International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-11 Issue-3, February 2022

Emerging Technologies for Internet of Things Refrigerator

Melike Ayşenur Yıldırım, Tarek Najjar

Abstract: ***Smart home technologies have accelerated with the internet of things and continue to develop by combining new ideas. Almost all electronic devices used in homes have been affected by this change. Smart refrigerator systems aim to prevent food waste and health problems as they continue to develop day by day. Researchers are working on smart refrigerators and generating new ideas. Users interact with internet-refrigerators using cameras, sensors and object detection, and artificial intelligence applications developed for these devices. Today, using cloud computing technology, robotic, artificial intelligence, and deep learning algorithms, smart refrigerator users can be informed about the expiry date and the amount of food in the refrigerator with warning messages and access the data loaded in the sensors. Recent advances in smart refrigerators have led to new developments using computer vision, image processing, and voice recognition algorithms. This article examines the methods used by researchers in their recent studies of smart refrigerators.***

Keywords: ***Artificial Intelligence, Cloud Computing, Deep Learning, Image Recognition, Internet of Things, Object Detection, Smart Refrigerator.***

I. INTRODUCTION

Since the invention of machines, inventors have been working to offer solutions that will make human life easier for the benefit of society in the most effective way. Researchers have focused on better solutions that will make our work easier day by day, preventing time wastage in many subjects. Technological developments continue without interruption. This development has accelerated with artificial intelligence, robotic, cloud computing, the internet of things, and smart technologies. Artificial intelligence, which is one of the important symbols of technological change, started to be researched after the second world war, and for the first time, courses on artificial intelligence were given by Alan Turing in 1947[1]. The basis of algorithms and approaches still used today is based on the view put forward by Alan Turing. Today, artificial intelligence emerges with studies on many subjects such as search algorithms, voice, and image recognition technologies, used in education and health [1]. Robotic is known as the application area of artificial intelligence. Research and development studies in the field of robotics provide the opportunity to monitor and observe abstractly logical, behavioral approaches or written codes. When the topic of machine learning came to the fore, studies on humanoid, personal and domestic robots increased. The main questions the researchers focus on are: "Is it possible for robots to make human-like decisions?", "Can the error rate be reduced in machines programmed with artificial intelligence?", "To what extent can robots do the work that humans can do?". Today, new approaches are brought to these questions, and results are obtained by applying them with sample robot designs. Every day, better algorithms are designed, and new approaches are developed, and studies are tried to converge to the natural reality. Researchers are working in the fields of artificial intelligence and robotics, focusing on production and design. Cognitive development in robots is provided by artificial intelligence. In addition, studies are continuing to enable robots to perform humanoid actions using deep learning and artificial neural networks. For example, in Pizza Hut restaurant, humanoid robots developed using voice recognition and artificial intelligence algorithms can communicate with customers who come to the restaurant and make it easy for customers to pay the bill at the end of the meal [2]. Cloud computing is a technology that enables interaction via the internet for collective data that can be used between many devices, systems or sensors and provides access to a database at the same time or anytime. The information flow between the sensors is actively used in the communication between the user and the machine, processing and working on large-scale data. Researchers can easily perform applications that require processing load by using this technology. Today, cloud computing is actively used in many areas industrially. Thus, the physical inadequacy barrier was overcome by using complex mathematical algorithms in the studies. Researchers, inventors, and even students can develop industrial products using cloud computing. Internet of Things (IoT) is one of the trend topics of today. Scientists have offered solutions to many problems with this technology. The internet of things has entered our lives with many different areas of use, from household appliances to camera systems and satellite systems. Getting news from space with spacecraft, accessing images from cameras placed on the streets, and remotely controlling electronic devices that remain open have ceased to be an unattainable target for our technology. The development of the internet of things has accelerated the innovative development of smart systems depending on the widespread use of the internet by society. According to the research, more than half of the world's population has access to the internet and this rate can reach over 80% in developed countries [3].

Manuscript received on January 25, 2022.
Revised Manuscript received on February 01, 2022.
Manuscript published on February 28, 2022.
* Correspondence Author
Melike Ayşenur Yıldırım*, Department of Computer Engineering, Ankara Yıldırım Beyazıt University, Ankara, Turkey. Email: 15050111037@ybu.edu.tr
Tarek Najjar, Department of Computer Engineering, Ankara Yıldırım Beyazıt University, Ankara, Turkey. Email: tnajjar@ybu.edu.tr

Due to the widespread use of the Internet, smart systems are frequently used in wearable technologies, transportation in cities, and electronic devices at home. Today, smart home appliances are a popular topic. Researchers have succeeded in making many machines in the home smart. Even non-electronic household items such as curtains, doors, and cabinets have been designed to be adapted to smart technologies and the latest technology has been applied to these items. Smart home systems are getting better day by day through wireless communication tools and sensors implemented in the systems. According to research on recent advances in robotics, artificial intelligence, and automation technologies (RAIA) [4], the professions of many people working today will be automated by machines in the future. Primitive industries that cannot keep up with change will face the danger of extinction in the coming years. The Covid-19 pandemic has made this automation mandatory. Thus, new professions and job descriptions were created. People's needs and the way they meet their needs have changed drastically. According to the Smart Technology, Artificial Intelligence, Robotics, and Algorithms (STARA) research [5], revealed that innovations are not seen as a threat in the industry. With the plans to be made according to the new situation, it will be possible to keep up with the technological change. Today, which is described as an industrial revolution, the situation of employees and employers will change. An interactive future with intelligent systems and robots awaits us. Since smart home technologies have entered our lives, they have saved us a great deal of time and power. For instance, even if we are not at home, our house is swept with smart vacuums and dirty clothes work on smart washing machines with the given command from the phone. With a smart oven, the pre-prepared food we put on the stove is cooked until we come home. With smart refrigerators, it is enough to look at our phones to remember what is in our refrigerator before shopping. The history of the use of smart systems in the kitchen began with the introduction of the Honeywell H316 model in 1969, as the first "Kitchen Computer" together with personal computers [7]. Implementation of smart systems in the kitchen has accelerated with the development of image processing systems and sensor technology. Researchers are continuing the adaptation of the machines in the kitchen to smart technologies. One of the primary focal points of this interest has been refrigerators. Liebowitz et al. talked about "Smart Refrigerators" in 1994 [6], and then researchers' work on smart refrigerators increased. Studies conducted between 1998 and 2008 are shown in Table1.

