FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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The Patent Rules, 2003

7

COMPLETE SPECIFICATION

(See section 10 and rule 13)

TITLE OF THE INVENTION

14 “AN IOT-BASED REFRIGERATOR MONITORING SYSTEM FOR REAL-TIME GROCERY TRACKING AND FOOD WASTE REDUCTION”

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The following specification particularly describes the nature of the invention and the manner in which it is performed:

FIELD OF INVENTION:

The present invention relates to the field of smart home appliances and Internet of Things (IoT) technology. Furthermore, the invention can be easily integrated into existing refrigerators with minimal cost, and it also offers the potential for further development to learn user habits and accurately predict when specific items need to be replenished based on consumption rates.

BACKGROUND OF THE INVENTION

In recent years, the integration of smart technologies into everyday household appliances has gained significant attention. Among these, smart refrigerators have emerged as a popular innovation aimed at enhancing the convenience and efficiency of food storage and management. With increasing concerns about food wastage and the need for better grocery management, there is a growing demand for systems that can provide real-time tracking of food items inside refrigerators. Such systems would help users keep track of their grocery inventory, ensure timely consumption of perishable items, and reduce unnecessary food waste.

The importance of such technology is underscored by statistics indicating that a substantial amount of food waste occurs at the household level, primarily due to improper tracking of food items and expiration dates. In addition, the convenience of being able to remotely monitor the contents of a refrigerator can significantly improve the shopping experience, making it easier for consumers to manage their grocery needs and avoid running out of essential items.

Several prior art solutions have attempted to address these issues. One common approach involves the use of RFID (Radio Frequency

Identification) systems to monitor the goods inside a refrigerator. These systems rely on RFID tags attached to the items, allowing for automated tracking of inventory. Another approach involves high-end refrigerators equipped with built-in cameras and sensors capable of detecting and analyzing the contents through image or video feeds. These refrigerators provide users with insights into the quantity and status of the items stored, including expiration dates and remaining shelf life.

However, these prior art solutions have notable shortcomings. RFID-based systems require each item to be tagged with an RFID chip, which may not be feasible for all types of groceries, particularly fresh produce and other perishable items. Additionally, RFID tags may not be readily available or affordable, especially in developing regions like India. The need for RFID tagging also adds to the overall cost of groceries, making this solution less accessible to the average consumer. On the other hand, refrigerators with built-in cameras and sensors tend to be expensive, making them a less attractive option for cost-conscious consumers. Furthermore, these systems often lack the sophistication required to accurately detect and interpret the condition and expiration dates of various items.

Accordingly, there remains a need in the prior art to provide an IoT-based refrigerator monitoring system that uses advanced image recognition and natural language processing (NLP) technologies. This system captures images of the contents of refrigerator drawers, processes these images using a custom AI architecture to identify and label different objects, and provides real-time information about the count and condition of stored items. By eliminating the need for RFID tags and offering a solution that can be installed in any existing refrigerator, this invention offers a cost-effective and

accessible means of improving grocery management. Additionally, the system's ability to detect expiration dates and learn user consumption patterns further enhances its utility, making it an invaluable tool for reducing food waste and optimizing grocery shopping, and therefore overcome the aforesaid problem and shortcomings.

SUMMARY OF THE INVENTION:

In the view of the foregoing disadvantages inherent in the known types of conventional system, now present in the prior art, the present invention provides an IoT-based refrigerator monitoring system for real-time grocery tracking and food waste reduction, which has all the advantages of the prior art and none of the disadvantages.

In an aspect of the present invention, provides an IoT-based refrigerator monitoring system that integrates a motion detection sensor and a light detection sensor, which collectively trigger an ESP32-CAM microcontroller to capture images of the refrigerator's contents. These images are stored on an SD card and subsequently sent to a server via a POST request. The server utilizes a deep learning-based object detection model, specifically a custom-trained YOLO (You Only Look Once) model, to accurately identify and count the items in the image. The detected object information, including the count and location, is then stored in a database for real-time inventory tracking.

