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Humanoid Robot To Help Reduce Food Waste by Detecting Food Quality Using Artificial Intelligence

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ABSTRACT– After assessing existing problems in food wastage and identifying if any solutions pre-exist, this eventually sparked the idea for developing a solution to detect food quality and reduce food waste. This was shown by doing a thorough study in order to fully comprehend the problem of food wastage. According to the study results, the leading cause/causes of food wastage are that most family members do not complete their meal and do not check the fridge, freezer, or cabinets before going shopping. In hindsight, this preliminary study aided in the creation of a solution that might aid in the reduction of food waste by identifying the food quality of fruits and vegetables and informing the person if it can be kept or should be consumed. The solution proposed was to train Pepper, a humanoid robot, to detect the food quality of fruits and vegetables using image recognition in order to decrease food waste.

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Introduction

By 2050, the world's population is predicted to grow by another two billion people. To fulfil this rise in demand, the global food supply must increase by at least 60% over 2006 levels. (Fao, 2017). Despite predictions of food scarcity, it is estimated that one-third of all food produced for human use is lost or wasted worldwide.

Food waste occurs for a variety of causes including customers ordering enormous servings at buffets, failing to correctly use leftovers, overcooking, and even discarding edible pieces such as fruit and vegetables. As a result, food waste has substantial environmental consequences, including greenhouse gas emissions, water usage, deforestation, soil degradation, biodiversity loss, and implications on livelihoods (Gull, 2021). Food waste is the second most common component of landfills, which, in addition to polluting the environment, have limited capacity. As a result, eliminating food waste at the is critical to addressing the problem.

The motivation behind finding a solution for food waste comes from the pandemic that started in 2020. Covid-19 has had a substantial impact on people's food purchase and consumption behaviours (Iranmanesh, M., et al. 2022). Due to disruptions in food supply systems, several grocery store items became limited. The restrictions imposed by the lockdown, as well as the risk of food supply chain interruptions, had resulted in a shift in shopping behaviour, such as an increase in food stockpiles at home or a change in the quantity and kind of food purchased. People began hoarding food in fear as a consequence of the epidemic, and as a result of many individuals losing their jobs and losing their money, some people were confronted with the issue of not having any food. Similarly, disabled people were harmed as a result of the lockdowns, which resulted in less assistance. People with visual impairments were unable to see when fresh goods such as fruits and vegetables were going rotten due to not being used. As a result, this study was undertaken in order to assist in the reduction of food waste and the identification of a solution that could be applied, utilizing new and current research. Artificial Intelligence (AI) holds great potential for helping decrease food waste and offers several options for reducing food waste. Artificial Intelligence (AI) using image recognition can help recognize food quality to reduce food waste.

The following is the recommended approach to help decrease food waste. "Pepper," a sociable humanoid robot developed by SoftBank Robotics, is the first of its kind in the world, capable of detecting faces and basic human emotions. Pepper connects with people and can converse with them through his touch screen and voice (Pandey, Gelin, Robot, 2018). Pepper will be programmed/trained to recognise things such as fruits and vegetables using image analysis in this project. It will also determine whether a given fruit or vegetable is ready to eat or may be stored for a few days, as well as categorise it into different baskets to prevent food waste. If a banana is ripe, it will tell the individual that it is ready to eat and how long they have before it goes bad. Similarly, if a banana is not ripe, it will notify the user that the banana will ripen in a few days and may be stored for a while. This will aid in determining food quality and preventing food waste.

The objectives for this project include:

- Collecting user data with the help of surveys to better understand the food waste problem.

- Successfully choose the best-suited dataset to work with or establish a new data set.
- Provide an adequate dataset for image analysis to Pepper (the robot).
- Train Pepper to correctly recognize the food item.
- Use Pepper to identify an item's food quality while categorizing it into separate baskets to prevent food waste.
- Have Pepper move his arm around to sort food into different baskets.

This deliverable initially delves into providing detailed information about the background of food wastage and how technology plays a role in helping to create solutions. The report discusses the existing solutions about how food wastage can be reduced along with a proposed solution to the existing food wastage problem. Additionally, the report aims to explore the problem area and find certain gaps in this domain.