Table-I: Commercial Smart Refrigerator Prototypes [6]

Year Introduced	Product
1998	V Sync Internet Refrigerator
1999	Electrolux Screenfridge
2000	Whirlpool and Cisco Internet Home Refrigerator with Embedded Tablet PC
2002	Whirlpool Connected Refrigerator
2003	LG Digital Multimedia Side by Side Fridge Freezer with LCD Display
2006	Electrolux Screenfridge, Second prototype with the same name
2008	Whirlpool Centralpark

After 2008, new developments in technology were implemented in internet-refrigerators and many smart refrigerators studies. Studies on smart refrigerators are still up to date. Researchers continue to work on smart refrigerators to solve the problem of food waste, make our diet healthier, and regulate our consumption habits. Efforts are being made to have a pleasant time in the kitchen and to make cooking fun through the screen that can be added to the lids of the internet- refrigerator. In addition, with the applications that can be installed on the phone, it is possible to connect with the refrigerator during shopping and to shop by the contents. Today, in the development of smart refrigerators, cloud computing technology to provide remote connection, especially internet of things, and to collect the contents of the refrigerator in a data center, artificial intelligence, and data mining are used in the tasks of giving smart suggestions according to the items in the internet-refrigerator, creating automatic shopping lists, detecting items visually, and giving commands to the refrigerator with voice recognition. Data flow can be provided between the user and the smart refrigerator over the internet through android applications installed on the phones. Equipped with voice-controlled door opening systems, refrigerators allow you to open the refrigerator door even when your hand is full. Generally, three stages in the researchers' work on smart refrigerators. Firstly, the detection of the items added to the refrigerator through sensors or cameras is designed in this part. Second, the transmission part is to transmit the data from the sensors, or the images taken from the cameras to the microcontrollers. If there is an Android application in the system, in this part providing internet connection with cloud computing and transferring information to common databases. Finally, the control part provides check of the food in the internet-refrigerator according to the features of the functions implemented in the system for the smart refrigerator. This article examines the researchers' recent studies on smart refrigerators the methods they used in their studies, and which equipment and technologies they used. The algorithms used in the studies and the approaches of the researchers are examined in detail.

II. RESEARCH REVIEW

Efforts to use smart refrigerators more efficiently and to reduce food waste in the refrigerator are increasing day by day. For smart refrigerators implemented in the Internet of Things technology, sensors, algorithms, and approaches used in recent studies are specified. The new functions implemented in smart refrigerators were evaluated with the studies of the researchers. Android or iOS applications for smart refrigerators, sensitive designs for voice and image recognition technology, wireless communication with cloud technology, and interface design that provides communication between the user and the internet-refrigerator, have been designed and implemented on the prepared prototypes. A study by Gaurav Anand and Lucky Prakash [7], aims not do waste stored food in the smart refrigerator. The concept used in the system consists of five parts: defining the items added to the smart refrigerator, identifying the food removed from the refrigerator, checking the freshness of the items, informing the user about the products whose quantity is decreasing, and monitoring the products in the smart refrigerator in real-time.

In the design used camera, Wi-Fi Adafruit CC3000 module, Ethylene gas sensor, Ultrasonic distance sensor, and load cell. As seen in Figure 1, first, the data from the sensors, and camera is processed with Arduino ATMega 2560 and informs the user from the Android phone via Google Firebase. The expiry date and the amount of remaining food are displayed. In the application, the detection of the foods in the cabinet is provided by the image recognition method. Ultrasonic distance sensor triggers the camera and provides control of the food in the smart refrigerator. Google Firebase is a cloud-based database used in the study for synchronous updating of data. Load sensor, which is sensitive up to forty kilograms, the weight of the food is renewed via Google Firebase as the refrigerator is opened and closed.

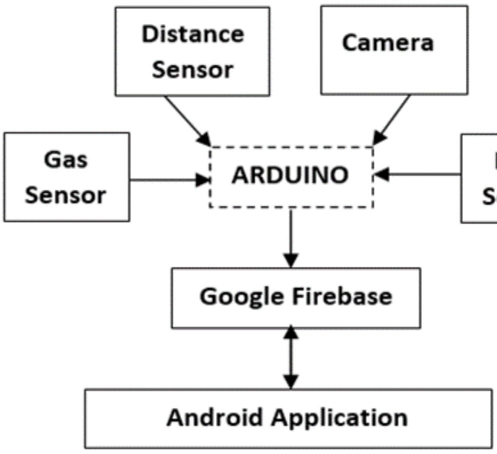

Fig. 1. Hardware architecture [7]

In addition, one of the strengths of the study is to combine, define and use information about the types and weights of foods in the refrigerator with the image recognition method in detecting foods, and to provide real-time control in the refrigerator. The gas detector informs the user whether there is any deterioration in the food. Notify messages are sent to the smart refrigerator user via the android application for expired foods and spoiled foods.

