

Inventory Control at a University Food Pantry Using an MVC Software Pattern and Data Visualization*

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Abstract— University food pantries have been opened on-campus to reduce food insecurity among students. However, they are relatively self-governed and receive a limited amount of support. This study aims to resolve the inventory management issue at university food pantries using the combination of the Model-View-Controller (MVC) software pattern and data visualization. As a result, a foundation is established to predict the food choices of clients and to manage food waste effectively. The benefits of visualization on decision making through the use of a resourceful inventory system are outlined. The focus of this research is on university pantries, in particular, the Aggie Source Food Pantry at North Carolina Agricultural & Technical State University. A sample of 50 clients' food choices was acquired from picklists for June and July of 2019. The inventory tracking system implemented is a client-server mobile application used for data collection. Data visualization was applied to evaluate the food donations and distributions. Students preferred essential foods (e.g., pasta, canned vegetables), over unhealthy foods (e.g., Pop-Tarts, cookies). The data consisted of 338 pounds of distributed food and almost 2,473 pounds of donations. Data was simplified into comprehensive visual diagrams. The MVC structure established a program interface that grouped application functions and managed data objects. The solution allowed the staff to understand pantry status and the trends in production. It is anticipated that the prototype will be implemented in the daily activities of the pantry.

Keywords—MVC software pattern, food insecurity, inventory control, mobile application, data visualization

I. INTRODUCTION

According to the 1996 World Food Summit, food security is defined as a situation where there is "access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [1]. Food insecurity occurs when these circumstances are not satisfied. It is inadequate access to sufficient healthy foods. It is a problem that is birthed from the social and economic restrictions of a given household. Because of food insecurity, non-profit organizations, such as food banks, have been established ever since the 1960s [2]. Food banks are warehouses that store large quantities of food and

distribute them to agencies. Some of these agencies are, for example, food pantries, homeless shelters, soup kitchens, and food drives. A food pantry is a distinct location that supplies food to those in need [2]. Pantries extend their services to people's communities, helping food banks increase their support to unreachable populations.

A. The Problem: Inventory Control System in University Food Pantries

Universities have founded food pantries on their campuses to reduce the prevalence of food insecurity among their students [3]. Campus pantries have been promoted to help meet the basic needs of students. Many of them have goals to care for the well-being and success of their students. The objective is to give every college student the same equal opportunity to receive their services. Food pantries have increased in number on college campuses, but some challenges are still faced. A qualitative research study was performed grouping university pantries' challenges into four categories: infrastructure and resources, operating within university systems, building and sustaining partnerships, and research [4]. Only a few food pantries have tried to implement additional steps to improve their effectiveness [5]. Not much has been researched on the daily functions of university food pantries.

Because many food pantries are relatively limited in resources, they do not possess a way to regulate their donations properly [4]. This often leads to an increase in wasted food goods. Inventory management allows pantries to provide suppliers with accurate estimates of food items available at any given time. Knowing the number of goods donated and distributed enlightens the food organization on their product performance. However, pantry workers are not all equal in data interpretation [6]. Data interpretation is the ability to understand the data collected and select the proper procedure to implement. Because data analysis varies for each employee, a solution needs to be applied. Visualization is the technique of using visual imagery, graphs, and diagrams to convey a message.

The purpose of this research is to implement an efficient inventory control system while examining the

benefits of data visualization on decision making in a university food pantry. This could ultimately predict the patrons' behavior and reduce food waste. Aggie Source Food Pantry (ASFP) was the industry partner used in this study to extract food data. Because the pantry did not possess an efficient database, data was collected from the picklists (completed student menus) and donation information forms. Data visualization was used to analyze food distribution and donations to predict outcomes. It was projected that visualization would effectively aid data interpretation in a university pantry because of the various recorded benefits and advantages.

B. Data Visualization

Data visualization is a popular way to decipher large amounts of collected data. This technique involves converting big data into a graphical and illustrative format for interpretation. Complex data is transformed into simple visual charts that are helpful for data analysis. Visualization methods are used in organizations to identify patterns and trends in business operations [6]. When trends in the data are recognized, the company can categorize factors, or variables, impacting commerce. From here, they can establish correlations between these factors and current business procedures. Conclusions are then formed from the generated charts.

