FruitPAL: A Smart Healthcare Framework for Automatic Detection of Fruit Allergens

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***Abstract*—To maintain good health, people should take care of their dietary choices to boost their immune system. Immune disorders, such as Human Immunodeficiency Virus (HIV) and fruit allergy, can compromise the immune system. Fruit allergy is a prevalent medical condition that impacts the immune system due to the nutritional significance of fruit as a food source. Individuals with fruit allergy who exhibit a deficiency in recognizing the possible risks of consuming fruits should be subjected to close monitoring. This paper proposes a device called "FruitPAL" designed to precisely recognize allergenic fruits and alert the caregiver to take necessary precautions for people with fruit allergies. FruitPAL can predict what fruit causes allergies in real-time to protect the immune system from any harm. YOLOv8, the most recent iteration of the YOLO series, has been incorporated into FruitPAL to increase precision and decrease time response. Using the technology of YOLOv8 in the FruitPAL device enhances the protection of people allergic to fruit.**

***Index Terms*—Smart Healthcare, Diet Analysis, Diet Management, Fruit Allergy.**

I. Introduction

Allergic responses have been documented to be caused by a wide variety of fruits. People may be allergic to one or more types of fruit. When a person's immune system incorrectly reacts to proteins in fruit, the result is a fruit allergy. This happens when the immune system's "memory" recognizes the fruit as a potential threat. Antibodies are formed against the offending fruit, and their subsequent meeting with the fruit's proteins may result in the release of histamine and other chemicals. An allergic reaction develops as a result. However, some people can develop a sensitivity to a fruit without ever developing an actual allergy to it [1]. On the other hand, anaphylaxis is a life-threatening allergic reaction which can be caused by fruit allergies and can cause death [2].

This paper introduces "FruitPAL" (Fruit Prediction of ALlergies device), a novel method for automated identification of fruits. This effective method can help people to identify the fruits they are allergic to. Obtaining advanced notification by a system like FruitPAL is very helpful.

Different fruit types might irritate the immune system. A person allergic to one citrus fruit is allergic to all citrus fruits. Fig. 1 shows all FruitPAL-detectable fruit groups. However, pomegranates, for example, can belong to multiple categories due to their characteristics.

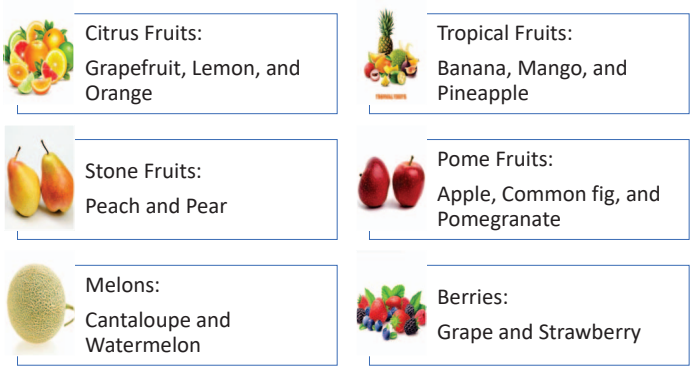

Fig. 1. Fruits categories

II. Contributions of the Current Paper

A. Research Problem

Many fruits induce allergies. Fruit allergies can be serious. As fruits provide a lot of nutrients, we always incorporate them into a balanced, healthy diet. However, when people are allergic to any fruit or any group of fruits, instead of providing nutrients, those fruits cause harm. So, identifying those fruits can reduce the number of urgent care and emergency visits.

B. Proposed Solution

The proposed FruitPAL can accurately predict 15 kinds of fruits. It is a real time approach that can send notifications to the user in real time.

C. Novelties of the Current paper

The novelties of the proposed FruitPAL are:

- The system automatically detects fruit that may cause allergies.
- It is a real time approach that produces the result almost instantaneously.
- An alert will be sent and it will persist until the system detects a change in status.
- Through the usage of the Global System for Mobile Communications (GSM), there is a channel for users to communicate directly with the system.

III. Related Prior Works

The majority of previous research have focused on fruit classification for industrial and agricultural purposes, whereas the present paper pertains to fruit detection within the context of smart healthcare. One notable advantage of the present study is the utilization of YOLOv8, a model renowned for its superior performance and reduced response time in the context of object detection. In the context of computer vision, image classification refers to the task of identifying a solitary object within an image, as opposed to the process of object detection which involves the identification of all objects present within an image [3].

Smart healthcare frameworks are disused in [4], [5]. The primary advantage of the [4] study lies in the utilization of the Fruits-360 dataset, which is known for its high quality, in conjunction with a Convolutional Neural Network (CNN) model that has demonstrated high levels of accuracy. However, it is important to note that the system is not entirely automated. The topic of assessing the nutritional value of food as a means of preventing obesity is addressed in [5], an updated version of [6]. Requesting users to perform an action, such as capturing a photo of their meal, is not useful for those whose forgetfulness is severe.