On the other hand, researchers did not use RFID technology in their design because they stated that barcoding every object in the refrigerator is complicated and impractical. Although creating a separate barcode for food and creating a food-specific tracking system is useful for smart markets, waiting for the user to put the same food in a certain section in personal refrigerators can cause difficulties for the smart refrigerator user. In this study, a hybrid smart refrigerator model, which uses more sensors and can be implemented more easily, has been made. With their work, the researchers ensured that it can be easily implemented in any refrigerator and function as a smart refrigerator, and the system integration problem is minimized due to its ease of installation. Another study by Afzal et al. [8], who applied the proposed smart refrigerator system for the storage of pharmaceutical products, provided access to the contents of the refrigerator on an IoT basis, thus making it easier for users to create a shopping list for food shopping. The concept used in this study consists of three parts: defining new items, creating the shopping list and the list of materials in the refrigerator, information output. Firstly, in the system, all products in the refrigerator are scanned so that when a new product is added to the system, the timestamp is checked and the foods in the database are checked with a web query. Every food placed in the refrigerator is not perceived as a new item because the products that have been entered before are kept in the system permanently. Product name, manufacturer, and expiry date information is stored locally in the database. In this study, to create a shopping list, first, the essential food inventory is determined, that is, a list is created in the center of our basic needs, such as eggs, milk. A new inventory can be added to the shopping list and the need definition can be updated by the user via an internet-connected device.

Hardware equipment for the designed internet-refrigerator is as follows: power supply, ARM LPC2148, IR sensor, load sensor, RFID, GSM, LCD. Embedded implementation is done using µVision2 IDE with ARM LPC2148 microprocessor. In addition, IR sensors, load sensors, and RFID are used. The panel is connected to the LCD, as shown in the Figure2. System outputs are also accessible to internet-connected devices.

One of the strengths of the project is that researchers can pre-determine the basic foods for the shopping list and can be added to the shopping list later. In addition, the implementation of the ARM processor to the system added implementation difficulties, as well as the emergence of a high-performance project in terms of memory and processing power. On the other hand, functions designed for smart refrigerator users were insufficient. The use of RFID has increased system complexity.

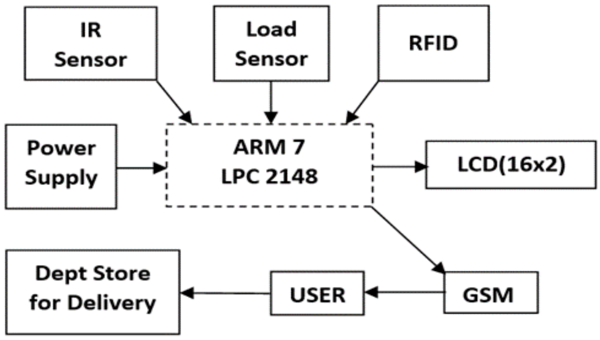

Fig. 2. Design of smart refrigerator system [8]

In the study conducted by Khan et al. [9] according to partial item classification in the refrigerator, the cloud system was integrated, and sensors and image processing were actively used in the detect of the food in the refrigerator. The researchers used three cameras, NodeMCU controller, HX711 load modules, Load cells for dry foods, Google Firebase database, and Raspberry Pi hardware in the project.

The most difference that distinguishes the study from other smart refrigerator studies is that the data from two different food storage areas, namely the refrigerator and a cabinet where dry foods are stored, is processed in the common cloud database. As seen in the Figure 3, the researchers sent, and received the data in the cabinet, which is the dry food storage area, to the Google Firebase cloud base by detecting the data classified using NodeMCU and the foods in the smart refrigerator, so that the information is flow to the user with the web interface.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Another remarkable detail in the project is the partial categorization of food in the refrigerator and the application of appropriate image recognition to the items for food detection. The egg shelf in the refrigerator and the areas where the vegetables will be placed are predetermined. For the detection of eggs, they were monitored by using image recognition and convolutional neural network algorithms via an IR camera. Since the lighting in the refrigerator is insufficient in the part where the eggs are placed, the number of eggs can be determined by processing the images taken with the IR camera placed in the smart refrigerator to detect the object with low light and using deep learning algorithms in the Raspberry Pi processor. To reach a meaningful result from the egg images, the convolutional neural network algorithm was used, and the number of eggs could be detected from the images taken with the camera. In real-time, weight and visual data are processed with the Raspberry Pi used in the system and stored on a cloud basis.

The image recognition methods used in item detection and the use of NodeMCU are different from similar studies on smart refrigerators in that they also allow access to the information of foods stored in two different places in any environment with internet access. The strengths of this study are the CNN and deep learning algorithms used by the researchers, the placement of cameras in different perspectives to view and identify foods, and the implementation of load cell sensors in the cabinets where dry foods are stored. The study aims to design a conventional refrigerator and cabinet intelligently and to flow data about the food in the refrigerator to the user.