Method

Data acquired expressly for the study and its research aims is referred to as primary data. Primary data is data that is collected specifically for the study and its research objectives (Hox and Boeije, 2005). The methods used differ depending on how the different researchers perform an experiment, survey, or research, but they always follow a scientific approach. Survey questionnaires are the most common method for gathering primary data in practical research since the researcher may choose the sample size and types of questions to ask. By directly asking individuals about their thoughts, behaviours, experiences, and qualities, data can be collected through survey questionnaires. In this study, each participant was asked to answer the same set of questions to avoid bias.

The ideal data collection approach for this study was to send out a survey to a number of participants above the age of 18 to collect information on people's behaviours and habits with food and food wastage. A survey is a quantitative approach in which a researcher asks a planned set of questions to a whole group, or sample, of people (Ballou and Markesich, 2009). When a researcher wants to characterise or explain characteristics of a big group or groups, survey research is particularly beneficial. The reason why surveys were chosen was because they can be easily analyzed. The online survey's results are available for analysis at any time. View real-time results allows to take action right away, build graphs for reporting and export data for additional research. Surveys may be used to gather data on a variety of topics, including personal information, attitudes, historical activities, and views. Survey research is also a reliable method of inquiry. This is because surveys are standardised in the sense that participants are asked the same questions, framed in the same way. Other approaches, such as qualitative interviewing do not provide the same level of consistency as a quantitative survey. One virtue of survey technique is its ability to deliver acc urate findings, assuming well-designed questions and questionnaires to provide reliable results.

Qualtrics, a web-based application that allows users to construct surveys and produce results without needing any prior programming experience was used to create the survey (Qualtrics, 2022). A total of 34 participants completed the survey after completing a consent form. Surveys are an excellent way to collect data since they may aid in the investigation of a group's qualities, actions, or attitudes. After examining the survey results, the software requirements were identified. Once the survey results were analysed, it was proven that food wastage is a problem. Hence the solution was created where Pepper was programmed to detect the food quality of the food item.

The results mostly were leaned to the students perspective as majority of the students had participated in the survey. This creates somewhat of a bias as it is only specific to students so having a variety of people, not only students would help to give more accurate results.

Result and Discussion

In hindsight, the data was gathered utilising the survey approach by distributing an online questionnaire to 34 individuals over the age of 18. It is necessary to discuss a survey and how this strategy may be more effective than others in order to understand how data obtained through a survey is crucial to the study. According to Müller et al. (2014), a survey is an useful data collecting method that may be used to get meaningful data from a large sample size that is well representative of the population being studied.

The results of the survey's general consensus were as follows:

1. When analysing the data, the majority of users chose "throwing away left overs" and "discarding additional food" as their definitions of food waste. Roughly 30 users (38.96%) said that throwing away leftovers is what food waste means to them, while around 27 individuals (35.06%) said that discarding extra food is what food waste means to them.

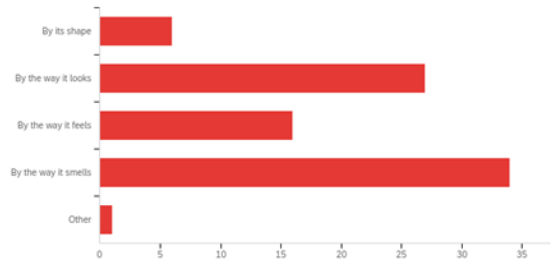

Figure 1. shows the results of what food wastage means to the users

2. Users were asked what they thought the main cause/causes of food waste in their households were, and the findings revealed that 19 people (33 percent) do not finish their meals, and 9 people (16 percent) only eat food that is as fresh as possible.

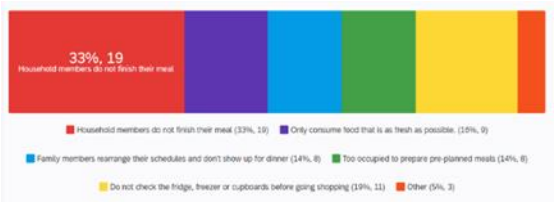

Figure 2. shows the results of the main causes of food wastage in users household

3. Users were asked what foods they think is wasted the most in their homes. When analysed, Vegetables were chosen by almost 21 individuals (42%), while bread was chosen by 12 people (24%) and Fruits were chosen by 8 people (16%). The least chosen was Fish by 1 person (2%).