C. Data Visualization for University Food Pantries

University food pantries need proper data interpretation to understand the status of their production. This can be accomplished with data visualization. The objective is to feed as many food-insecure students as possible on campus. This can be difficult to consistently achieve without correctly responding to issues that present a limitation to business. Most campus food pantries in the United States do not use data visualization in their problem-solving practices [5]. Proper data interpretation from visual diagrams is reported to help identify problems [6]. From this approach, a university food pantry can implement improvements needed to overcome the identified challenges. For example, inventory for a campus food pantry would involve the regulation of food donations, distribution, and damaged items. The workers can interpret the volumes of data in a short period and then form intelligent opinions. The staff would be able to detect the possibility of the depletion of resources and donations. This is effective because of data interpretation for employees at a food agency tends to vary [7].

Proper data interpretation would present the opportunity of predictive analytics. University pantries would be able to consider potential future scenarios and predict outcomes. Data visualization would aid in

improving worker response time, simplifying data analysis, and concluding accurate predictions. Consequently, preventive measures would be applied to reduce the conflicts in the pantries.

D. Research Questions

University food pantries need proper data interpretation to understand the status of their production. This can be accomplished with data visualization. The research questions addressed here are the following.

1. *What's the current process used at the pantry?* This question was asked to gain knowledge of the existing process that is applied for inventory control. Before creating the design of the solution, the details of the present process should be analyzed.
2. *What variables do the pantry supervisors need to monitor inventory?* These variables are the factors that determine the pantry status and provide a perspective on how inventory is measured. These variables will be used in the visual graphs.
3. *Is the MVC architecture an adequate software design pattern for an inventory control app?* This question was asked to determine whether the MVC structure is a suitable solution. The architecture has three components that handle the application development process and is not the only possible innovation.
4. *To what degree can visuals help the pantry staff make effective decisions?* This question helps to analyze the impact of visualization on pantry staff collaboration. Data is transformed into legible diagrams for better understanding of the pantry status.

E. Paper Organization

This paper introduces the concept of food insecurity and what university pantries are doing to solve this issue. Next, data visualization and its usefulness in the work environment are summarized. The focus of this study is inventory management at university pantries. The proposed solution, an MVC inventory tracking application, is presented, and it incorporates data visualization. The methodology of this study is outlined. Then the MVC architecture is explained in more detail. The solution is implemented to collect food data at the pantry. The benefits of data visualization in analysis are presented in the results and discussion sections. After the app has been tested,

a guide is given as a reference for pantry workers in the transition to practice section. The paper ends with a summary of the results and interpretation, which answers the research questions.

II. METHODOLOGY

Because ASFP did not have a database to retrieve real-time data, an improved data collecting procedure was incorporated. Frequent meetings were scheduled with the supervisors of the pantry. The required variables for analysis were identified. The following variables were useful to the pantry staff: weight (lbs.), the number of food categories and items, and their names. Numeric data on food donation and distribution was recorded. The food items distributed to the clients were recorded on a picklist. The picklist is the menu patrons use to order food items, which stores their food choices. A unique identification (ID) number was used to protect clients' privacy, concealing their names, and revealing only their food selections.

The MVC app was constructed using the Swift programming language and configured to communicate with the RealmSwift database. Visual diagrams were generated in the app from the imported food data. Then visual data was presented to the pantry staff for insight into the pantry's productivity. Popular food categories and items were identified. The dependent variable was the expected occurrence of a food item and category, and the independent variable was time.

Figure 1 displays the method process and Figure 2 shows the design model for the app. Note taking was the first phase of the method process, which involved recording our observations during our visits to the pantry. Information was gathered about the current process, pantry status, and variables needed for decision-making. Next, meetings were scheduled with the staff to discuss desired improvements in inventory control. Their responses were used to determine the necessary app features. Designing the app involved creating virtual sketches and use case diagrams. Next, program code was created in Xcode. The last phase entailed establishing a connection to the RealmSwift database. The solution model has four components: inventory, user, mobile app, and the database. Inventory is recorded by the staff user and inputted into the app. The app then updates the database.