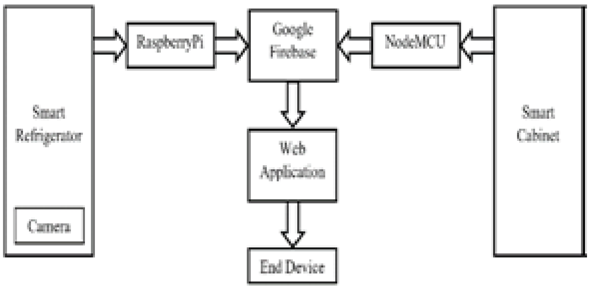

Fig. 3. Data communication for smart refrigerator, cabinet, and user connection [9]

A study by Ahmed and Rajesh [10] is to examines the food in the traditional refrigerator by providing access via the internet and using cloud architecture. In particular, the weight, temperature, and humidity sensors used aim to inform the refrigerator user about the amount of food and whether there is any deterioration. Many platforms can be used when implementing cloud technology in smart technologies. In the study, Google Firebase was used and Arduino UNO, NodeMCU, load cell, LM35 temperature sensor, DHT22 humidity sensor was used as the hardware equipment. Shown in this Figure 4, the steps followed to ensure smart refrigerator and user interaction with the cloud technology applied by the researchers in this study are as follows: First, received data from the sensors are processed according to threshold values using Arduino UNO and transferred to the cloud service with the Wi-Fi module. By using Arduino UNO as a useful and highly adaptable processor used in the project, data was easily obtained over the humidity and weight sensors defined in the system, and wireless communication with the internet was provided by adding the Wi-Fi module and firebase libraries. In the case of an item with a weight below the specified threshold, a warning or reminder message is sent to the user via the cloud, namely Google Firebase. The user can access the data in the refrigerator in real-time through the application developed with MIT App-inventor.

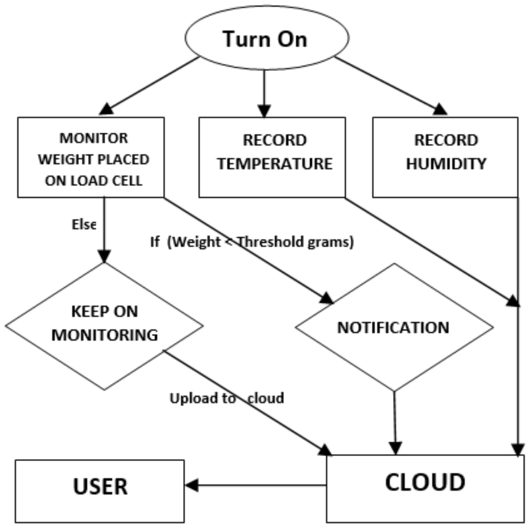

Fig. 4. System design of smart refrigerator [10]

The study is an example of the use of Google Firebase, but the information received from the sensors in the refrigerator and received to the user with the application interface is less than in other studies. Another study of Krishnamoorthy et al. [11], on the Internet-based and real-time control of smart home technologies is about identifying the items in the smart refrigerators, informing the user about the expiration date of the food, temperature, and gas status in the refrigerator with the help of sensors, and automatically creating an alarm via the door sensor. Researchers used in the project Raspberry Pi 3, HC-SR04 ultrasonic sensor, MQ-2 gas sensor, LM-35 temperature sensor, Node MCU ESP8266, GMS module, and Think Speak IoT Platform as hardware equipment. The proposed model of the system is completed in five steps. First, the system informs the user of the smart refrigerator about the weight and quality of the food through gas, temperature, and ultrasonic sensors, and measures environmental factors such as temperature inside the internet-refrigerator. The second step is to ensure that the collected and measured values enable the system to take the necessary actions with Raspberry Pi. In the third step, reminder information and warnings about the food in the refrigerator send to the smart refrigerator user via the Android App. Fourthly, based on the data from the sensor about the refrigerator door, if the refrigerator door is left open, the refrigerator door can be closed using the motor implemented in the system. At the same time, warnings about temperature or information about food items' status can be monitored with LCD and Android app via thermostat. Finally, real-time interaction is created by connecting the android APP used by the smart refrigerator owner and the Raspberry Pi connection on the refrigerator via Wi-Fi.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The test cases of the system are shown in Figure 5.

The algorithm of the designed smart refrigerator is completed in seven steps. First, the internal temperature of the refrigerator will always be recorded. If the door of the refrigerator prototype is left open or an anomaly is observed in the gas level, it will be immediately notified to the user. Thirdly, the values below the determined threshold values will be transmitted to the user via the Android App. Then, a list of purchased products is added to the system with the expiry date, and a notifying message is sent to the smart refrigerator user one day before the expiry date. At this step, reminder messages sent to the user prevent the waste of food in the refrigerator. As the fifth stage, the application module designed for the prototype monitors every item that enters the refrigerator and its usage status and provides monitoring to the user. In addition, the user can add items manually via the web application. Sixth, the user can manually change the expiry dates using the recommended products via the application. Finally, the user is informed about the food items whose expiry date passed, via SMS.

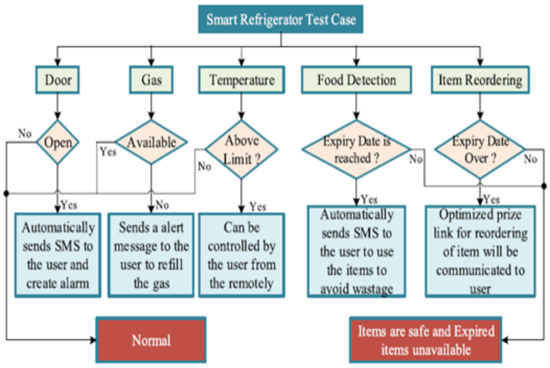

Fig. 5. Proposed work smart refrigerator test case [11].