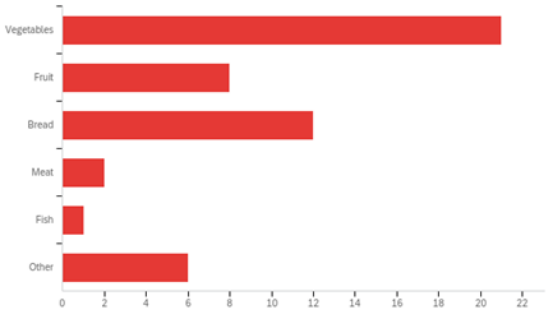

Figure 3. shows the results of most wasted food in the users household

4. When analysing the data, majority of the users stated that they can tell when the food is going bad by the way it smells as claimed by 34 people (40.48%). 27 people (32.14%) claimed that they can tell when the food is going bad by the way it looks.

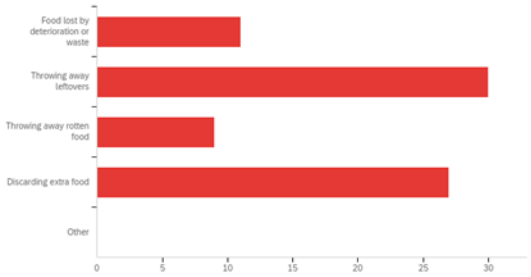

Figure 4. shows the results of how users can tell if the food is going bad

5. When users were asked which categories the bulk of the discarded fresh vegetables and salads belonged to, approximately 19 people (34.55 percent) selected leftovers after storing, while 15 people selected meal leftovers (27.27 percent).

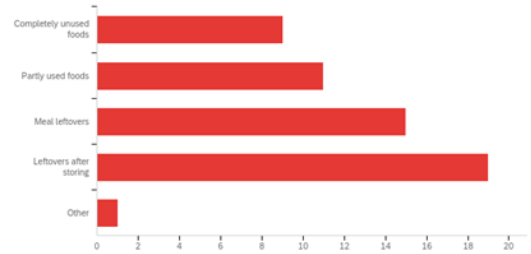

Figure 5. shows the results of which categories the discarded fresh vegetables and salads belonged to

6. When users were asked how they would feel if they had a smart solution that identifies food quality to assist minimise food waste, 25 individuals (60.98%) said they would be happy, and 14 people (34.15%) said they would be excited.

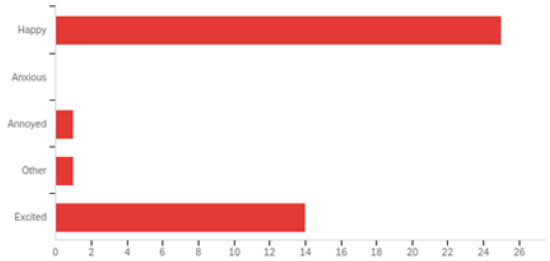

Figure 6. shows the results of how users feel about having a smart solution

7. Users were questioned about how they cope with food waste. Following the results, 23 people (40 percent) stated that they would share food with others and 14 people (24 percent) stated that they would dispose of waste.

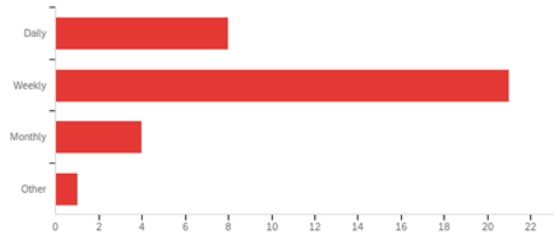

Figure 7. shows the results of how users cope with food wastage

8. Users were asked How likely they are to consume all the food they have prepared at home and after analysing the results, it showed that 15 people (44.12%) are somewhat likely to consume all the food and 11 people (32.35%) are extremely likely to consume all the food.