Further enhancing the system's capabilities, a subset of images containing perishable items is processed by a second custom-trained YOLO model to detect and extract manufacturing labels. An Optical Character Recognition (OCR) model (PaddleOCR) converts the text on these labels into digital string format, which is then analyzed by a fine-tuned BERT (Bidirectional

Encoder Representations from Transformers) model to extract critical information such as expiry or use-by dates. This processed data is stored in an SQLite3 database and is accessible through a user application, which uses a GET request to display the current inventory, including item counts and expiry dates. Users can also set minimum quantity thresholds for specific items, prompting notifications for restocking when quantities fall below these levels. The system's integration with FastAPI ensures efficient API management for seamless user interaction and data retrieval.

In this respect, before explaining at least one object of the invention in detail, it is to be understood that the invention is not limited in its application to the details of set of rules and to the arrangements of the various models set forth in the following description or illustrated in the drawings. The invention is capable of other objects and of being practiced and carried out in various ways, according to the need of that industry. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

These together with other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be made to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the

following detailed description thereof. Such description makes reference to the annexed drawings wherein:

Figure 1 illustrates Complete operational sequence of the frontend, in accordance with an embodiment of the present invention;

Figure 2 illustrates Comprehensive system architecture from hardware module to the data processing flow in the backend, in accordance with an embodiment of the present invention;

Figure 3 illustrates schematic diagram illustrating the electrical connections between the ESP32-CAM microcontroller and a Future Technology Devices International (FTDI) programmer for the purpose of uploading firmware, in accordance with an embodiment of the present invention;

Figure 4 illustrates schematic diagram showing the electrical connections for the ESP32-CAM microcontroller with the Passive Infrared (PIR) motion sensor and the Light Dependent Resistor (LDR) light sensor in its operational configuration, in accordance with an embodiment of the present invention;

Figure 5 illustrates Line graph for mean average precision (mAP) of Model 1 – YOLOv8x, in accordance with an embodiment of the present invention;

Figure 6 illustrates Line graph for mean average precision (mAP) of model 2 – YOLOv8s, in accordance with an embodiment of the present invention;

Figure 7 illustrates Line chart for model accuracy of BERT model, in accordance with an embodiment of the present invention;.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description, reference is made to the accompanying drawings which form a part thereof, and which is shown by way of illustration specific embodiments in which the invention may be practiced. These

embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that the embodiments may be combined, or that other embodiments may be utilized, and that structural and logical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims and their equivalents.

The present invention provides a method for mitigating cognitive impairment from sleep deprivation via glutamate regulation, as shown in Figures 1-2.

Best Mode & Enablement for the present invention for enabling a person ordinarily skilled in the art

The present invention is an IoT-based refrigerator monitoring system designed to enhance grocery tracking and reduce food wastage through real-time monitoring of refrigerator contents. The system employs a combination of sensors, microcontrollers, deep learning models, and natural language processing (NLP) techniques to achieve its objectives.

The system is equipped with a motion detection sensor and a light detection sensor installed inside the refrigerator. These sensors are configured to detect when the refrigerator door is opened. When both sensors are activated simultaneously (indicating the presence of both motion and light), they send a high signal to the ESP32-CAM microcontroller. This microcontroller, upon receiving the high signal, captures an image of the refrigerator's contents. The captured image is then stored locally on an SD card attached to the microcontroller. After storing the image, the system initiates a POST request, sending the image to a remote server for further processing.

Upon receiving the image, the server processes it using a deep vision model for object detection known as YOLO (You Only Look Once). This YOLO model is custom-trained with data specifically tailored to recognize common grocery items. The model analyzes the image and identifies the different objects present, pinpointing their locations within the image. The detected items are then counted, and the data is recorded in a structured format within a database for easy access and analysis.

Hardware Module Embodiment:

The IoT Hardware Module is a compact, low-cost unit designed to retrofit conventional refrigerators. Its core is the ESP32-CAM microcontroller, chosen for its dual-core processor, Wi-Fi, and camera slot. An OV2640 camera provides high-resolution images for vision tasks.

A key feature is the dual-sensor trigger mechanism combining a PIR motion sensor (e.g., HC-SR501) with an LDR. The system captures images only when both motion is detected and ambient light sharply increases, minimizing false positives, power use, and server load.

Programming connections (FIG. 3) use an FTDI programmer with 5V to Vcc, GPIO0 grounded for flashing, and TX/RX cross-wired. Operational wiring (FIG. 3) links PIR and LDR outputs to ESP32-CAM GPIO pins (e.g., GPIO 13) with a 5V supply. Images are first stored on a MicroSD card, then sent to the server via HTTP POST.