The study conducted to reduce food waste by using sensor data effectively has guided the researchers with the algorithms used and new methods. On the other hand, in the study of the researchers about smart refrigerators, manual item detection was performed without using image recognition for new item detection.

In this study by Mallikarjun et al. [12], intelligent refrigerators are based on IoT and machine learning technologies. The study has three purposes: analyzing the amount of food in the smart refrigerator, purchasing the needed foods via online-shopping, and recommending recipes according to the items in the internet-refrigerator.

Three different sensors have been implemented in the system for the foods in the smart refrigerator. These are the IR sensor, ultrasonic sensor, and load cell sensor that provide the control of foods by the threshold values defined in the system. As seen in the Figure 6, the information about the items continues to flow instantly according to the threshold values to the cloud platform, and the food items in the refrigerator is monitored with the Android application designed with Android Studio for the smart refrigerator user. If the user wishes, user can make up the missing food in the refrigerator by shopping through the online application. The camera, which is placed on the shelf where the vegetables are located, can be accessed via the Message Queuing Telemetry Transport (MQTT) client through the application. The images taken from the camera are classified according to three groups and send to the cloud database. These groups are the colors red, green, and blue. According to the K-means approach, fruits or vegetables are classified. The system suggests recipes suitable for the foods in the refrigerator to the user.

The critical detail that distinguishes the study from other studies is that system can classify vegetables according to their colors and shapes and makes this distinction using machine learning algorithms. With the camera placed in the smart refrigerator, the images receiving from the vegetables in the refrigerator are processed by the classify algorithms using the Raspberry Pi and send to the Google Firebase cloud database and then to the user with the Android application.

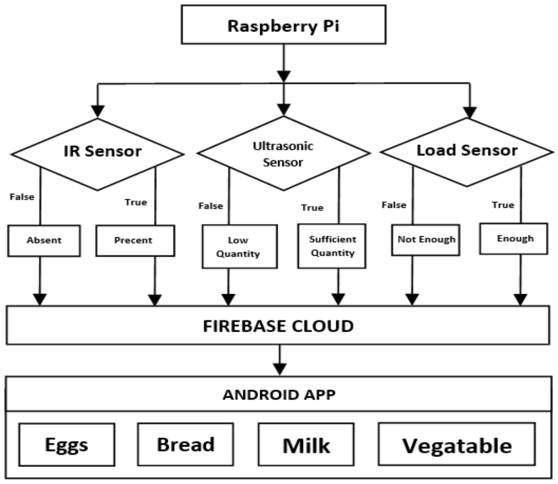

Fig. 6. Proposed the working mechanism of system [12]

The software design applied in the study consists of five parts. First of all, Raspbian Stretch is an operating system that is based on the Debian operating system and can work with Raspberry Pi, Firebase Database provides cloud-based data to be kept on site, the android application prepared for the Android Studio user was coded with this application, MQTT Client was used in the project for sending and receiving data over the internet, OpenCV library is the library used for processing the images taken from the smart refrigerator.

Hardware parts used in the system are: Raspberry Pi B3, IR sensor, HC-SR204 ultrasonic sensor, HX711 load cell, Camera module (INTEX IT-305EC). The effective application of machine learning in the internet-refrigerator, thus implementing the fruit or vegetable recognition features to the system and creating the recipe suggestions to the smart refrigerator user are the critical aspects of the research.

In this study by Shweta A.S [13], for smart refrigerators, image recognition and classification were made for vegetables by using artificial intelligence algorithms. System aims to inform the user by giving warnings about the items in the smart refrigerator, which are identified with image recognition and not consumed within 30 days.

The study consists of three stages: keeping the data about the freshness of the vegetables in the database, processing the data about the vegetables with the photos taken from the camera inside the refrigerator, and sending the audible warning message about the decaying food to the smart refrigerator user.

The camera used for smart refrigerator design is a 360-degree micro camera. The training process continues by updating the data in the system and developing with the selected images. For this, the images taken by the camera implemented in the refrigerator are processed every hour. The aging algorithm is created by daily analysis of the photos taken from the camera. The process that starts when the food enters the refrigerator is calculated separately for each item and then continues until the vegetables or fruits are finished. The microprocessor sends the images processed by the camera in the smart refrigerator and triggers the user interface to send voice messages about the vegetables in the refrigerator. Classification techniques are made according to the texture, shape, size, color, and weight of the vegetables analyzed with the camera inside the smart refrigerator. It is classified by applying and matching multiple filters from image processing methods on the obtained images.
When necessary, warning signals are sent to the microprocessor for foods that are in the refrigerator and forgotten to be consumed.