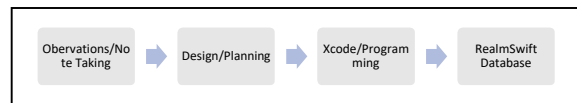


Fig. 1. Method Diagram



Fig. 2. Solution Model

A. Data Acquisition

A sample of 50 clients' food choices were recorded from the picklists of June and July of 2019. Their food choices were imported into the app. The pounds of donations and distribution was retrieved. The data was initially stored in folders. A folder contains at least three groups of picklists. Each group represents a month of the year 2019. Each food category and item were assigned a unique identifier (ID) to be stored in the database.

B. Software Engineering

The MVC, displayed in Figure 3, is the software pattern used to organize the various code [8]. The MVC design describes three components: model, view, and controller [8]. The model is the representation of the data in the app. It is independent of the other components and presents an interface for them. The model contains wrapper classes that extract specific data and convert it into an interactive form. The datatypes of database variables are expressed in these classes. The view is the user interface, the object the user interacts with. This component manages the app window. The controller interprets user input from the view and updates data using the model. Testing the controller and view component involves instantiating visual objects in the app as variables in the controller classes. Code errors occur when the variables are invalid, which means the view objects were not recognized.

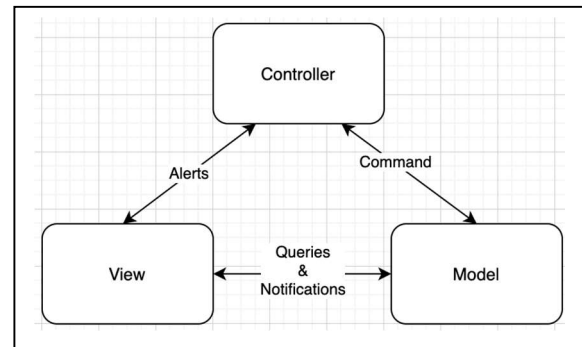


Fig. 3. MVC Diagram

III. IMPLEMENTATION

This paper outlines an appropriate design for an inventory tracking system. This was completed by using a design software tool called Sketch [9]. A

prototype mobile app was developed using the Swift programming language for iPhone OS (iOS). The Xcode platform was used to execute object-oriented programming algorithms [8].

In the model, data structures were created. These data structures reference the RealmSwift database. RealmSwift is an open-source database solution that is used for iOS applications. [10]. The framework runs directly inside a mobile device. It saves and persists data in the app. Specifically, the database collects and stores data into tables. Visual graphs are programmatically generated from the database for observational purposes. The data values are stored into arrays, where they are passed through class methods. The data is then exported from the app as Microsoft Excel spreadsheets. The user can view data from the inventory interface and send it to an email address for download. This feature allows data to be exported from the app to a workstation. From there, graphs can be generated from the spreadsheets manually. The app can be viewed from a single iOS device where one user can operate it at a time. The data points are then plotted in periods of days and months.

IV. RESULTS

Figure 4 consists of half of the food item inventory of June and July of 2019 that were generated. Figure 5 displays the rest of the item inventory. The numbers of items are on the y-axis, and the item names are on the x-axis. In this sample, the green beans product was the most demanded good for both months. The food category inventory of the same period is charted in Figure 6. Again, the numbers of items on the y-axis, and the category names are on the x-axis. Figures 4, 5, and 6 were created from the spreadsheets emailed from the app. Pasta was the most selected food category by clients. The anticipated result was that patrons would prefer snack items (junk food) over the other categories [11]. However, snacks were the third most preferred category. This is clearly identified by visualization instead by the use of data sets and algorithmic formulas. It is concluded that more data will present more precise results. These results can be used to forecast patrons' food choices using predictive analytic techniques such as time series, regression, and factor analysis.

As mentioned, Figures 4 and 5 (produced at a workstation from spreadsheets sent by the app) display the food items distributed to clients during a two-month period. The number of items is the y-axis, and the item names is the x-axis. In this sample, green beans were the most demanded good for both months.