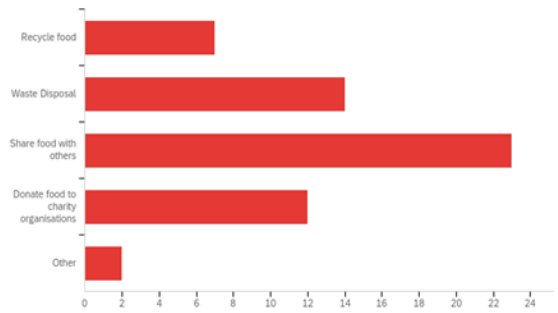

Figure 8. shows the results of how likely users are to consume all food cooked

9. When analysing the data for how often users clean their refrigerator, 17 people (50%) chose monthly and 14 people (41.18%) chose weekly.

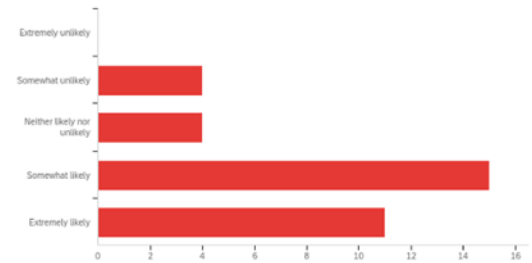

Figure 9. shows the results of how often users clean their refrigerator

10. When users were asked how frequently they purchase food, 21 individuals (61.76%) said they purchase food on a weekly basis, and 8 people (23.53%) said they purchase food daily.

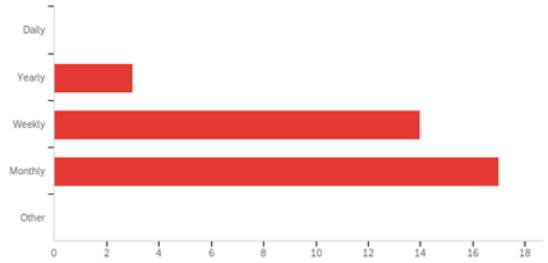

Figure 10. shows the results of how frequently users purchase food

After analysing the survey data, it was evident that the issue of food waste existed, thus this project was started to discover a solution utilising Pepper to assist minimise food waste. When combining all the results together, they show that each question correlates and leads to food wastage. These results would help draw out the requirement specifications and lead to finding a solution for the food wastage problem using Pepper.

To get more insights on the food wastage issue, interviews could take place but due to time constraints it was not possible to collect all that data. Ideally for the study to be generalised, it would require more than 100 participants so it could help a larger population but due to time constraints, the survey was only done with 36 participants.

Requirements Specifications

The first stage we did in this project is to determine the requirements after the execution of certain data collection techniques. During this phase, the client's needs are prioritized, and the choice is taken whether or not to automate the process. According to Champawat (2020), if the process can be automated, the procedure's complexity is assessed, and the possibilities of automation are laid out.

The following are the two most common types of requirements:

- Functional requirements: A system or one of its components is described in this specification. It outlines the tasks that must be completed by the system (GeeksforGeeks, 2020).
- Non-Functional requirements: describes a system's performance characteristics meaning how the system should perform. They are a collection of criteria used to evaluate a system's specific operation (GeeksforGeeks, 2020).

Analysis and Design

To develop a successful project, the project should undergo the steps of the Robotic Process Automation lifecycle which is the method of automating processes with the use of robots or software to eliminate human participation. The development is done in an agile and customizable methodology. The Robotic Process Automation (RPA) lifecycle gives structure to the automation process, allowing to check if the deployment is going as planned at each stage (Jiménez-Ramírez, et. al, 2020). It's all about employing robots to perform repetitive or difficult activities that need a high level of precision.

The stages of this life cycle model are broken down, into identifying the problem, research/analysis, design, development, testing, and implementation. The development stages are handled using an agile project methodology. Each stage has its own unique beginning and conclusion, though this varies depending on the setting.

