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Optical Waste Identifier using Google's Vision AI and MQTT protocol

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Optical Waste Identifier using Google's Vision AI and MQTT protocol

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***Abstract*—This project was developed with the intention of providing a tool that helps users to manage waste generated at home. The development was based on the use of two microcontrollers: one in charge of managing the activation of actuators and indicators, as well as the physical interaction with the user. The second was used to carry out the image processing by creating a connection to Google's Vision AI. Both boards were connected wirelessly via the MQTT protocol. The outcome regarding the use of Vision AI helps the reader to understand the ease of use of this tool, as well as its versatility, leading to an easy incorporation in different projects related to image processing. On the other hand, the results referring to the MQTT protocol demonstrate why it should be one of the first considerations when the objective is to create a stable and scalable wireless connection between two or more clients through the same server. The results obtained adduce the basis for future research, which should provide scalability to the project and take it to be a commercial product that will help any user who is seeking to perform greener practices at home.**

Keywords—Google cloud, Vision AI, Adafruit, topics, broker, MQTT, FRDM K-64, Raspberry Pi, waste.

II. Introduction

The urgency of encouraging a better waste management culture is because the rate of urbanization of our planet has been exceeded by the rate of garbage production [1]. Most of Latin American, South African, and Mid-Eastern countries tend to burn in the open a third of the waste generated by their inhabitants [2]. This lack of waste management is also present in cities like New York and Mexico City, where 33 million and 12 million tons of garbage are produced per year, respectively. Furthermore, an average citizen produces around a kilogram of garbage per day [3,4].

Domestic, industrial and commercial activities also generate waste; however, the main source of solid waste is domestic (residential). In Mexico, according to the Ministry of the Environment and Natural Resources (SEMARNAT) and Ecology and Business Commitment (ECOCE), garbage is classified as 46% organic, 15% paper, 8% glass, 5% plastic, and the 32% pending waste comes different sources. Of all the solid waste generated, only 30% is recycled [5].

Nowadays, to classify the generated waste properly, several enterprises have developed garbage sorting machinery using intelligent classification systems. Picvisa is a company that offers robotic and artificial vision products [6]. Their machines allow waste sorting and separation based on composition, form, and/or color thanks to artificial vision software implementations and the use of robotic designs. Another enterprise that offers disposal management services is the SPR group, which provides waste management facilities for different industries, such as food, glass, metal, urban waste, etc [7]. TOMRA is another organization that helps mining, food, or recycling companies to acquire a proper waste management thanks to the sensor-based solutions they offer [8].

The available waste management solutions on the market are clearly intended to help industries that produce large amounts of waste. However, the number of products that help the household sector is very limited, if not null. As a result, household waste is not properly classified and recycling is not encouraged.

Therefore, a system capable of identifying different types of waste was implemented, utilizing a computer vision-based system. The present project led to the design and development of the Optical Waste Identifier, which aims to be a product for household waste management using Google Cloud's Vision AI, MQTT protocol and an electronic system to properly identify each kind of waste in a reliable way.

III. Methodology

A. System Overview

A computer vision system evaluates data provided by an image source, usually a camera, and extracts information from the captured images. The camera used in this system (Fig. 1) was a Raspberry Pi camera Rev 1.3 due to its ease of use and the image quality this module provides. To send the images to Google Cloud's Vision AI for recognition, a Raspberry Pi 2 board is used. However, the trigger for the snapshot is generated by a FRDM K-64 microcontroller. When the Raspberry Pi board receives Vision AI's data, it will consecutively send the information to the FRDM-K64 board via MQTT protocol, to activate the actuator (servomotor) connected to this last microcontroller depending on the data received.

