions allow data to be collected on merchandise availability, which may indicate high or low stock or even an emergency.

These features may prove useful in certain environments, such as warehouses, but for case it would not be very useful. It would be difficult for the NeWave smart shelf to specify the position of the items on the shelf, preventing an efficient way to determine whether or not the shelf is faced, and this aspect of the design is important for customer satisfaction. As for customer traffic and flow, the only useable data from this the NeWave shelf would be how quickly items are removed from the shelf by the customers. We believe our application offers a better alternative to this problem, as it can directly observe the flow of customer traffic within the store.

Aisle Management

Our decision to gather information on shelf facing and pedestrian flow stems from several studies that relate these aspects to items being purchased and therefore to the general success of the store. Research compiled by Larson [7] has shown that focusing on aisle management can be beneficial for improving a store's success. When products are grouped into different zones (aisles), these aisles can be monitored and analyzed in order to try to maximize the traffic in and profits from each of the zones. It was also found that if a greater number of people observed a certain product display, traffic increased in the aisle which had that product. Aisle length also has an impact, as it has been noted that consumers are less likely to go down an aisle that is too short or too long. While there are a number of principles which can be followed (for example, grouping products by type is more effective than grouping them alphabetically by their name) [7], stores may also find that some situations or trends are specific to the demographics and organization characteristic of their own store.

Further research, conducted by P. Chandon et al. (2009) [8], used eye tracking technology to measure attention towards items on supermarket shelves. The technology measured eye movements such as fixations and jumps. In complex settings, such as a supermarket shelf, eye fixations represent object identification, and the movement is a good indicator of the direction that the eye is looking. This study suggests that not all shelf locations attract equal attention, and that the items located near the center of two shelf displays were noted more often [8]. It is inferred from this that an increase in shelf space, or an increased number of facings, draws more attention. The report concludes that the effects of increasing the facing of the display area directly and positively impacts the profit made by the store, making it an important aspect for all store owners to consider.

Shelf Facing

Stores often arrange their stock as specified in a planogram, which acts as a map for their products on their shelves. However, planning out how to arrange the products is one matter – ensuring that products are in the correct locations and maintain an organized appearance is another matter. This task is often very labour-intensive and time-consuming. In order to address this problem, Intel has developed an intelligent shelf compliance solution. The solution is a robot named AndyVision, which navigates the aisles of the store using sonar technology and uses a Microsoft Kinect as eyes to check the shelves. The collected images can wirelessly alert staff when stock is low and if items are disorganized or misplaced. These images, once processed, can also help staff identify product placement issues (e.g. if a product has been allocated too much or too little space). While the research project prototype was a robot, a typical retail deployment might consider using existing cameras or installing miniature cameras on the sides of shopping carts, as a robot might inconvenience shoppers during opening hours [9].

The main goal of monitoring shelf facing is to be able to alert staff as to whether or not a shelf is faced, so that if it is not, an employee can remedy the situation. In order to reduce some of this time-consuming work, stores sometimes use shelves which have tracks, dividers and springs to automatically organize products, pushing them to the front of the shelf. These are available in different sizes to accommodate different types of stock [10].

Retail Analytics

Currently, there are two main ways in which retailers collect data about traffic in stores: using video or using cell phone signals. These two ways have been researched and implemented because it typically requires little additional hardware setup. Many stores already have an existing set of closed circuit television (CCTV) cameras in their stores, and nowadays most customers carry cell phones with them while they shop. Leveraging the existing technology is a common strategy employed by several commercial companies and research groups. Some specific examples of both cases are discussed here.

As mentioned, many stores are already equipped video cameras throughout the store, in order to track suspicious behaviour and have resources for offline investigation if any theft occurs. However, having people monitoring surveillance cameras can be quite inefficient, as it requires a lot of time and some events (particularly in larger facilities) could go unnoticed. Hence, having some kind of automatic detection or monitoring systems can be useful. As developed and tested by [11], the video recordings can be augmented with various algorithms to help real-time monitoring of stores. For example, people can be tracked as they enter or leave the store, including what they carry with them when they enter. This is useful information to help with returns fraud, where people take new items and return them without having actually purchased them. In [12], video cameras are used to understand the shopping behaviour of customers. For example, they use various detection algorithms to determine if a shopper should be classified as goal-oriented or disoriented based on their walking speed. In addition, they detected facial expressions and interactions with objects.