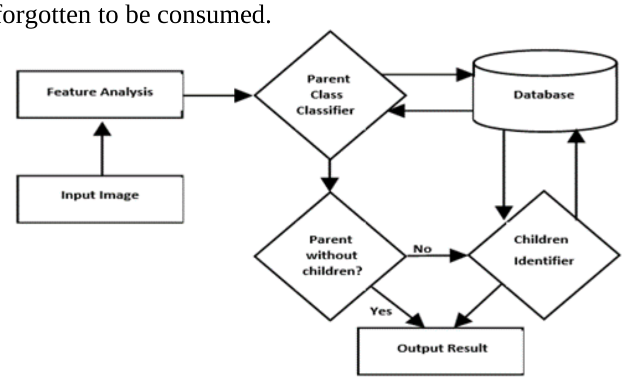

Fig. 7. Classification algorithm by vegetables or fruits images in the refrigerator [13]

Let's examine the image analysis in more detail as seen in Figure 7. First, the images taken with the lights on and off in the smart refrigerator are compared with the items front and behind the shelf inside the refrigerator. The foods that the system is trained by default when classifying from images are broccoli, zucchini, cabbage, and apple. In the perception of food, images are taken according to the hue, saturation, value (HSV) model. After the histogram values of the images are calculated and analyzed, the feature is integrated, and the classification process begins. The classification process is placed in the database in the appropriate class according to the texture, histogram, and structural features of the image. If the fruit or vegetable placed in the smart refrigerator does not have the characteristics of a class according to the trained data, a new class is defined.

In this study, the system was designed to control the freshness of the foods in the refrigerator and to consume them fresh. The fact that the images of vegetables and fruits taken from the smart refrigerator are sent to a database for training using artificial intelligence algorithms and that new classes of vegetables and fruits can be created according to the physical properties of foods such as shape and texture from the images taken with a 360-degree micro camera distinguish the study from other studies on smart refrigerators.

This study by Nasir et al. [14], made a design consisting of three parts to be implemented in smart refrigerators. According to the three-stage approach used in the design, first, information about the humidity, temperature, and gas sensors and the data in the smart refrigerator is obtained. Then, the data received from the sensors are checked by comparing them with the threshold values applied to the system, and finally, the necessary notification messages are sent to the smart refrigerator user. The MQ3 model is used as the gas sensor, and the assumptions made by the system about whether the food put in the smart refrigerator is spoiled or fresh is made according to the values measured with MQ3 gas sensor.

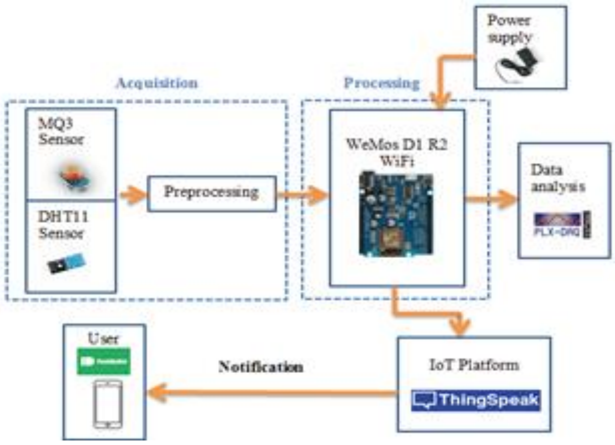

Fig. 8. System design of smart refrigerator [14]

As seen in Figure 8, the data flow in the DHT11 temperature and humidity sensor is effective in determining the freshness, and when the optimal values determined in the system are exceeded with the MQ3 gas sensor, more accurate information about freshness is sent to the user. The values taken from the three sensors used are compared with the threshold values and trigger the notification messages sent to the smart refrigerator user. With the WeMos D1 R2 module, wireless communication is provided between the smart refrigerator and the user via sensors that implemented in system. The Pushbullet application, which is used to send an SMS alert to the user when the food becomes rotten, is suitable for Android and iOS. In their smart refrigerator study, the researchers used ThinkSpeak IoT Platforms so that the data received from the sensors could provide data flow with the internet and interact with the user. The PLX-DAQ spreadsheet was used to record the data. This table, which allows data to be sent to directly in Excel, can work with Arduino. Researchers aim to provide a healthy diet for the smart refrigerator user by controlling the quality of the food stored in the smart refrigerator with temperature, humidity, and gas sensors in the refrigerator environment. Android and iOS compatibility of the developed application is one of the differences between the other studies examined in the article. In the studies of the researchers, general evaluations were made about the quality of the foods without making a design according to the optimum values suitable for each food type.

This study by Sangole et al. [15], designed a smart refrigerator with IoT using the Arduino ATmega328p board as the controller. Algorithms designed for the system were written in C++ language via Arduino IDE,

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

and the android application designed for user interaction was written interactively on Android Studio with Google Cloud in C++ language. In the study, an IR proximity sensor was used to detect eggs. Sensor provides data flow to the system about the entity of eggs by detecting the distance. IR proximity sensors can also be used to detect boxed liquid foods such as milk or fruit juice in a smart refrigerator. The microprocessor is triggered according to the data from the sensors to send a notifying message when the eggs are finished, as seen in Figure 9.

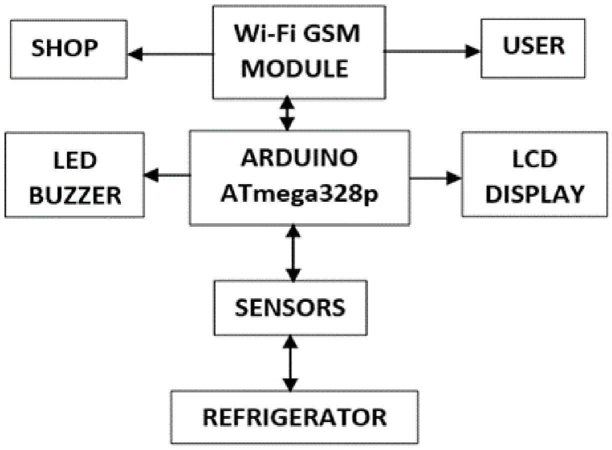

Fig. 9. Hardware design of refrigerator [15]

In this design, possible to detect the vegetables or fruits on the load cell according to their weight, and it is not known which food item is stored in the smart refrigerator on the sensor. The user is warned when the total organic food weight is at a level that will cause a problem for the refrigerator to store vegetables and fruits under healthy conditions. Smell detection in the system is provided by gas sensors.