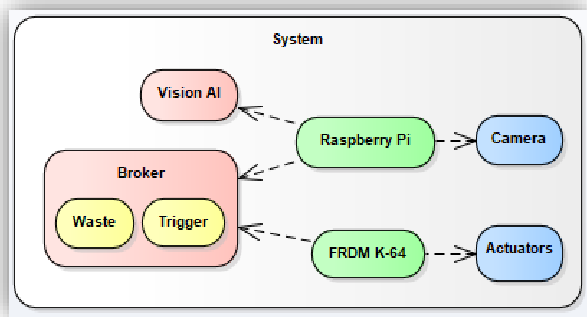

Fig. 1. System's architecture.

B. System Operation

An ideal condition for a proper operation of the system is to have a fixed setup for the image environment. For good quality pictures without colors or brightness intervention, a uniform flat background and proper illumination is set with the same configuration for all photos. With this condition met, Vision AI responses are more reliable.

To establish a wireless connection between the Raspberry Pi and FRDM-K64 boards, the MQTT protocol was chosen because of its ease of use and its adaptability to changes. This protocol's basis relies on two entities: a broker, which is a message-oriented server where topics are established; and clients, which subscribe to the topics created. As for this project, the clients were both Raspberry Pi and FRDM K-64 microcontrollers. The topics to which they were subscribed in the adafruit.io broker were "Trigger" and "Waste". Therefore, if one of the boards posts an update in any of the topics, the other one will notice the change. This way, it is easy for the Raspberry Pi to know when to trigger a snapshot if the FRM K-64 microcontroller generates such a request.

The FRDM K-64 board is configured to post in the "Trigger" topic; the Raspberry Pi is set to just react to the changes. Initially, the message posted on this topic is a number zero, thus, in the FRDM-K64 flashed software, an interrupt service routine (ISR) had to be created, looking for a number one to be posted when the board's SW3 button is pushed down. Then, the Raspberry Pi will notice the change in the topic's message and will trigger a snapshot in consequence.

Since the Raspberry Pi board handles the captured image, it also sends the photo to Vision AI. The cloud will reply with a list of string referring to the most valuable findings detected in the image sent. That is why, in the software flashed on the Raspberry Pi, three banks of words were created, one for each type of waste to be identified: Organic, Glass and Metal. Then, the Vision AI's response will be compared with the labels found in these three banks, leading to a more accurate decision to be taken. The type of waste that recounts most matches between the strings received and the words in its bank, will be posted to the "Waste" topic.

When the FRDM-K64 notices the changes in the "Waste" topic, it can decide whether to activate the actuator for the "Organic", "Glass" or "Metal" position and turn on the corresponding color in the LED indicator, depending on the message published. Thus, a simulation of the waste being placed in the appropriate container will be performed.

After the process is completed, the system will remain expectant to another snapshot request, i.e., it will be placed back to its initial state and wait for another waste to be identified. For this to occur, once the actuator has finished its task, the FRDM K-64 board will post a zero to the "Request" topic, so the Raspberry Pi notices this change. Then, when the SW3 button is pushed down, the system operation starts all over again.

IV. Results

To have a calibrated system, i.e., to make a proper distinction between different types of waste, the following steps were followed:

1. Different samples of a specific waste were captured several times from different perspectives and sent to Vision AI. This way, using the most concurrent labels received from the cloud, the three banks of words were created as shown in Table 1 for each type of waste to be identified.

2. A script compares the response received from Vision AI with the labels of each bank of words. The bank that reports the highest number of matches between its labels and the strings received, will be posted to the "Waste" topic in Adafruit.io.

TABLE 1. MOST MATCHED LABELS RECEIVED FROM GOOGLE VISION FOR RECOGNITION ALGORITHM

Waste	Labels
Organic	"Food", "Organic", "Fruit", "Vegetable", "Ingredient", "Dish", "Natural"
Metal	"Aluminum", "Tin", "Metal", "Silver", "Foil", "Steel", "Can"
Glass	"Bottle", "Liquid", "Tableware", "Drinkware", "Serveware", "Water"

To obtain more accurate pictures, the set-up for image recognition included a controlled environment with smooth white walls, a white light bulb, an Internet-connected Raspberry Pi with a Pi Camera (Fig. 2).