There are also some commercial solutions available for gathering and communicating retail analytics. One commercial service is called ShopperTrak, which offers a variety of solutions for retailers to understand key questions about their consumers. This includes questions such as, “is my marketing effective?” and “which zones attract the most traffic?” [13]. This service again leverages video camera technology and also uses mobile analytics from cellular phones.

Another commercial solution is Path Intelligence, which also has a variety services such as location usage analysis using interactive heat maps, signage effectiveness reports, flow management analysis and dwell time reports. All of these services help retailers understand their customers better. Path Intelligence uses the strength of cell phone signals in order to triangulate a location for each customer. While the locations are known, the identity of each consumer remains anonymous [14].

Other retail analytics companies also use cell phones in order to track shopper movements, but they use MAC addresses instead of cell phone signals sent to cell towers. If a phone is Bluetooth or WiFi-enabled, it will broadcast its own MAC address in order to communicate with other devices. Based on detection of MAC addresses belonging to each device, their locations can be determined. Aggregate reports formed from this data provide insight into current waiting times at cashiers, optimized store location and consumer shopping patterns [15].

Sensor Servers

In order to be able to communicate with different sensors simultaneously, a sensor server is typically used. There are several types of existing sensor servers which have been marketed commercially. Some of them are only able to interface with certain sensors, such as the PCW-SSRX Sensor Server made by SenSource [16]. This server communicates specifically with proprietary wireless sensors equipped with radio frequency transmitters, or wired sensors. From one or more servers, information can be communicated to a central PC, which can query the server using proprietary Server Manager Software or by simple ASCII commands.

Another sensor server has been created by Oracle, which is well-known for its database management systems. The Oracle Sensor Edge Server integrates data from different sensors, which includes RFID, temperature sensors, humidity sensors and others, as well as command/response-type equipment. It is the middle-tier component which communicates between these objects and applications [17].

Hardware Specifications

Functional Specifications

The purpose of this project is to have a smart shelf where multiple sensors are connected to determine whether the shelf is faced or not, and to detect the behavior of a customer in the store. The sensors are connected to a micro-controller (Netduino, Arduino, or an RPi). This would make it easier to replenish the product in order to maintain a full display. This section consists of the current models that are being created which address's a similar problem and brief descriptions of the sensors that we are considering.

One of the options that we are considering for our Smart shelf is spring load racks. Spring loads (also known as product pusher racks or shelf facing racks) are shelving racks that are spring loaded and they automatically push the product towards the front of the display, guaranteeing a full, well organized shelving system [18].

Advantages for using spring loads (product pusher racks) are [18]:

- Maintains consistent facing and organization of products
- Guarantees optimal use of shelf space and inventory
- Increases sales potential at the point of merchandise

For this project, we want to use different sensors, for example, infrared sensors, light sensors, weight sensors etc. Previous iterations of the smart shelf idea used Radio-Frequency Identification (RFID) tags. RFID is an automatic way for data transactions in object identification without human intervention (Qing and Chen).

A study has been done previously which talks about how a metal-backed loop antenna (MBLA) at high-frequency (HF) is applied to a RFID smart-shelf system. This study shows that the magnetic-field distribution of the metal-backed loop antenna can be effectively controlled by changing the size as well as the separation of the backing metal plate. Therefore, the antenna can be controlled by using the detection range of an RFID system. This is a huge advantage for the metal-backed loop antenna in applications for RFID smart-shelf systems. To achieve high system-detection accuracy, it is vital to control the coupling zone of the antennas for constraining the interference between the antenna in the adjacent tiers of the shelves. A metal-backed loop antenna provides more flexibility for RFID smart-shelf systems design and implementation, in order to make the system more cost effective [19].

