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GROUP ASSIGNMENT

Topic: Smart Food Waste Management System

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Background of Smart Food Waste Management System

Food wastage is a quickly escalating global issue, which causes pollution in the environment, money loss, and resource waste. The Food and Agriculture Organization estimates that around a third of food production globally to waste. It is not just food wastage occurring after production and before getting delivered at stores but being lost during sales and consumption as well, most predominantly at the consumer level or homes. Then food waste has generated some serious environmental issues, such as greenhouse gas emissions, natural resource depletion, and unnecessary landfill. Therefore, food management effectively for homes and businesses is important to prevent food waste, save money, and promote sustainability.

For modern families, they are likely to buy a lot of food, but it is not easy to maintain records of the food's expiration dates, and this leads to food waste. It also happens in restaurants and supermarkets, where it is difficult for them to effectively track inventory of food. Traditional food waste management need manual tracking, which is time-consuming and easy to have human error. Thus, restaurants and supply chains of food have been struck by financial losses due to expired products, while households discard large amounts of uneaten food due to poor planning or lack of memory.

The Smart Food Waste Management System is designed to integrate IoT and cloud computing to optimize food storage, reduce wastage, and provide real-time data about the consumption of food. By employing technologies such as IoT sensors and cloud-based data processing, this system enables users to track food inventory, receive expiration alerts, and visualize information for better food management. This system not only helps in reducing food waste at the domestic level but also provides a scalable solution to food suppliers and commercial food establishments. Utilizing automation and data analytics, the Smart Food Waste Management System ensures food is eaten before it spoils, reducing wastage and promoting sustainability. The goal is to reduce food wastage while promoting an efficient, technology-driven way of eating food.

History of Smart Food Waste Management System

Most of the food waste management today relies on manual tracking methods such as handwritten inventory lists, physical tags, and calendars that note dates of expiration. While those methods are simple, they are prone to error and are inefficient, especially when the number of households or corporations rises [1]. After discovering the limitations of manual methods, the food industry began implementing technological ways that automate tracking and managing food waste. Early, the Point of Sale (POS) systems have been a solution in reducing food wastage [2]. They helped track inventory but were still lacking real-time monitoring of food conditions and predictive analysis. After that, the introduction of smart appliances marked a milestone in the history of food waste management. By using the cameras and sensors that are built into the smart refrigerators, users can remotely check their food inventory via mobile apps. Despite this innovation, the smart systems were limited to only providing basic visual data, a lack of advanced analysis or active alerting functionalities.

Thankfully, technology has ushered in a new era of food waste management, which is often in the form of software paired with hardware to suit the demands of the kitchen environment. The evolution of cloud computing, Internet of Things (IoT), and Artificial Intelligence (AI) technologies brought about a major transformation. The cloud platforms allowed centralised storage of food waste data, making it possible for comprehensive dashboards and visual analysis to support better decision-making [3]. The application of Internet of Things (IoT) sensors in the kitchen have further increased real-time tracking of food storage conditions, allowing companies to identify early spoilage and prevent waste before it happens [3]. The artificial intelligence (AI) and machine learning (ML) models are utilised to predict demand to avoid overproduction and waste and provide actionable insights for kitchen operators [3]. Additionally, image recognition technologies were also started being utilised, where the cameras could identify and classify discarded food waste, offering even more detailed waste analytics [3].

Today, smart food management systems are increasingly adopting integrated solutions by combining various technologies. These systems not only automatically track foods, but they also predict expiration times, send timely alerts, and offer actionable insights to prevent wastage of food. The Smart Food Waste Management System enhances these inventions to create a more intelligent, responsive, and sustainable food management ecosystem.

Future Trend of Smart Food Waste Management System

According to estimates and predictions by United Nation (UN), there was almost one-third of the food generated was wasted [4]. This brings some significant negative impacts to the economy of nations, leads to depletion and reduced of resources as well as significant negative consequences to the environment through the releasing of greenhouse gases such as carbon dioxide gas and methane gas during decomposition of food waste [5]. Methane gas is the one of and more significant causes of global warming than carbon dioxide gas [5]. Hence, to reduce the deterioration of environmental issues, more and more nations place more concerns in food waste management by investing in food waste management projects to try to mitigate the effects of food waste which is a critical global issue.