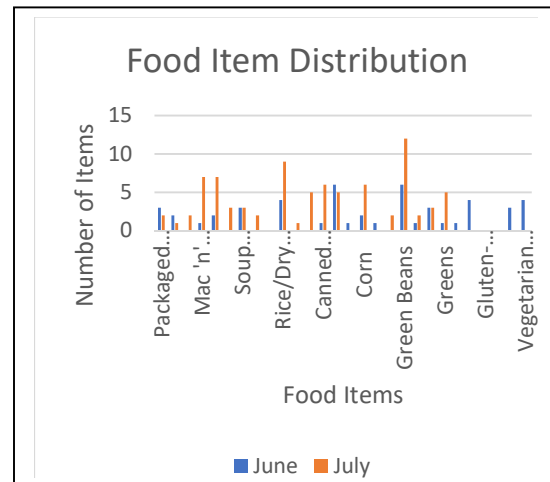


Fig. 4. Food Item Distribution

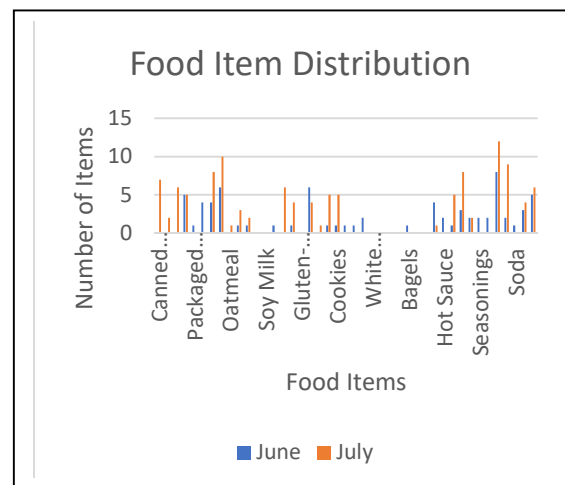


Fig. 5. Food Item Distribution

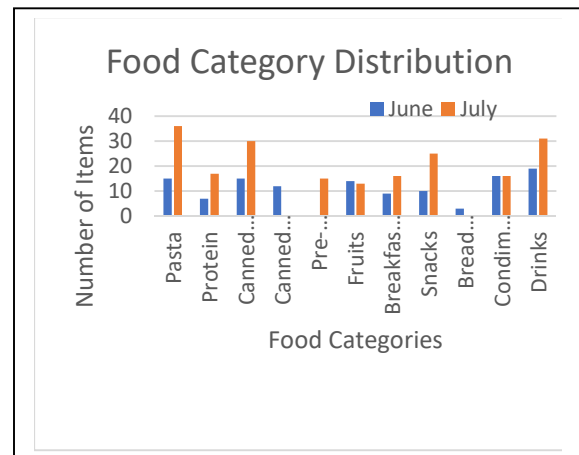


Fig. 6. Food Category Distribution

As mentioned, Figure 6 (also produced at a workstation from data sent by the app) shows the food categories distributed to clients during the two-month period. Drinks was the most distributed good in June, and pasta was the popular good for July.

Figure 7 is a visual produced by the app Vendo. The purpose of the time series model was to visually measure the frequency of food items and categories distributed to clients. Another reason is to create a foundation for time series forecasting, as shown in Figure 8. The app produced this diagram showing the daily weight distribution in July. The numbers of items are on the y-axis, and the category names are on the x-axis. The category names from left to right are canned meals, pre-packaged meals, fruits, breakfast items, snacks, bread items, condiment supplies, and drinks. Patrons demanded drinks more than any other category. The orange bars represent the food distributed in June and blue is for July. A bar turns brown when it is selected.

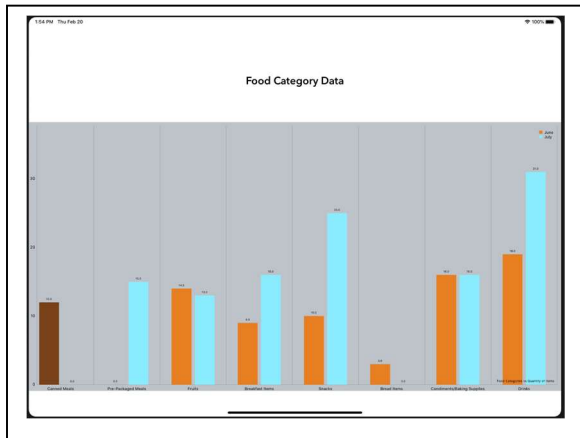


Fig. 7. Vendo App Screenshot: Food Category Data for June and July

Figure 8 is another screenshot from the app. In that figure, the weight in pounds is the y-axis, and the days the pantry opened (June 11th to June 30th) are on the x-axis. The days from left to right are June 11th, 18th, 25th, and 27th. The remaining days are July 2nd, 9th, 11th, 16th, 18th, 23rd, 25th, and 30th. Distribution occurred the most on June 18th.