There was another study which was done on RFID smart shelf but with confined detection volume at UHF (Ultra High Frequency). This study was specifically done for book identification at UHF with proper confinement of the electromagnetic fields to avoid detection of books located outside the interrogated shelf, without the need of EM isolation barriers. This approach has an embedded leaking microstrip transmission lines to enable proximity tags detection. Even though their work mainly focused on shelves and books, the concept was successfully tested for other applications where tight detection at UHF is required. It can also be used at isolated RFID reader points in the store [20].

There was another study which was done on the design of the near-field reader and tag antennas in UHF that can be used for various smart shelves, specifically the wine shelf. The tag antenna is designed by introducing an S-shaped or +-shaped slot to the circular patch and the radar one is a rectangular slot array fed by a microstrip line. The reader antenna, which is embedded in the shelf, offers uniform near-field distribution over a specified range, 41cmx32cm, without dead zones and it has a design flexibility to easily change the size and shape of the antenna depending on the shelf configuration. The antennas that are operated in UHF near-field are more reliable in many RFID applications where the reading distance is not that important [21].

NeWave Sensor solutions made major technology advancement with the use of their unique WAVE antenna, which provide retailers the ability to continuously monitor for merchandise availability at the shelf level, and the called it NeWave Smart Shelf. NeWave Sensor Solutions is a leading provider of optimized solutions for today's most challenging item-level RFID problems. This company develops an open RFID technology platform based on the patented Wave antenna that sets a new standard for versatility, efficiency, and accuracy. This system can see both the front and the back of the shelf. The following things are needed for a four foot wide shelf system [6]:

- 4 NeWave antennas
- 1 RFID reader
- RF cables
- Smart Shelf controller
- Shelf dispensers and spacers
- RFID labels
- Mounting hardware and network cables

The studies mentioned above are similar to what we are planning on doing for this project but all of them use RFID tags. We want to use sensors, such as, infrared, light, weight sensors. Then we want to connect the sensors to a micro-controller to store all data collected.

Non-functional Specifications

Specifications for a Raspberry Pi

The Raspberry Pi [19] can be used in the conventional computer configuration, with a keyboard, mouse and display, or in a headless configuration where it is available on a network and is controlled from another computer on the network. If you want to use a raspberry pi, the typical hardware that you will need are, Raspberry Pi Board, Power Supply, SD Card + OS, USB keyboard, USB mouse, Display, Display cable, Network cable, WiFi, USB adapter, Powered USB hub, Real-time clock module.

Some of the specifications for the raspberry pi are:

- Memory = 256 MiB
- USB 2.0 Ports = 1 (provided by the BCM2835)
- Onboard storage = Secure Digital|SD/MMC/SDIO card slot

- Power ratings = 500mA (2.5 W)
- Power source = 5V (DC) via Micro USB type B or GPIO header
- Size = 85.0x56.0x15 (mm)
- Weight = 31g

Specifications for a Netduino

Netduino is an open source electronics platform using the .NET Micro Framework [22]. The following are the system requirements for this micro-controller:

- Windows 7 or 8
- 1.6 GHz or faster processor
- 1 GB RAM
- Up to 3 GB of available hard drive space for Visual Studio Express 2010

For this micro-controller, the speed is 120 MHz, the code storage is 192 KB, the ram is 60KB, and the operating system (as mentioned earlier) is .NET Micro Framework 4.2.

Specifications for an Arduino

Arduino is an open-source electronic prototyping platform that is based on flexible, easy-to-use hardware and software [23]. Projects that are done using an arduino can be stand-alone or they can communicate with software running on a computer. To get started you would need an arduino board that is designed around an 8-bit Atmel AVR micro-controller and the arduino software, which consists of a standard programming language compiler. Most board include a 5 volt linear regulator and a 16 MHz crystal oscillator. The arduino board exposes most of the micro-controller's I/O pins for use by other circuits. These pits are on top of the board, with 2.5mm headers. There are several plug-in application shields that are also commercially available.