The future of food waste management can be shaped by the advancements in Internet of things (IoT), artificial intelligence (AI), data analytics, distributed computing and cloud services offered by companies such as Amazon Web Services (AWS) and Microsoft Azure. In the future, we may anticipate a increasing amount of wide range interconnected IoT devices and sensors deployed in our homes especially in kitchens that exchange data with each other and AWS IoT Core will act as the central hub to collect information from all IoT devices for real-time monitoring of conditions food stored in refrigerators. AWS Lambda may be used to trigger notification to inform user that a particular food item in the refrigerators is about to expire. Amazon QuickSight may be used to provide users with insights such as how much food they have wasted and what type of food they most probably will waste and then suggest alternatives to the food that is wasted most probably to be purchased next time.

Besides that, the usage of image processing was also the future trend of food waste management. It can be anticipated that there will be a refrigerator equipped with many IoT sensors specifically IoT Camera in its each compartment to capture the images of food items in the refrigerator compartments and identify the names of the food items and track the expiration dates and update the quantities of the food items in a dashboard that can be displayed to user. This can provide information to the user on what food items can be found in the refrigerator and their quantities. This allows users to decide what ingredients they can use to prepare meals.

Problem Statement (Food Waste)

Across the world, food waste is a critical problem. Poor inventory management at the household level, combined with a relative lack of sophistication regarding food expiration, contributes a large share. Research shows that 30 to 40 percent of food in homes goes to waste, often due to a lack of recollection towards the perishables or misjudging the shelf life. Existing solutions such as manual tracking applications or simple fridge sensors do not suffice; they require users to enter data regarding food into the system, often fail to predict expiration dates accurately, and do not provide timely alerts. In this regard, we plan to develop an intelligent food waste management system integrated with AI and IoT that autonomously tracks food items, predicts spoilage, and curbs waste.

The system will eliminate manual entry of food items by using AI driven cameras to recognize food using AWS Rekognition or a custom model. Real time inventory tracking will be done using IoT Camera and temperature sensors, DynamoDB, and active updating of quantities as items are added and removed. The system will monitor the types of food and known expiration data and will send proactive notifications via AWS SNS to remind users before spoilage. A dashboard which is implemented using Amazon QuickSight is further planned to visualize food consumption helping users make optimal spending decisions.

Still, many important challenges such as the real-time response between the food recognition modules and database containing IoT devices, Lambda functions, generic models (and their corresponding abilities to manage diverse food item packaging), as well as general scalability issues like latency during multiple fridge access interactions, remain unsolved. If solved, household food waste could decrease on average by 20 to 30 percent, helping decrease overall grocery spending while enabling users to adopt smarter food management habits.
Less repetitive in nature, smarter systems aimed at food management enable the adoption of sustainable lifestyle choices.

The solution's architecture comprises AWS services like IoT Core, S3, Lambda, Rekognition, DynamoDB, SNS, and QuickSight, hence creating an automated, self-scaling, and user-friendly system to meet the users' needs while minimizing and efficiently managing waste.