Table 1 summarizes the preferred hardware components.

Table 1: Hardware components specification

Sno.	Component	Model/Type	Function
1	Microcontroller	Espressif ESP-32 CAM	Image capture, sensor data processing, Wi-Fi communication

2	Camera Module	OV2640	Captures high-resolution images of refrigerator interior
3	Motion Sensor	HC-SR501 PIR	Detects motion to identify user presence
4	Light Sensor	LDR	Detects ambient light to confirm door is open
5	Storage	Micro SD card	Temporary local storage for captured images before transmission
6	Programmer	FTDI USB to TTL Adapter	Interface for uploading firmware to the microcontroller

Backend Server and AI Pipeline:

The Backend Server manages data flow, built on FastAPI with Uvicorn for speed and simplicity. Its main role is running the multi-stage AI Pipeline (FIG. 2), which uses a modular, hierarchical process. Instead of one large model, it chains specialized models—starting with broad analysis and narrowing to faster, focused tasks.

Stage 1: Item Detection

An incoming image is processed by a YOLOv8x object detector trained on ~21k images and 90k annotations across 28 refrigerator item classes. It distinguishes both type and quality (e.g., *apple* vs *apple_rotten*). The model outputs labeled bounding boxes, which are aggregated into counts stored in the database.

Stage 2: Label Localization

For items that usually carry labels (e.g., milk, ketchup), the bounding box region is cropped and sent to a lightweight YOLOv8s model. Trained on ~600 images, this model detects only labels, making it more efficient than scanning the full image.

Stage 3: OCR

The label region is passed to PaddleOCR, which converts printed characters into raw text with high accuracy.

Stage 4: Expiry Extraction

The text, often cluttered with branding or nutrition info, is parsed by a fine-tuned BERT model trained for date recognition. Annotated OCR data was used for training, enabling it to extract expiry dates across varied formats (e.g., “Best by,” “EXP”). The final structured date is stored with the item record.

Frontend User Application

The Frontend User Application provides the system’s interface, developed for Android using Kotlin and Jetpack Compose for a modern, reactive UI. Its architecture (FIG. 1) follows the MVVM pattern: Models handle data and logic, Views are Jetpack Composables, and ViewModels bridge them. This separation improves modularity and maintainability.

Network calls to the FastAPI backend are handled with Retrofit, while LiveData and ViewModel ensure the UI updates automatically with new data. This delivers a smooth, real-time user experience.

Key features include a Home Screen (FIG. 10) showing all refrigerator items with quantities, images, and expiry dates. Users can set minimum stock thresholds; when levels drop, the app triggers device notifications. A Shopping Cart feature can also auto-add low-stock items to a grocery list, simplifying restocking.

In cases where the identified items are perishable goods, a further layer of processing is initiated. The regions of the image corresponding to these perishable items are cropped and processed using a second, specialized YOLO model. This model focuses on detecting manufacturing labels on the

items, which may contain vital information such as production and expiry dates. Once the labels are detected, the cropped image segments are processed using an Optical Character Recognition (OCR) model, specifically the PaddleOCR, to convert the text on the labels into a machine-readable string format.

The extracted text strings, which may contain information like expiry dates, are then analyzed using a fine-tuned BERT (Bidirectional Encoder Representations from Transformers) model. This NLP model is adept at extracting and identifying key information such as expiry or "use by" dates from the text. Once identified, this information is stored in the database alongside the item counts, providing a comprehensive view of the refrigerator's inventory, including the condition and shelf life of perishable items.

The system includes a user-friendly application that allows users to interact with the data. When the application is opened or refreshed, it sends a GET request to retrieve the latest data from the database. The application displays a detailed inventory of all items present in the refrigerator, along with their respective counts and, if applicable, their expiry dates. Users have the ability to set minimum quantity thresholds for different items. If the quantity of any item falls below the set threshold, the system automatically sends a notification to the user, prompting them to restock

For managing the inventory data, the system utilizes SQLite3, a lightweight and efficient database management system. The interaction between the application and the database is facilitated using FastAPI, a modern, fast web framework that enables seamless API integration.

This invention introduces several technical advancements, including the use of object detection models to accurately identify and count refrigerator items, the ability to detect and interpret labels on objects for extracting expiry dates, and an efficient IoT-based system for capturing images based on sensor input. These features collectively contribute to a robust, cost-effective solution for real-time grocery tracking and effective management of food supplies, ultimately reducing food wastage and improving user convenience.