Software Specifications

For any project involving software, it is important to identify our goals and projected results. As mentioned in previous sections, we found that there is a clear advantage for store owners and retailers who wish to know more about how their store is faced, as well as the distribution and pattern of customer positions within the retail outlet. It has also been shown by Ko [24] that this concept is not strictly limited to supermarket retailers, but can be expanded into other industries such as construction or site management in tracking and maintaining appropriate stock for work to be completed. However, despite similarities in the concepts embodied in the applications at hand, it is important to note the distinction of our project, which focuses on sensor integration for the Internet of Things (IoT), whereas most previous projects use RFID tag tracking to accomplish the same task [24].

The advantage of sensor-based solutions can primarily be seen in the software aspect of our solution. While RFID tags have been popular in the past, some disadvantages associated with the technique are:

1. RFID signals are very noisy and require objects to perfectly oriented with respect to the sensor in order to improve the overall accuracy [21].
2. Unlike direct sensors, or remote sensors, direct information cannot be obtained without computational overhead. For example, in [24] it is shown that storage of construction

materials required additional computation such as the gradient descent method. On the other hand, weight sensors and magnetometers can detect item positions (on or off the shelf) directly, which provides a much faster solution.

3. RFID chips are cheap and often can be disposable, which would require new, unique chips for each type of product. In the context of a supermarket, this can add up fast in both time and direct cost despite the price of an individual RFID chip being very low. On the other hand, web-enabled sensors require a single set up, and can be modified remotely (over the web), as opposed to requiring direct modification or change of the RFID chips themselves. In practice, this means that using sensors makes the entire system more robust to change, as a software update won't require an entire overhaul or re-indexing of the store.
4. Unlike RFID tags, sensors can be built in additively, so more sensors or improved sensors can be added as time allows. In this scenario, we find that RFID tags are one method of tracking stock, but current RFID based systems cannot integrate future solutions and methods to better or more accurately assess changing problems.
5. RFID tags cannot provide any insight into differences between customers shopping. At best they can identify product trends, but no spatial or temporal data can be garnered about customers using RFID chips.

For the purposes of this project, the major concerns regarding RFID tags are numbers 2 and 5 above. It is important to realise that while the above may appear to be beating a dead horse in terms of RFID applications, the selling point of our project is twofold: to determine the status of shelf facing, and providing analytics in the form of customer interest and time spent within each aisle (i.e. to determine the number of customers in a given aisle and how long they stay there).

Functional Specifications

The following functional specifications need to be met in order to deliver a product that allows non-professionals to interact with our proposed system:

- The ability to view shelf facings in real time, and determine where products in the store need to be restocked.
- The ability to track customers entering and exiting each respective aisle, and determine how long each customer stayed in that section of the store.
- The ability to generate some basic analytics based on data from the sensors. This can include items such as determining hotspots or busy times around the store, analyzing which parts of the store are more popular (most shelves empty), and other organizational information, such as busy times within the store, or average time left unfaced.

These specifications, if achieved, will result in a product that produces value for non-professionals in a managerial or aisle-management context within a retail organization.

Non-functional Specifications

Although there are many things to consider when discussing the overall functionality of our end software, it is important to also note some of the non-functional requirements, as follows:

1. The system should be painless and simple to introduce. Specifically, it should not require the user to do anything beyond setting up the hardware. For this reason, a central website that distributes management of multiple entities is preferred to a more decentralized system,

where entities would set up their own specialized hardware for their application.

2. The system should be secure and prevent unauthorized entry.
3. The system should be robust enough that events such as power loss or switching products between shelves should not produce any significant over head to the system.
4. The system should be easy to manage and should provide managers with the ability to readily pull up any information from a given store or branch that they might choose.

These specifications are particularly necessary in that it will be important to establish ease-of-use in order to market the final product. If the system is painless and simple to introduce, there is a more likely chance that such a system will establish itself in the market. This is often referred to as the technological acceptance model [25], and makes a strong argument for ease-of-use over initial functionality. This also factors in to our 3rd and 4th non-functional specifications, because we find that they represent a measure of *ease-of-use* in slightly different ways.