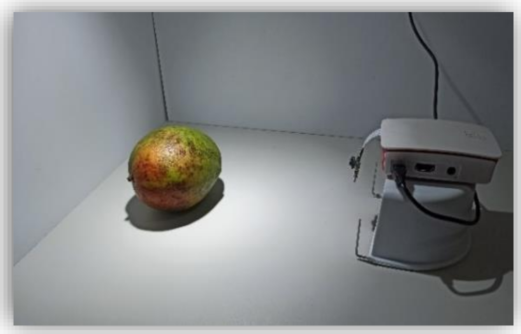

Fig. 2. Set-up for image recognition.

To achieve a stable connection between the boards and the broker, the process shown in Fig. 3 was followed.

First, a connection between the client (FRDM K-64 board) and the Adafruit.io broker is established by using DHCP protocol. Once the connection is stable, the subscription to the topics is feasible. A quality of service (QoS) should be provided. Finally, the request to generate a snapshot of the waste is triggered by publishing a number one to the "Trigger" topic when the SW3 button is pushed down.

Fig. 3. MCU Xpresso shell.

When the Raspberry Pi notices the change in the topic, the board starts the capture of the picture and sends it to Google Vision to recognize the object. Finally, an answer with descriptive labels is received (Fig. 4).

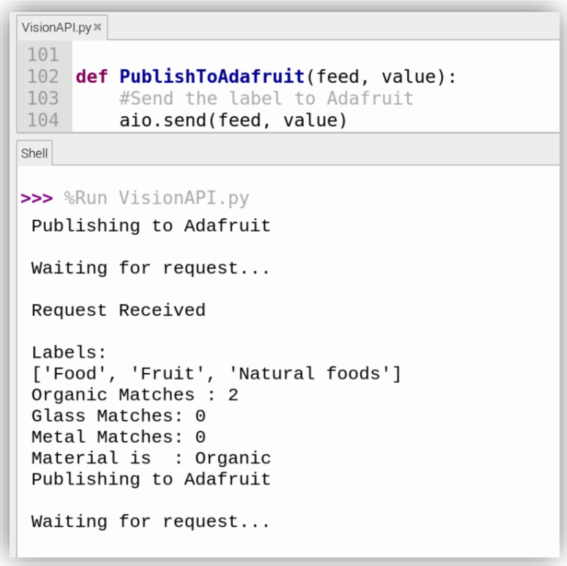

Fig. 4. Example of a logging execution in the shell of the Raspberry Pi.

After the descriptive labels are filtered, the script in the Raspberry Pi board publishes the specified waste to Adafruit (Fig. 5) in the "Waste" topic. The FRDM-K64 board, which is also subscribed to this topic, will turn on the respective LED and move the actuator according to the type of waste detected (Figure 6). After receiving the data, the FRDM-K64 board will consecutively post a zero to the "Trigger" topic.

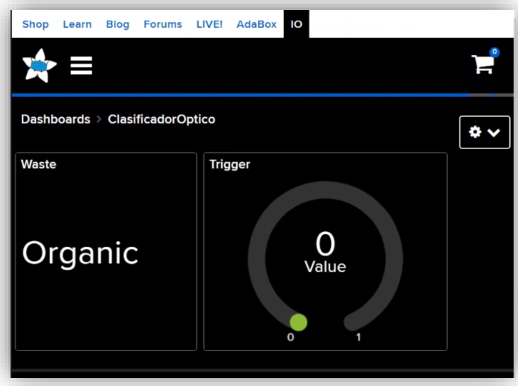

Fig. 5. Example of a post to Adafruit.