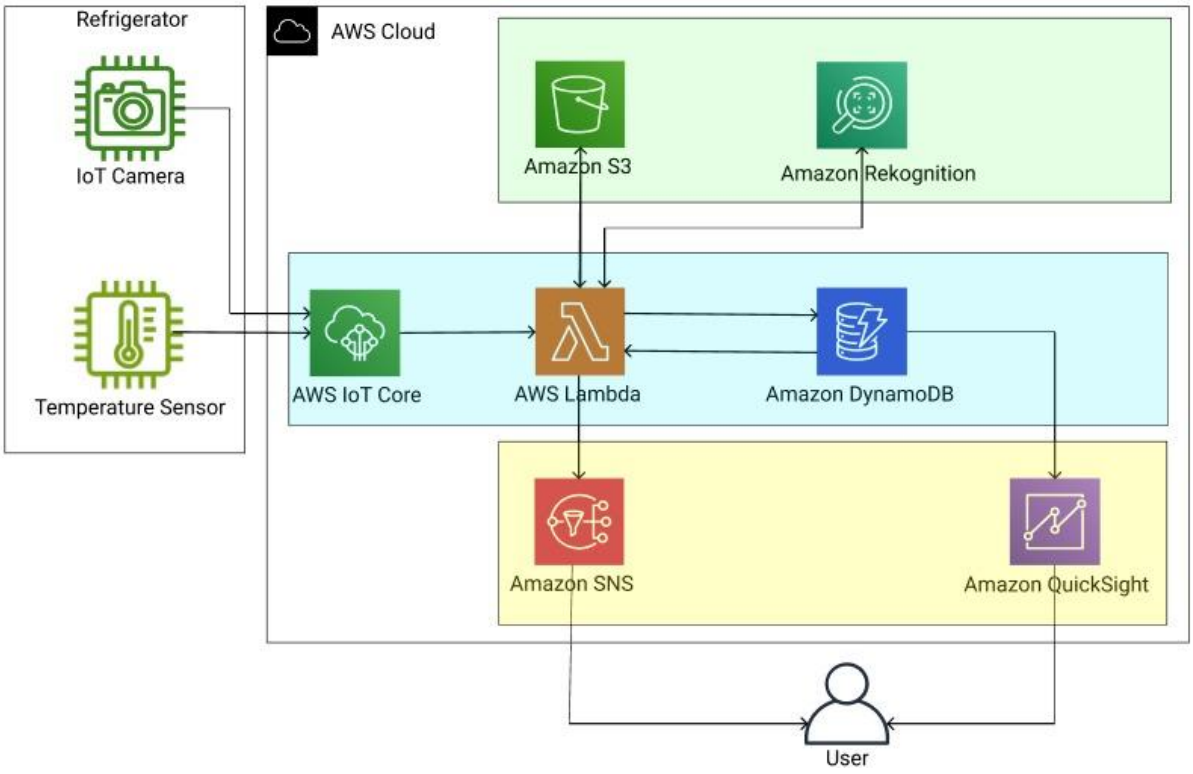
Objectives and Proposed Solutions

The main objectives of our project are:

- To develop smart food waste management system for a refrigerator to help households in managing food waste
- To address the issue of lack of real-time information
- To address the issue of limited storage and processing power of IoT devices and sensors

In our project, we aim to develop a smart food waste management system by utilising AWS as a platform. The food waste management system is designed for household's refrigerator or any other party who owns refrigerators to manage the food items and ingredients in the refrigerator to reduce food wastage. A dashboard with all food items and ingredients found in the refrigerator with expiration dates and quantities will be displayed to users. A food item in the refrigerator will be captured by IoT sensors and recognised and classified by a pretrained model, and the expiration date of the food item will be predicted and stored, and its quantity will be updated in the dashboard. There is also a temperature sensor which is responsible for monitoring the temperature in the refrigerator. The system will send notifications to the user's email to inform the user when a food item is near to its expiration date. It may also provide some useful insights to users such as how much food they are wasting and what alternatives for a food item to be purchased next time if it is found that the food item is being wasted most of the time. The use of IoT devices allows the exchange and display of real-time information while the use of AWS addresses the issue of limited storage and processing power of IoT devices and sensors as AWS which is one of cloud service providers provide unlimited storage and processing power and user of AWS just have to pay cost according to usage.

Architecture Diagram of Proposed Solution



The diagram above is the architecture diagram of our smart food waste management system using Amazon cloud platform. There are a total of 7 Amazon platform components in our architecture diagram which include AWS IoT Core, AWS Lambda, Amazon SNS, Amazon DynamoDB, Amazon Rekognition, Amazon S3, Amazon Quicksight. AWS and each of the components function in the platform were briefly explained.

Amazon Web Services (AWS)

Amazon Web Services (AWS) is a popular and powerful cloud platform created by Amazon. It gives individuals and businesses access to a wide range of services like computing power, data storage, databases, analytics, networking, machine learning, and IoT tools all through the internet. With AWS, systems can build, run, and grow applications without needing to buy or maintain their own physical servers or hardware.