With regards to information security, the website will enforce a strict client-server authentication model, where specific shelves will be attached to different accounts based on universally unique identifiers (UUIDs). The specific research for this is not fleshed out here, as many common development frameworks are bundled with a sufficient client-authentication system, and will be largely implementation dependent. However, it should be noted that for the majority of the website development proposed by this project, it is likely that client-side computations will be necessary, as the group has not been able to secure any hardware with the capability of performing server-side computations and storage. Therefore, modern technologies such as HTML5, CSS, and Javascript will be necessary in order to allow us to perform computation of database results and analytics, as well as allow us to use some form of local storage for result caching.

Methodology

A large amount of research has gone into studying ways to increase sales in retail stores. Within this large area of advertising, store layout, pricing, loyalty programs, and others, we have decided to focus on two main goals for the project. The first is aisle management, and the second is product facing.

Aisle management, a term which means changing the placement of products to increase traffic, sales, and profits is one method stores use to succeed in the competitive retail market. According to Larson [7], the value of moving a product's shelf space can be estimated by tracking customer traffic within a store. Working with this higher level statistic (treating the aisle as an entity) as opposed to a categorical approach, resource costs for analysis can be reduced. Dreze et al. [26] found that on average, a 4-6% sales increase could be found by optimizing product placement. Moving a product from the least ideal to the most ideal location could have an increase in sales of up to 60 percent. Additionally, creating a layout in which customers browse more isles is important to creating sales. A study by Coca-Cola [27] found shoppers travel and average of 41% of the aisles on a typical shopping trip. These findings prompted one of the goals of this project to be tracking customer movement through aisles. This would allow optimizations for store layout.

The second metric our team is interested in tracking is product facing. The facing of a product refers to the location and amount of shelf space is allocated to it. According to research by Chandon et al. [28], eye movement studies, shopper surveys, and field experiments have all confirmed that large increases in shelf space increase sales even when the price and location of the product stay the same. A logical extension of this is that a product's facing will not be optimal after stocks begin to be depleted by shoppers and the product does not fill the front of the shelf properly. To combat this, a common task for store clerks is to pull stock from the back of the shelf forward to create the illusion that the shelf is full. This is essentially bringing the facing of the product back to its allocated space. By tracking which products need to be faced, management and store owners can see areas which need attention at a glance without needing to travel the store personally. This data would also indirectly show popularity and out of stock problems if a clerk had faced an aisle but products are shown as missing by the sensors.

These two data sets could be useful in other applications as well, such as one that makes use of detailed models to estimate stock levels. These statistical methods use historic and current data such as order/delivery numbers, sales averages, volatility, shelf space and point of sale monitoring [28]. This type of approach is seen in systems such as KSS Retail's Heartbeat [29].

To accomplish the two metric tracking goals detailed above the group will be split into two teams. The first team will be focused on the hardware configuration and sensor interfacing while the second team will focus on developing the necessary software and website.

Hardware based methodology

The hardware and interfacing team's responsibilities can be broken down into to the following tangible tasks:

1. Determine which sensors & micro-controller are most appropriate for the chosen specifications
2. Design the proposed sensor configuration & initial testing
3. Develop interface to send data to the server
4. Construction of prototype
5. Testing of prototype
6. Improvement to prototype (interfacing or hardware configuration)

Task 1: Determination of sensors & micro-controller

The sensor array being developed for this application is focused on embracing the IoT mantra as a main design influence. This means that the sensor network should include a number of sensors that are networked and accessible in a way that allows a full interoperability of interconnected devices..., providing them with an always higher degree of smartness by enabling their adaptation and autonomous behavior, while guaranteeing trust, privacy, and security" [30]. The required sensors will be decided upon based on IoT values, OGC standards, the technical specifications detailed by the team, and the goals of increasing sales in a retail environment.