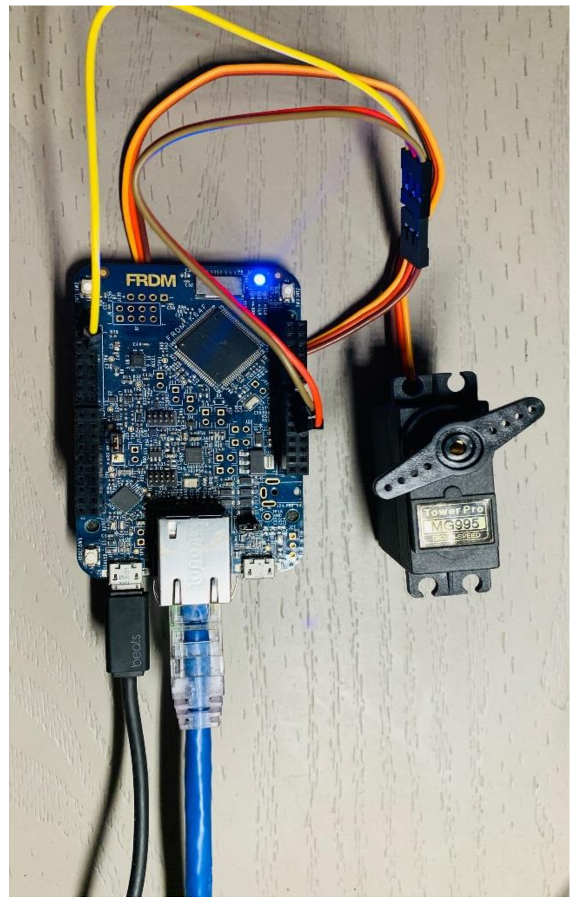

Fig. 6. FRDM-K64 board with the LED turned on in blue color and the servomotor moved the corresponding degrees for the Organic waste.

The results obtained show that an area of opportunity to improve the system's performance and capabilities is to incorporate robotic implementations. This way, the simulation of actuators would be replaced by arms capable of separating and locating a specific type of waste into its corresponding container. A mechanical system may satisfy these necessities as well.

V. Conclusions

The separation of wastes generated at home is a feasible option when trying to contribute to green practices. Creating a system capable of carrying out such a task is possible thanks to the versatility and ease of use of Google's Vision AI and MQTT protocol.

The limitation with the process followed for this project is that an internet connection results essential, and it is not always feasible or reliable. Depending on what is required, other approaches can be sought to satisfy the need in question. An example is the implementation of neural networks to provide artificial intelligence to the system. This way, it can take decisions based on the information provided by sensors, without depending on a connection and a cloud that may not be always available.

Addressing this kind of considerations and making the necessary implementations may result in a useful commercial product for any user seeking to contribute to a cleaner environment through greener practices.

Acknowledgment

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References

[1] World Bank (2018, 20 september). The future of solid waste management.. [Online]. Available: https://www.bancomundial.org/es/news/immersive-story/2018/09/20/what-a-waste-an-updated-look-into-the-future-of-solid-waste-management

[2] World Bank (2018, 20 september). Global overview of solid waste management [Online]. Available: https://www.bancomundial.org/es/news/infographic/2018/09/20/what-a-waste-20-a-global-snapshot-of-solid-waste-management-to-2050

[3] ElDiario.es. (2016, 29 octubre). Which city is the one that generates the most garbage in the world [Online]. Available: https://www.eldiario.es/internacional/theguardian/ciudad-genera-basura-mundo_1_3762498.html

[4] INEGI. (2019). Environment. Tell me about Mexico [Online]. Available: http://cuentame.inegi.org.mx/territorio/ambiente/basura.aspx?tema=T

[5] ECOCE (2020). figures and statistics of Mexico [Online]. Available: https://www.ecoce.mx/fichas-tecnicas-por-estado

[6] Picvisa. (2020). Sorting and sorting technologies [Online]. Available: https://picvisa.com/

[7] Grupo SPR. (2021). Technology Provider in the form of Comprehensive Solutions for the Management and Recovery of Waste [Online]. Available: https://www.grupo-spr.com/

[8] TOMRA. (2020). Sensor-based solutions for optimal resource productivity [Online]. Available: https://www.tomra.com/e