Warnings of sensors sensitive to the smell of spoiled food are displayed on the LCD panel placed in front of the refrigerator. Data about the cleanliness in the refrigerator sends to the user application via gas sensors. When the door of the refrigerator is left open for five minutes, the buzzer is activated and warns the user to close the door. Preserving the freshness of vegetables and fruits is directly related to keeping the internal temperature of the refrigerator in balance. If the door is left open, temperature balance is disturbed, so the sensors putted in the refrigerator door are important for the items stored in the refrigerator to preserve their freshness. With the IR sensor and timer placed in the ice cube tray, a message is sent to the indicator on the LCD panel when ice forms on the ice trays. Although the algorithms used in the study and the system basic, a new perspective has been revealed about the usage areas of the sensors used for smart refrigerators by using IR sensors in liquid foods and freezer parts. On the other hand, the study is work in the variety of sensors used in different functions. Since the camera is not used in the system, the notification message sent to the user about the items gives general information. For example, when a warning about spoiled food in the smart refrigerator is sent to the user via LCD or an Android application, all the food items in the refrigerator should be checked because the system cannot detect that the rotting food is tomato.

In this study by Wang Zhongmin and Yu Yanan [16], the STM32F103 ARM microprocessor is used in the smart refrigerator designed by integrating embedded systems. In this study with ARM, every detail made in the system, from card design to circuit diagrams, is explained in detail in the article [16].

Air quality sensor, infrared sensor, temperature and humidity sensor, load sensors are used in the smart refrigerator. The air condition in the refrigerator is measured with the air quality sensor ZP07. The load sensor is integrated into the embedded chip. The response to the force created by the weight of the food and the value on the sensor are calculated, so that the weight of the food is sent to the system via load sensor. The touch screen module LS530H-A8 features WIFI connectivity for display and wireless communication. In the system, the touch screen energy consumption is higher compared to other sensors. After the hardware design was completed, work continued for software design and creating applications. While the system is being designed, an interface is created where the user interacts with the new features and functions implemented in the refrigerator with the touch screen. This application allows the user to experience the newly added features more easily and understandably, without feeling the system clutter in the background. Let's examine the functions implemented on the touch screen. As can be seen in Figure 10, the functions system functions are shown in seven subheadings. Firstly, the temperature measurements of the freezer and refrigerator can be displayed on the screen. Temperature values can be changed according to the needs of the smart refrigerator user via touch screen. Secondly, the wake-up function is possible to check information about the status of food stored inside the smart refrigerator, by touching the touch screen or by a defined specific sound. Thirdly, the reminder function of the foods in the smart refrigerator is available in the application. This function displays warning messages for foods with reduced weight via the touch screen and informs about the weight and number of eggs in the refrigerator via the IR sensor. In addition, system checks the freshness of the food with the air sensors inside the refrigerator and the necessary warnings are sent to the user via the touch screen. Fourth function is food identification and data display. Food identification function is done with Load sensor and IR sensor. Data processed with ARM microprocessor can be viewed with a touch screen. The Memo function is designed for the smart refrigerator user to have fun and as a reminder feature. It can be added by drawing. This function is a notepad-like application found on mobile phones. With the electronic photo album, memories can be displayed on the refrigerator. With the edit function, the draws, photos, and tables on the touch screen can be changed. This study does not use image recognition algorithms or cameras to identify refrigerated food. Adding a new item to the smart refrigerator is done using load sensors and the touch screen implemented in the system. Through the designed application, the smart refrigerator and its user interact.

This project, which is made by using a touch screen and having a strong hardware background with an ARM processor, differs from other projects.

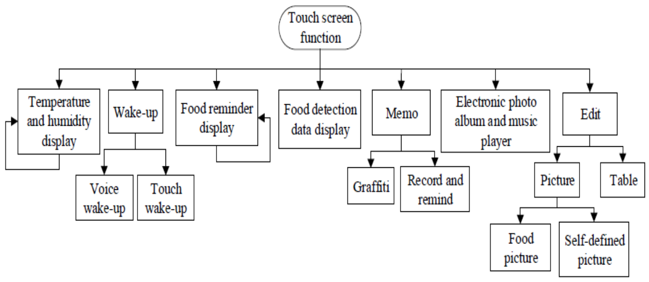

Fig. 10. Diagram of System Functions [16]