Performance and Results:

Model Comparison:

The efficacy of the AI pipeline is supported by rigorous training and validation. Before training, all images in the datasets undergo a standardized preprocessing and augmentation pipeline. This includes auto-orientation to correct for camera rotation, resizing all images to a uniform dimension of 640×640 pixels, and maintaining a consistent ratio of annotated to non-annotated images. To enhance model robustness and prevent overfitting, extensive data augmentation is applied. This includes geometric transformations (rotation, flipping, shear, zoom, cropping) and photometric distortions (adjustments to brightness, noise levels, saturation, hue, and blur).

The performance of each model in the pipeline was evaluated using standard industry metrics on a held-out validation set. The results demonstrate a high degree of accuracy and reliability. A consolidated summary of the training parameters and performance metrics for each model is presented in Table 2.

Table 2: Model result comparison and overview

Parameter	Model 1: Item Detection	Model 2: Label Detection	Model 3: Date Extraction
Model Architecture	YOLOv8x	YOLOv8s	Fine-Tuned BERT
Task	Detect 28 food classes	Detect 1 "label" class	Extract expiry date from text
Dataset Size	~21,000 images, ~90k annotations	>600 images	Custom Excel Sheet
Training Epochs	~110-120	~300	~35
Model Parameters	~68 Million	~11 Million	~110 Million
Key Metric	mAP (mean Avg. Precision)	mAP (mean Avg. Precision)	Validation Accuracy
Performance	~90% mAP (**FIG. 5**)	>98% mAP (**FIG. 6**)	~97% Accuracy (**FIG. 7**)

It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-discussed embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description.

The benefits and advantages which may be provided by the present invention have been described above with regard to specific embodiments. These benefits and advantages, and any elements or limitations that may cause them to occur or to become more pronounced are not to be construed as critical, required, or essential features of any or all of the embodiments.

While the present invention has been described with reference to particular embodiments, it should be understood that the embodiments are illustrative and that the scope of the invention is not limited to these embodiments. Many variations, modifications, additions and improvements to the

embodiments described above are possible. It is contemplated that these variations, modifications, additions and improvements fall within the scope of the invention.

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We Claim:

1. An IoT-based refrigerator monitoring system for real-time grocery tracking and food waste reduction comprising:

a microcontroller comprising an ESP32-CAM configured for image capture, sensor signal processing, and Wi-Fi communication;

a camera module (OV2640) operatively connected to the microcontroller for capturing high-resolution images of the refrigerator interior;

a motion sensor configured to detect user presence when the refrigerator door is opened;

a light sensor configured to detect ambient light variation corresponding to door opening;

a data storage medium comprising a micro SD card configured to temporarily store the captured images before transmission;

a backend server operatively coupled with the microcontroller via Wi-Fi, configured to receive image data through a POST request;

an AI processing pipeline on the backend server consisting of

a first object detection model (YOLOv8x) trained to detect and classify refrigerator items and their quality,

a second object detection model (YOLOv8s) trained to identify labels on selected objects,

an OCR module (PaddleOCR) configured to extract text from detected labels, and

a fine-tuned NLP model (BERT) configured to extract expiry dates from the OCR-extracted text;

a database (SQLite3) configured to store item identity, quantity, and expiry data obtained from the AI pipeline;

a mobile application configured to retrieve and display item information, expiry status, and quantity, and to generate notifications when the quantity of an item falls below a user-defined threshold;

wherein the microcontroller is programmed to trigger the camera when both the motion sensor and light sensor output a high signal, thereby capturing an image of the refrigerator contents.