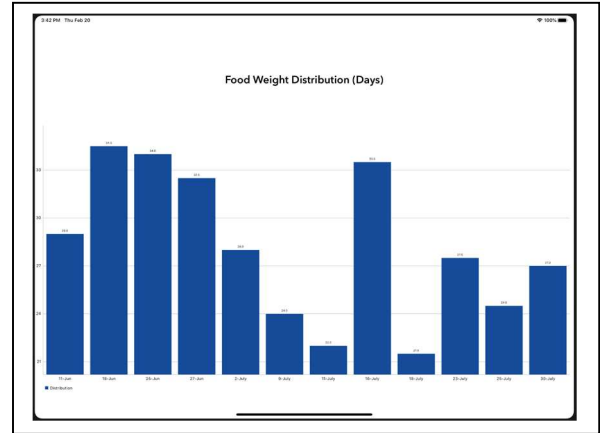


Fig. 8. Vendo App Screenshot: Food Weight Distribution in Days

Figures 9 and 10 were generated by the offline analysis. The weight in pounds is the dependent variable, and the months represent the independent variable. Figure 9 shows food donations acquired from suppliers and client distribution is represented in Figure 10. July has more distributed food pounds than June but has the least value of food donations received. Though the data is slightly insignificant when compared to the population data from 2019, it presents useful suggestions for inventory optimization.

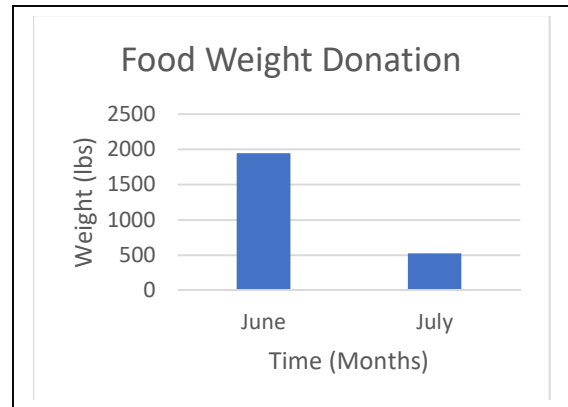


Fig. 9. Food Weight Donation for June and July

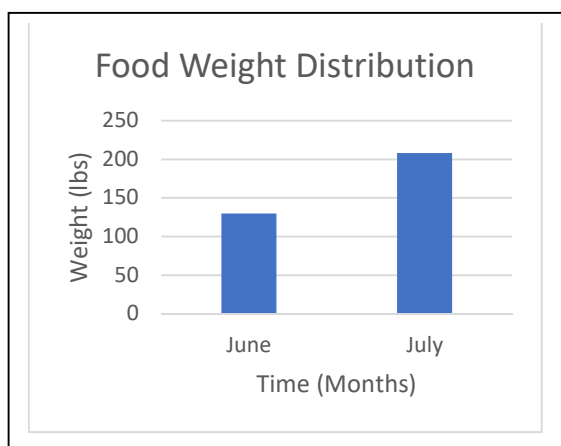


Fig. 10. Food Weight Distribution for June and July

V. DISCUSSION

In this section, we return to the research questions. For the first question (What's the current process used at the pantry?), the inventory process was determined with frequent meetings with the staff. Clients who visit are given picklists to complete. Once completed, they are served their desired food items out of the available stock. Stocking and replenishing are accomplished by merely looking on the shelf for item shortages. The quantity of items is not recorded. The present worker retrieves the picklist and stores it in a physical folder in a file cabinet. Picklists are separated by months. They are food records providing evidence of food distribution. However, the numeric value for food distribution is not determined. The current process does not record the stock information of food items that have been stored in the pantry in the past. When items are donated, the staff distinguishes expired items with dotted markers. This aids them to track the expiration dates of food. Damaged food goods are stored in a box for disposal.

To monitor inventory, variables are needed for measurement, which brings us to the second research question: What variables do the supervisors need to monitor inventory? From the staff feedback, the required variables are the weight of food, and the number of food categories and items. The independent variables are the food category and item names and the time when they were donated and distributed.