In the context of the Smart Food Waste Management System, AWS provides all the necessary tools to:

- Connect and manage IoT devices (AWS IoT Core)
- Process and analyze data in real-time (AWS Lambda, Amazon Rekognition)
- Store structured and unstructured data (Amazon S3 and DynamoDB)
- Notify users and visualize results (AWS SNS and QuickSight)
- All while ensuring scalability, reliability, security, and cost-efficiency

By using AWS, the system benefits from seamless integration, high availability, and the ability to quickly adapt or expand according to user needs.

1. **AWS IoT Core**

AWS IoT Core is managed by the cloud platform that connects devices such as an IoT camera, or a temperature sensor to securely and reliably communicate with applications and devices in the cloud. It is used in our food waste management system where AWS IoT Core serves as a central point to collect, process, and take action on data collected from smart refrigerators. With the IoT camera and the temperature sensor connected to AWS IoT Core, the system can monitor food conditions as they happen to mitigate spoilage and waste.

Inside the refrigerator, the IoT camera was installed and will capture the images at regular intervals, such as putting in new food or removing existing food from the refrigerator. These images will be transmitted to AWS IoT Core for further processing. For example, we will identify those types of food or detect the signs of spoilage by using the Amazon Rekognition. The system is able to automatically alert the users when found that certain food items are nearing spoilage. This will help the users to take timely action.

At the same time, the temperature sensor will keep monitoring the internal temperature of the refrigerator. It will send the temperature records time by time to AWS IoT Core at specific intervals. If the temperature is higher than the safe zone, AWS IoT Core will trigger a notification or a corrective action immediately through services like AWS Lambda and AWS SNS. Monitoring temperature seems like the most important part of the system because the food spoilage will accelerate if improper cooling. This system can further contribute to waste reduction by promising the food is kept in optimal condition in the refrigerator.

2. **AWS Lambda**

AWS Lambda is a serverless computing service which run code in response to the event. It is used to trigger some services by using Lambda function. In our system, we use Lambda to respond to the upload of image onto the Amazon S3. For example, when there is an image uploaded onto Amazon S3 bucket, it will trigger the AWS Lambda. Then, Lambda initiates the Amazon Rekognition to use trained model to recognize the uploaded image. By doing so, the system can detect the type of food in the uploaded image without human involvement, allowing for real-time image processing and automation of complex workflows.

In addition to image recognition, AWS Lambda plays a crucial role in retrieving related data and notifying users. After detecting the food type, the same Lambda function fetches the corresponding shelf-life information from DynamoDB. It then uses AWS SNS to publish the

results via email to the intended recipients. This automation enhances communication efficiency by ensuring users are promptly informed of the analysis outcomes. Overall, AWS Lambda streamlines the end-to-end process, reducing operational costs, increasing system responsiveness, and enabling seamless integration across AWS services.

3. Amazon S3

Amazon S3 (Simple Storage Service) is a scalable, secure, and reliable cloud-based object storage service used to store and manage any amount of data, including images, documents, and videos. In our smart food waste management system, Amazon S3 plays a key role in storing both the images used for training the Amazon Rekognition model and the images uploaded by users for analysis. During the training phase, labeled images are organized into specific folders in Amazon S3, which Amazon Rekognition accesses to learn and build a custom model capable of recognizing different types of food.

Apart from training, another folder of the Amazon S3 bucket is used to store real-time food images uploaded by users. Whenever a new image is uploaded to this location, Amazon S3 triggers an AWS Lambda function through event notifications. This function then starts the Amazon Rekognition model to analyze the image, checks DynamoDB for shelf-life information, and sends the results to the user via AWS SNS. This seamless integration makes Amazon S3 the central storage layer that enables automation and coordination between multiple AWS services in the system.

4. Amazon Rekognition

Amazon Rekognition is a cloud-based image and video analysis service offered by AWS which uses deep learning techniques for high accuracy [6]. Amazon Rekognition requires no machine learning expertise, and it offers a wide range of key usages such as text detection and facial analysis [6]. Amazon Rekognition Custom Labels makes it possible to train a model to recognise and identify objects that are specific to user's business needs [7]. In our project, we are using Amazon Rekognition Custom labels to train a custom model to recognise and identify a food item when given an input image. A dataset containing raw images of food items which are obtained online from Kaggle.com is stored in Amazon S3 and is used train the custom model. When AWS Lambda detects an input image being uploaded, it will trigger the Amazon Rekognition Custom Labels to use the custom model to classify and identify the input image. Then, the expiration date of the food item stored in Amazon DynamoDB will be retrieved and AWS SNS will send the expiration date along with the name of the food item as results of recognition to user's email. Finally, Amazon QuickSight will update the inventory

data which includes the food item and its quantity in a dashboard.