2. The system of claim 1, wherein the PIR motion sensor is an HC-SR501 and the light sensor is an LDR connected to GPIO pins of the ESP32-CAM.
3. The system of claim 1, wherein the images are captured only when both the PIR sensor and LDR are active reducing the power consumption and false positives.
4. The system of claim 1, wherein the mobile application is developed for Android using Kotlin and Jetpack Compose, implementing MVVM architecture for real-time updates.
5. A method for monitoring groceries in a refrigerator and reducing food waste, the method comprising the steps of:
    a) installing a hardware module comprising an ESP32-CAM, a camera, a PIR motion sensor, and a light dependent resistor (LDR) in a refrigerator;
    b) detecting user activity by sensing motion and light increase using the PIR and LDR sensors;
    c) triggering the ESP32-CAM microcontroller to capture images when both sensors are active;
    d) storing captured images on a micro SD card and transmitting said images via HTTP POST request to a backend server;
    e) processing the images using an AI pipeline including:
    f) detecting grocery items and determining their type and quality using a YOLOv8x model, detecting manufacturing labels on perishable items using a YOLOv8s model, extracting label text using OCR, and identifying expiry or use-by dates from the text using a fine-tuned BERT model;
    g) storing the processed data, including item identity, quantity, and expiry date, in a database;
    h) providing a frontend mobile application to display item details, expiry status, and notifications for low-stock items, thereby reducing food wastage and improving grocery management.
6. The method as claimed in claim 5, wherein the YOLOv8x model is trained on at least 21,000 images with 90,000 annotations across 28 refrigerator item classes, achieving a mean average precision (mAP) of approximately 90%.

7. The method as claimed in claim 5, wherein the YOLOv8s model is trained on more than 600 images for label detection, achieving a mean average precision (mAP) greater than 98%.
8. The method as claimed in claim 5, wherein the BERT model achieves an expiry date extraction accuracy of approximately 97% across varied date formats.

7 **Dated this 29th day of August 2025**

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Application no: 202411066595 **Sheet no: 01**

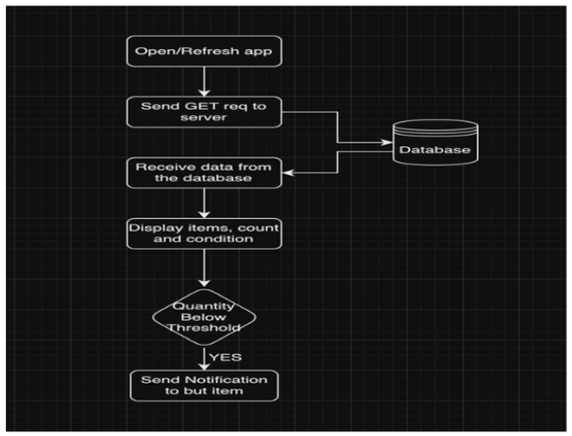

FIG.1

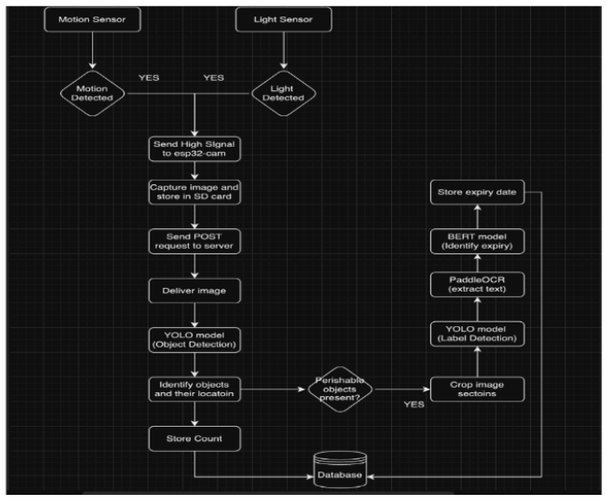

FIG.2

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Application no: 202411066595 **Sheet no: 02**