The Sensor Web Research group at the University of Calgary [31] will be the first point of entry into deciding what sensors and micro-controllers will be used after a period of hands on experimentation with their resources. Some of these resources may be leveraged for the duration of the project. It is likely that not all of the required components for the project will be available in which case these will need to be acquired via an online vendor. A broad set of sensors may be tested for an initial investigation before the sensors for the final configuration is ordered.

Task 2: Design the proposed sensor configuration & initial testing

With the technical specifications in place, a sensor configuration will be developed to meet these design requirements. The main factors to be considered are cost, effectiveness, durability, robustness, and the protection of privacy.

To meet the cost requirements, different arrangements of sensors should be examined to find the best configuration of sensors and micro-controllers. With the cost of a micro-controller board being as much or more than most sensors, a design should emphasize on providing the needed detection methods for as much area as possible per micro-controller. Varying costs of sensors such as infrared ranging, magnetometers, luminance sensors, etc, may allow different combinations to achieve the same end goal.

To be effective, sensors need to be mounted in the optimal location. Logical mounting points for customer traffic tracking depend on the type of sensor used. A more naïve solution would be to track movement past certain gates, in which case sensors at the entrances and exits to aisles would count how many customers travel through the aisle, and potentially time spent in an aisle. Adding additional sensors in the middle of the aisle could also be beneficial to increase the resolution of the statistics gathered. Another option is image based soft-biometrics, which is more expensive both in terms of price and computationally. This type of tracking uses descriptors such as height and clothing color to track people in images, even between separate cameras [1]. Data from either method will be useful in correlating the length of the aisle, the products contained in it, and the time spent in a section. Shoppers may avoid going down aisles that are too short or too long [31]. In terms of facing detection, Christenfeld [8] found that when identical products are found side by side (an allocated product facing), that consumers tend to choose the middle product. This means that for products with greater than one facing, the sensors should be located in a position that they favor the middle of the display.

Durability is a great concern with any business purchase, so the sensors must be configured in a way that is not susceptible to major wear from normal customer behavior. This durability could be the result of mounting sensors in a way that customers will not interact with them, or in a way that the sensors are protected.

The system must be robust, so that the system can stay productive over long periods of time. In the software dealing with the sensors, functions to test and calibrate the sensors may be needed to detect and remedy errors in the system. The type of tests that each sensor will be subject to depends on the sensors used.

With any IoT implementation, privacy is of primary concern to consumers [30]. The customer traffic tracking aspect of the project is the most likely to create privacy issues. To protect consumer privacy, the system will need to be developed in such a way that people are not identifiable from the data collected. Additionally, the data collected will only be available to authorized user.

With the sensor design and set-up tentatively chosen, an intermediate step must be taken to verify that the product will work as envisioned. This will require the sensors to be connected to the micro-controller and data will need to be accessed to ensure that the intended behavior is abided by. At this stage the data read from sensors does not necessarily need to be transformed, analyzed, saved, or sent anywhere. Verifying that the sensor is giving the correct output will be a large but necessary step in the design process. This will likely require some programming to read the output of the sensors as well as circuitry design.

The final part of this task is drawing up schematics for the system as it would be installed on a retail shelf based on the knowledge gained through previously completed steps. This design will be a recommendation which can be adapted as new challenges arise. The format of this design should be a technical drawing or 3D model to ensure that the envisioned product can be created in 3D space. This may highlight some flaws in design choice which can be changed or adapted before sinking significant development time into interfacing sensors or building a prototype.

Task 3: Develop interface to send data to server

Once the configuration of the sensors has been chosen, the next step will be programming the software that handles the data. This will consist of the following steps: reading, interpreting, and temporarily storing data in a robust way; developing an interface between the server and micro-controller; testing and verification.

Depending on the sensors used, the data may come in analog or digital format. Useful data will be streaming from multiple sensors concurrently, and along with other metrics such as time of day will likely need to be included in what is sent to the database. Depending on the timing of incoming data, temporary storage will need to be allocated and managed. Due to the relatively low computing power of some micro-controllers, memory management will be an important consideration during this step.