5. **Amazon DynamoDB**

AWS offers one of the storage services known as Amazon DynamoDB which is a serverless, fully managed NoSQL database with high performance [8]. It offers many benefits which include it handles most of the things such as setup, configurations, hardware provisioning, backups, security and more for customers which makes it high scalable, have high performance and can meet production workloads when a user starts to use it [8]. Amazon DynamoDB is used in our project to store the food items, names of food items, their entry times and expiration dates. When a food item is placed in the refrigerator, the image will be recognised and identified and its information which includes the name of the food item, entry time and expiration date will be stored in Amazon DynamoDB. The entry time will start to count down and when the entry time near expiration time, AWS SNS will be triggered by AWS Lambda to send notification to inform user that the food item is about to expire.

6. **AWS SNS (Simple Notification Service)**

AWS SNS provides an automated alert system that notifies users when food items approach expiration. A Lambda function runs daily to check food expiration dates stored in DynamoDB. If an item is near to its expiration for example within 2-3 days, AWS SNS will send a push notification via email, SMS, or mobile app alert. This proactive alert system ensures that users are aware of the food that almost expired in time to reduce food spoilage and waste. Additionally, AWS SNS can be configured to send category-based alerts, such as prioritizing high-risk perishable foods like dairy and fresh produce.

7. **Amazon QuickSight**

Amazon QuickSight enables real-time data visualization for food inventory. By connecting with DynamoDB, it allows users to track their stored food, monitor expiration trends, and analyze consumption habits. Amazon QuickSight can generate detailed reports on food wastage, highlight frequently discarded items, and offer insights into optimizing food purchases. Users can customize dashboards to display food categories, expiration timeframes, and trends over different periods. This visualization ensures better decision-making and promotes waste reduction efforts.

Overall System Flow

1. Data Collection from IoT Devices

Inside the refrigerator, two types of IoT devices which are IoT camera and temperature sensor that constantly monitor food conditions:

- The IoT camera captures images whenever food is added or removed.
- The temperature sensor regularly logs the internal refrigerator temperature.

These both devices transmit their data to AWS IoT Core which act as the centralized gateway to securely connect and manage IoT devices in the cloud.

2. Data Routing and Processing via AWS Lambda

When new food images are received, or temperature thresholds are breached:

- AWS IoT Core routes the data to AWS Lambda.
- For new images, Lambda stores them in Amazon S3, which acts as the central storage.
- When there is new image in Amazon S3, Lambda trigger the Amazon Rekognition to recognize the added food, then retrieve shelf life of the food and trigger SNS to display the food information to the user.
- For temperature violations, Lambda can trigger an immediate alert.

3. Food Recognition with Amazon Rekognition

Once an image is uploaded to Amazon S3:

- AWS Lambda triggers Amazon Rekognition Custom Labels, which uses a pre-trained deep learning model to identify the food item in the image.
- The food item type is then returned to Lambda for further action.

4. Shelf-Life Tracking with DynamoDB

After identifying the food item:

- AWS Lambda queries Amazon DynamoDB to retrieve information such as the expected shelf life and current inventory status.
- DynamoDB stores data including food names, shelf life, and quantities.

5. Notifications via AWS SNS

If any food item is nearing its expiration:

- AWS Lambda triggers AWS Simple Notification Service (SNS).
- AWS SNS sends automated alerts (via email) to inform the user of items that are close to expiring.

This real-time alerting system helps users take timely action, reducing food spoilage.

6. Visualization and Analytics with Amazon QuickSight

All data stored in DynamoDB is also visualized using Amazon QuickSight:

- QuickSight generates real-time dashboards showing food inventory status, consumption

trends, and waste patterns.

- Users can monitor food categories, expiration timelines, and identify commonly wasted items to make informed purchasing decisions.

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