Stage 1: Identifying the problem

In this stage, the strategists who work with RPA ensure that the business teams define a process for RPA development. The methodology that is usually followed to accomplish this is agile and customizable to contribute towards rapid improvement.

Stage 2: Research/Analysis

Within this stage, a Process Architect is responsible to analyse and identify the needs of the client. The extent of automation that is required is assessed based on the complexity of the process at hand, as a result, the usefulness of the automation is elevated through this study.

Stage 3: Design

Based on the requirement analysis, Process and Technical Architects generate Process Definition Documents (PDDs) which explain the information step by step in each process. The flow of the process can be expressed by diagrammatic representation called as a flowchart or Object Model Diagram. The Robotic process Automation tool is then chosen that will automate the process once the flowchart is completed.

Stage 4: Development

During the development process/phase, developers build automation scripts and codes using specific RPA tools (UiPath, Blue Prism, etc.) and technologies, as well as the PDD reference.

Stage 5: Testing

Post-development phase testing is carried out by the testing team, which comprises Quality Assurance (QA) as part of the standard Software development lifecycle (SDLC). The ideal way is to have a dedicated testing team to perform QA. The robot is put through its paces in a pre-production setting to ensure that it meets the requirements for automating a certain task.

Stage 6: Implementation

After all of the components have been constructed, unit testing should be performed. All of the components are tested to guarantee a seamless connection. If any flaws are detected during the diagnostic, the robot is sent back to the development and testing teams to be fixed.

Hardware and Software Requirements

The Hardware Requirements include:

- A Laptop is required to program the robot.

- A Humanoid robot- Pepper robot by Softbank robotics to carry out the main tasks which include detecting the food item, identifying the food quality and dividing it based on whether it can be kept or not.
- Fruits/ Vegetables that Pepper will be trained with- In this case, different coloured bananas would be required as each should be at a different ripeness level for training Pepper.

The software requirements include:

- Choregraphe software to program Pepper the robot.
- Microsoft office to create reports and store updates.

Implementation

Computer vision is used in robotics, self-driving cars, and facial recognition. Image recognition is at the heart of computer vision (Forsyth and Ponce, 2011). Dealing with enormous amounts of image data is common in image-related tasks. Image analysis is a computer technique that analyses images and finds things within them. AI's capacity to identify, categorize, and recognize objects is known as image recognition. Pepper, for example, can determine the food quality of a food item, which is an example of image recognition solutions. First, the system must identify the food item, then categorize the object's food quality, and finally determine whether the food item may be kept or discarded.

Pepper was programmed using Choregraphe as part of the project. Choregraphe is a multi-platform desktop software that may be used to programme a virtual or real robot (Pot, et. al, 2009). It contains a capability that allows you to utilize the image recognition database to teach Pepper to recognise objects other than the human face. The images were saved in Choregraphe's vision recognition database in this scenario. The dataset was built by capturing images using Pepper's camera, highlighting the item, and saving it in the vision recognition database (.vrd format) for image recognition and training purposes.

Demonstration

The demonstration for Pepper begins in the following order:

A human (user) interacts with Pepper by saying “Hi, Hello, Good morning, Greetings, etc” and Pepper replies back saying any of the following from “Hello, How are you today?, Hi, How are you doing?, etc”. Then the user replies back saying any of the following, “I am good, I am fine, I am sad, etc.” Pepper hears the reply and says “I am glad to hear that”. The user asks Pepper “How are you?”. Pepper then replies by saying “I am well, thank you”. The user asks Pepper to Introduce himself and Pepper replies by saying "My name is pepper. I am a humanoid robot. I live in the robotics lab in block 16, Middlesex university. Nice to meet you". Pepper is then asked about what it can do and pepper replies “I can detect objects such as fruits or vegetables with the help of image analysis. I can tell you whether a fruit or vegetable is ready to eat or can be stored for a few days. I can also notify you if anything is spoiled so you do not eat it.”