Collected data must be packaged and sent in a way that is useful and efficient for transferring as well as storing in the database supplied by the Sensor Web Interface for IoT Standard working group [31]. The complexity of this task will very much depend on the micro-controller used and its supported languages. Although the prototype will see a very limited amount of data transfer in practice, the design should be created with a much larger scale of transactions in mind.

Once the interface has been developed, testing of the system as a whole can begin. This testing will ensure that the system can meet technical specifications before being built into a more permanent prototype. Testing will focus on correct results for test cases, uptime for the micro-controller, and reliability of the data being sent to the database. If any significant problems are encountered, they will be resolved before creating the system prototype.

Task 4: Construction of prototype

Once the product has a set of working sensors with a database connection, construction of the prototype can begin. This will be either a purpose built shelving unit or an adaptation of an existing shelve as described in the design completed in task 2. Sensors will be mounted and connected to the micro-controller, which will need its internet and power supplies implemented. Any non-permanent durability enhancements can be done at this point as it will be beneficial to test these adaptations.

Task 5: Testing of prototype

Having constructed the prototype, testing will commence. To begin, testing will be done against known cases which will have been developed as part of tasks 2 and 3. To supplement this, testing will also be done to verify the system performance in a real life scenario, which will involve team members adjusting stock over long periods of time. Data collected during this testing session could potentially be used for presentation purposes so it will be organized and saved. If bugs or improvements are encountered, they will also be recorded.

Task 6: Improvement of prototype

Any potential improvements or bug fixes derived from prototype testing can be added after they are verified by the team. Any changes to the hardware or software will have to be regression tested to ensure new bugs are not introduced and that the system is still functional. This will be an iterative process which will run until the project has reached completion.

Software based methodology

Collecting data from the sensors alone is not enough to achieve the goals of the project. The team also aims to interpret and present this data by means of a website. The software and website team's tasks are as follows:

1. Develop interface between website and database
2. Testing of website/database interfaces
3. Design website prototype

4. Testing of website prototype
5. Improvements to website prototype and website/database interface

Task 1: Develop interface between website and database

Similar to the hardware team's interfacing of the micro-controller to the server, the software team will need to interface the website and database. This should be done with security, efficiency, and robustness in mind. This task will require a small amount of website development in order to verify that the interface is working properly, but minimal time should be invested in an appealing graphical user interface (GUI) or layout issues.

Task 2: Testing of website/database interfaces

Once the interface has been developed, testing should be conducted to verify that the correct queries are being made, that errors can be identified, and that the interface is reliable. This task may be done in conjunction with task 4, after most of the website development is done.

Task 3: Design of website

Designing the website will be the major piece of work tackled by the software and website team. To begin with, the website framework must be chosen. Additionally, decisions pertaining to what browsers to support, what authentication model to use, update period, hosting solutions, and if the connection should be encrypted also need to be decided. Once the basic infrastructure has been planned, the team will focus on what kind of information is valuable to users, and what the best way to present this data is. This will cover things such as what statistics can be calculated, what kind of graphics can be generated to represent these data/statistics, what kind of navigation and structure should the website use, all the while maintaining a system that is easy to expand if new functionality is required. Information that can be derived from the data collected could include things such as stagnant products, traffic to aisle facing condition, historical vs. current trends, or a variety of others. The website will be the most visible part of the project, so the experience must be polished and easy to understand.

Task 4: Testing of website

The website should be tested on all supported browsers using a set of test cases as well as simulating real life conditions. Data and generated statistics need to be checked for accuracy as well as proper display. All navigation should be verified and authorization needs to be tested to ensure that user's data is secure. Feedback should also be gathered from user's outside the team to find potential improvements.

Task 5: Improvement of website and website/database interface

Any bugs or improvements noted during the testing tasks should be considered and implemented if the team agrees they are achievable and worthwhile. Outside opinions will also be considered. Again this will be an iterative process of updating and testing until the completion of the project.

Conclusion

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