Based on the results, food donation and distribution were determined for June and July. More food items were donated to the pantry in June, but more were distributed to clients in July. Productivity was at a higher level in July because the weights of items distributed and donated were closer in range compared to June. This observation was made because data was properly organized into a visual form. Trends can be analyzed to detect patterns. Shifts in data allow the

pantry to perform proper preparations for a given period in the semester. In summary, answering the last research question (To what degree can visuals help the pantry staff's decision making?), visuals help the pantry staff understand the strengths and vulnerabilities of production.

Turning to the third research question (Is the MVC architecture an adequate software design pattern for an inventory control app?), the MVC architectural pattern was able to record data, transmit it, and present it in a format convenient for the staff. This model is recommended because it can be applied to web apps. Vendo has simplified data into a legible format for effective collaborations. The app has a feature that organizes food data into categories. New categories and items can be created for the freedom of pantry workers.

VI. TRANSITION TO PRACTICE

A. Training

The inventory tracking system is expected to provide an interface that allows university pantry workers to regulate inventory. Using the mobile app, the employees record the inventory. For example, the food category table is represented in Figure 11 (on the iPhone 8). The updated database displays real-time data that can be used to resolve business questions. The mobile app is intended to be the beginning of efficient food regulation for the food pantry. This solution requires consistent usage in order to maintain its accuracy. The visual graphics are updated, giving the supervisors a valid status report of the pantry.

Workers are required to be trained on this solution process before they are given the opportunity to begin working. Improvements in worker training are projected to advance employees' productivity and meet the pantry's quality standards. As a result, this will increase the pantry's value and potentially satisfy the food necessities of the end-consumer.

Category	Count
Pasta	8
Protein	4
Canned Vegetables	7
Pre-Packaged Meals	4
Fruits	5
Breakfast Items	6
Snacks	8
Condiments	8
Drinks	4
Baking Supplies	6

Fig. 11. iPhone 8 Screenshot: Food Categories Table

B. Reception

These visual charts were shown to the food pantry supervisor to inform them on the organization's status. They concluded that the data mirrors a trend in the correlation between donation frequency and client choices. These semesters are longer time periods than the summer sessions, which equates to more data collected. The supervisor is willing to adjust their decision-making procedures to improve the food pantry's overall performance based on the information received. Clients' choices are based on the availability of foods in the pantry. Therefore, the projection is that more consistent food donation schedules would result in a more accurate representation of demanded foods in the visual diagrams.

C. Anticipated Impact

It is projected that effective decision-making will be improved. This is because accurate summaries describing the status of food pantry will be conveyed. Student satisfaction and health are very important. The app will help to predict the food choices of patrons. This will present the opportunity to request demanded goods for the pantry while still being able to meet their nutritional requirements. The mobile interface provides four concepts: convenience, speed, durability, and protection. The app can perform the necessary basic functionalities discussed in this paper. The inventory tracking system's design is projected to be updated as time goes on and more data is persisted to the server.

VII. CONCLUSIONS

The benefits of visualization on decision-making in this study are clear. One benefit is that it simplifies complex data, making it understandable. It also allows for the best possible preventable solution to be correctly matched to its associated business problem. Teams of workers are able to gain business insight from visual graphs. In particular, inventory management becomes problematic when one has to scan through long spreadsheets of data. Data visualization condenses large amounts of data to comprehensible summaries. Shapes and color have been proven to enhance the memory performance of individuals [12]. Visual charts contain noticeable figures with color that enlightens the viewer to the message that is expressed. Consequently, if data visualization can increase workers' performance, the overall productivity will improve. Workers who understand the status of the food organization will be more inclined to relate to its goals.

A few of the challenges university pantries are facing are limited donations, the inability to meet nutritional requirements, and the dissatisfaction of the

end-consumer. The recommended solution is to develop an inventory tracking system using the MVC framework that collects real-time data and generates visual figures for effective analysis. These visual representations will accurately display information for enhanced staff collaboration. Data visualization can influence business decisions and lead to the rapid innovation of solutions. Ultimately, this will aid in the achievement of the objective of the food pantry: client satisfaction and retention. This study has some limitations. We are exploring further research in food insecurity using cloud computing to improve speed and performance. This study serves as a reference for inventory management at a campus food pantry.

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