The human then asks Pepper to demonstrate it. Pepper begins the process of detecting the food item, followed by a verbal message on the food's quality. Pepper adopts a precise position in which it bends to examine the food item, determines what it is, and then declares its food quality. Pepper recognises the food item after being trained with an image dataset built by taking photos with Pepper's camera and storing them to the vision recognition database. Once Pepper recognises the food item and its food quality, it says it out loud to the user. For example, if it is a green banana, Pepper will say “This is a banana. It seems that it can be kept for a couple of days before consuming. Let it ripe.”, If the banana is yellow, Pepper will say “This is a banana. It seems that this banana is ready to be consumed. Please eat it within a day or two.”

Conclusion

Food waste reduction and prevention saves a lot of money and resources. Over the course of a decade, a 20% decrease in food waste may divert 13 million tons from landfills and on-farm losses, resulting in a net social economic benefit of $100 billion. Food waste reduction and prevention saves enormous resources across the food chain and has been a hub of innovation. Food waste prevention businesses might have a substantial influence on decreasing food insecurity and the environmental cost of the food system as they expand and scale. Additionally, the research conducted throughout the course of this deliverable proves that food wastage is an existing problem.

Through the research it has been identified that this problem area does exist and requires a solution therefore the proposed solution that will be carried out will aid towards reducing food wastage. The detailed literature review has helped in gaining insights about the existing solutions and how it has helped in reducing food wastage. Additionally, it aids in identifying where the gap lies and how the gap can be bridged with the proposed solution. The solution proposed will help in detecting the food quality of the food item that notifies users about how long the food item can be kept further or how quickly it needs to be consumed so it does not go to waste.

When the project was shown to others for evaluation, they were impressed with the solution and the interaction with Pepper. Pepper's ability to recognise food items and state their quality was commended by majority of the evaluators. Many assessors were especially astonished by the way Pepper interacted and conversed with them, stating that it seemed more like speaking with a human than a robot.

Overall, the project was a success because Pepper was able to recognise the food item and indicate its quality; nevertheless, the device had several limitations. The following were some of limitations faced:

- Training Pepper with real bananas led to a lot of food wastage and caused the dataset to be smaller as less bananas were used for training as the goal of the project was to reduce food wastage.
- When it came to image recognition training, the environment had a role. When training, the light intensity had an impact on the findings; if the light was dim or different from the images in the dataset, Pepper would struggle to distinguish the banana. Sound, on the other hand, was a concern as well.

Pepper cannot hear, listen, or identify the food item or its quality if there are a lot of people in the room. This makes it difficult for Pepper to concentrate, and as a result, he performs poorly.

- Due to accuracy, the location in which Pepper recognises the food item might pose certain complications. Pepper will be unable to recognise the food item if it is not in the proper posture.
- Another constraint was time. Pepper was trained with a smaller dataset due to lack of time, as creating a large image dataset was quite tedious. Due to time constraints, just one fruit was chosen to show; however, if more time had been available, Pepper could have been trained to recognise a variety of fruits and vegetables as well as their food quality.

This research might be expanded to assist prevent food waste on a bigger scale, such as allowing Pepper to recognise fruit items at a supermarket. This can assist staff in determining how to sell products that are about to rot. Food items that are about to expire might be offered at a cheaper price to prevent food waste.

Pepper can also help people with vision impairments who can't tell whether a fruit or vegetable is rotting since they can't see it. Pepper can identify when a food item is about to expire or rot using its camera and image processing capabilities, alerting the user to consume the item to prevent food waste.

In the future, the project could be improved by using OpenCV or Tensorflow to train Pepper using an existing image dataset of fruits and vegetables rather than training with real bananas, which would result in additional food waste. With the help of using an image analysis software like Tensorfloe or OpenCV, Pepper would be able to detect the results more accurately as it would be trained with a large dataset with multiple images and images taken from different angles and views. An API can also be used where when Pepper is trying to detect the food item, with the help of the API it can detect what the item is and then state the food quality accordingly. Using an API, Pepper can then be programmed quickly with a dataset of other fruits and vegetables that will help Pepper detect the food items and food quality faster.

This solution can also be implemented in agriculture use where Pepper can be used to detect the food quality in terms of ripeness and can take them off from the trees and plants. If the fruit or vegetable is ripe, it should take off the fruit/ vegetable. If not, It should leave it their and must inform how many are not ripe yet.

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