III. CONCLUSION

Smart refrigerators have become a popular topic with the widespread use of the internet. Better algorithms are being worked on day by day to create healthier nutrition messages to users about smart refrigerators and to prevent wastage of foods that are kept in inappropriate storage conditions, expired, or go to waste because they are forgotten in the refrigerator. Researcher's use of cameras has been to be more effective in detecting food items in smart refrigerators. K-means classification algorithm and machine learning algorithms were applied to detect and categorize the types of food items in the images coming from the cameras placed inside the refrigerators. In the designed smart refrigerator studies, a system that communicates with the internet has been established, and cloud computing and wireless communication architectures have been used for this. The platform, which provides the easiest adaptation according to the type of microprocessor used by the researchers in their studies, is included in the hardware design. In a system that communicates over a same database, the application prepared for the user is simple and useful. The microprocessors used for the system designed in the studies on smart refrigerators have changed according to the purpose of the study. Arduino and Raspberry Pi microprocessors are mostly used in Internet of things applications for smart refrigerators. Researchers have also rarely used ARM processors, which have a strong infrastructure, in their studies. In this article, the hardware equipment used by the researchers in their studies, the software designs, algorithms, the working principle, and process of the functions they developed and implemented on the refrigerator were examined in detail. Strengths and weaknesses in the studies were evaluated comparatively.

REFERENCES

1. McCarthy, J. (2007). What is artificial intelligence?
2. Yang, L., Henthorne, T. L., & George, B. (2020). Artificial intelligence and robotics technology in the hospitality industry: Current applications and future trends. Digital transformation in business and society, 211-228.
3. E. Yaacoub and M. Alouini, "A key 6G challenge and opportunity—connecting the base of the pyramid: A survey on rural connectivity," Proceedings of the IEEE, vol. 108, no. 4, pp. 533–582, 2020.
4. Webster, C., & Ivanov, S. (2020). Robotics, artificial intelligence, and the evolving nature of work. In Digital transformation in business and society (pp. 127-143). Palgrave Macmillan, Cham.
5. Brougham, D., & Haar, J. (2018). Smart technology, artificial intelligence, robotics, and algorithms (STARA): Employees' perceptions of our future workplace. Journal of Management & Organization, 24(2), 239-257.
6. M. Kuniavsky, Smart Things: Ubiquitous Computing User Experience Design, Ch 5. Amsterdam: Morgan Kaufmann, 2010.
7. Anand, G., & Prakash, L. (2018, October). IoT Based Novel Smart Refrigerator to Curb Food Wastage. In 2018 3rd International Conference on Contemporary Computing and Informatics (IC3I) (pp. 268-272). IEEE.
8. "Smart Refrigerator with Internet of Things", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN:2349-5162, Vol.8, Issue 7, page no.f186-f190, July-2021, Available :http://www.jetir.org/papers/JETIR2107653.pdf
9. Khan, M. A., Shahid, M. H. B., Mansoor, H., Shafique, U., & Khan, M. B. (2019, December). Iot based grocery management system: smart refrigerator and smart cabinet. In 2019 International Conference on Systems of Collaboration Big Data, Internet of Things & Security (SysCoBIoTS) (pp. 1-5). IEEE.
10. Ahmed, R. M. A., & Rajesh, R. (2019). Implementation of smart refrigerator based on internet of things. International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN, 9(2), 2278-3075.
11. Krishnamoorthy, R., Krishnan, K., & Bharatiraja, C. (2021). Deployment of IoT for smart home application and embedded real-time control system. Materials Today: Proceedings, 45, 2777-2783.
12. Mallikarjun, B. C., Harshitha, S., Harshita, B. K., Bhavani, S., & Tarwey, S. (2020, June). Smart Refrigerator: An IOT and Machine learning based Approach. In 2020 International Conference for Emerging Technology (INCET) (pp. 1-4). IEEE.
13. Shweta, A. S. (2017, January). Intelligent refrigerator using ARTIFICIAL INTELLIGENCE. In 2017 11th International Conference on Intelligent Systems and Control (ISCO) (pp. 464-468). IEEE.
14. Nasir, H., Aziz, W. B. W., Ali, F., Kadir, K., & Khan, S. (2018, July). The implementation of IoT based smart refrigerator system. In 2018 2nd International Conference on Smart Sensors and Application (ICSSA) (pp. 48-52). IEEE.
15. Sangole, M. K., Nasikkar, B. S., Kulkarni, D. V., & Kakuste, G. K. (2017). Smart refrigerator using internet of things (IoT). International Journal of Advance Research, Ideas and Innovations in Technology, 3(1), 842-846.
16. Zhongmin, W., & Yanan, Y. (2018, August). Design of an interactive smart refrigerator based on embedded system. In 2018 International Conference on Sensing, Diagnostics, Prognostics, and Control (SDPC) (pp. 589-592). IEEE.

AUTHORS PROFILE

Melike Ayşenur Yıldırım, I completed a bachelor's degree in Computer Engineering from Ankara Yıldırım Beyazıt University. My postgraduate studies in Computer Engineering from Ankara Yıldırım Beyazıt University. I am working on embedded system applications, IoT and smart home technologies, and cloud systems. My research interests include Cyber Security, Robotics, Data Mining and Artificial Intelligence.

Tarek Najjar, after obtaining a bachelor's degree in computer engineering, he moved to Japan in order to pursuit his postgraduate studies. He completed his master's degree in Robotics & Artificial Intelligence from University of Tsukuba and then joined Tokyo Institute of Technology for his Doctoral degree focusing on studying the human brain and investigating cortical mechanisms of learning in order to build Machine Learning algorithms that are cortically-inspired and can be applied to Cognitive Robots. His PhD can be described as a combination of Computational Neuroscience, Machine Learning and Robotics. Beside AI and Robotics, Dr. Tarek's research interests include Embedded Systems, Microprocessors, Digital Design, FPGA and VLSI Systems.