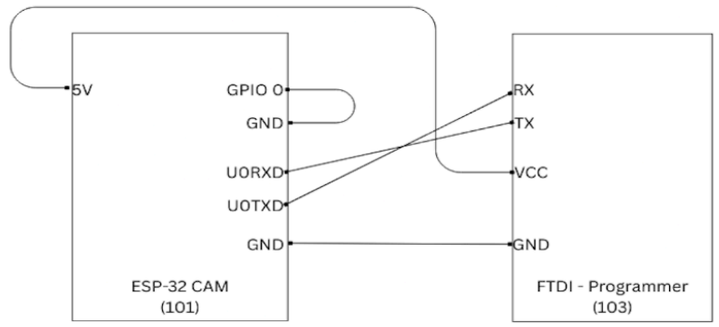

FIG.3

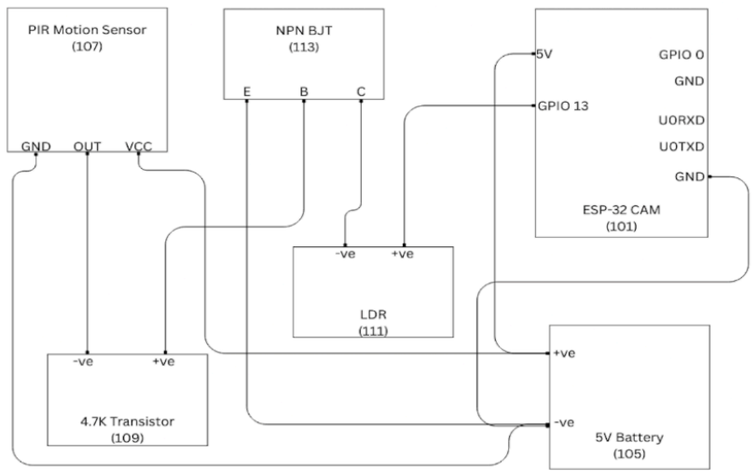

FIG.4

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Application no: 202411066595 **Sheet no: 03**

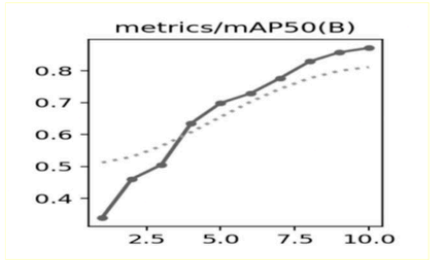

FIG.5

FIG.6

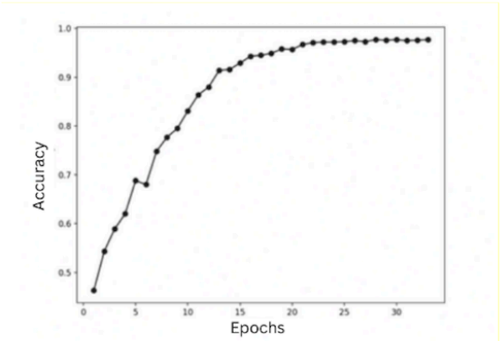

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FIG.7

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ABSTRACT

AN IOT-BASED REFRIGERATOR MONITORING SYSTEM FOR REAL-TIME GROCERY TRACKING AND FOOD WASTE REDUCTION

The present invention relates to an IoT-based refrigerator monitoring system designed to track groceries in real-time and reduce food wastage. The system comprises a hardware module incorporating an ESP32-CAM microcontroller, an OV2640 camera, a PIR motion sensor, and a light sensor, configured to capture images of the refrigerator interior only when both motion and light variations are detected. An AI pipeline sequentially processes the images using a YOLO-based object detection model to identify and count food items, a label detection model to locate packaging labels, an OCR module to extract text, and a fine-tuned BERT model to identify expiry dates. The processed data, including type, count, and expiry status of groceries, is stored in a database and displayed through a mobile application. The application provides real-time inventory, expiry notifications, and low-stock alerts, while also enabling automatic shopping list generation. The invention provides a cost-effective, retrofittable solution that improves household food management, minimizes waste, and enhances user convenience.

Accompanied Drawings **[Figure 1-7]**

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FORM- 5
THE PATENTS ACT, 1970
(39 of 1970)
&
The Patents Rules, 2003
DECLARATION AS TO INVENTORSHIP
[See Section 10(6) and Rule 13(6)]

1. NAME OF THE APPLICANT~~(S)~~

~~I/~~ We, Amity University, Address: AMITY UNIVERSITY Campus, Sector-125, Noida, Uttar Pradesh, India, 201313

hereby declare that the true and first inventor~~(s)~~ of the invention disclosed in the complete specification filed in pursuance of my ~~/ our~~ application numbered 202411066955 dated 03**-09-2024** is/are

2. INVENTOR(S)

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Shilpi Sharma	INDIAN	Amity University Campus, Sector-125, Noida, Uttar Pradesh, India, 201313

~~3. DECLARATION TO BE GIVEN WHEN THE APPLICATION IN INDIA IS FILED BY THE APPLICANT(S) IN THE CONVENTION COUNTRY: -~~

N.A.

~~We the applicant(s) in the convention country hereby declare that our right to apply for a patent in India is by way of assignment from the true and first inventor(s).~~

Dated this 25th day of August 2025

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To,
The Controller of Patents
The Patent Office, New Delhi