The field of Smart Agriculture encompasses a range of publications such as [7]–[9]. These research works identify the fruit planted in crops that assist the substance of the food chain. In addition, the utilization of CNN models in industrial applications has been examined in previous studies [10], [11], yielding valuable insights.

Identified fruit is given in different publication by the researchers, and it solves multiple issues. Our work automatically detects the danger of fruit allergen earlier in the domain of smart healthcare.

IV. Proposed Healthcare Cyber-Physical System Architecture of FruitPAL

A. Overview

Fig. 2 illustrates the system level explanation of the concept proposed in FruitPAL. Both components Passive Infrared sensor (PIR) and smart camera are on the same level. Once the power supply is activated, the camera captures a series of consecutive images. The captured images undergo automated processing and the resulting data is stored within the system. The data obtained will not be transmitted to a platform that sends notifications unless the PIR sensor detects movement by the human. The notifications will be delivered to the caregivers via their mobile devices, and they will have the ability to withdraw the notification as necessary. The system is distributed across different computing platforms. All those computing platforms are connected to each other by wireless communications. The objectives of the end platform are image acquisition, motion detection, and image processing. The main purpose of the cloud platform is to communicate with the other platforms of the system. The other platform is the edge platform, and its feature is to receive notifications from and send the user's decision to the cloud.

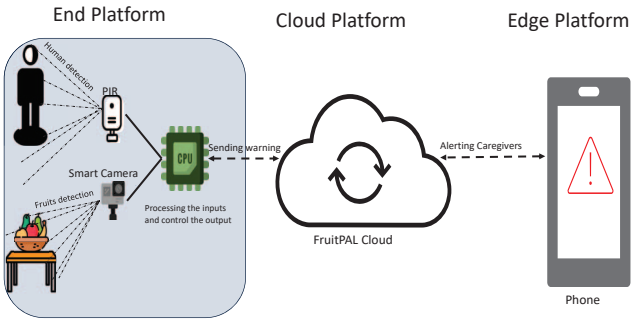

Fig. 2. Three Different Computing Platforms Visible in FruitPAL's Architecture: End Platform, Cloud Platform, and Edge Platform

B. End platform

In this stage, FruitPAL detects the fruit that cause allergies and sends the collected data to the next stage. Fig. 3 shows the end platform components, PIR and smart camera. The PIR sensor and smart camera work synchronously to provide a faster response. PIR is a movement sensor that detects humans and animals via their bodies' temperature [12]. The PIR sensor should be placed in a wide area that can detect the motion the allergic person easily. It is necessary to calculate the sensitivity.

For the second component of the first level, the smart camera is able to detect fruit that cause allergies. Excellent visual capabilities are required to acquire a high result accuracy.

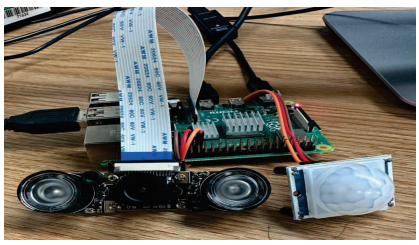

Fig. 3. End Platform

C. Cloud Platform & Edge Platform

The Cloud Platform connects the end platform with the edge platform. The communication between those two platforms are done by WiFi connection. The cloud platform receives requests from the end platform and warns the caregivers in the edge platform. The caregiver must respond to the warning that comes from the detection platform to ensure the danger is acknowledged. The warning comes to the caregiver as a phone call with voice messages. The warring stops when the allergic person responds, or the caregivers takes the required action.

As the object detector in FruitPAL, YOLOv8 has been used. It gives high accuracy and fast detection of the objects. Our dataset has around 3000 images that are collected from the Open Images Dataset V7 [13]. This dataset has high quality images that have been captured in different environments. There are 15 classes were used in our dataset which are Apple, Banana, Cantaloupe, Common Fig, Grape, Grapefruit, Lemon, Mango, Orange, Peach, Pear, Pineapple, Pomegranate, Strawberry, and Watermelon.

V. EXPERIMENTAL RESULTS

A. Hardware for Prototyping

The hardware components within the FruitPAL system exhibit high levels of effectiveness and efficiency. Nevertheless, it is possible to modify the PIR sensitivity as required. The calculation of the sensitivity of PIR sensor is imperative in order to effectively detect human motion [12]. The sensitivity of the PIR can be adjust using the following expression:

$$T_i = 24 \times R_9 \times C_7 \tag{1}$$

T_i is the sensitivity. Adjusting the values of the resistor (R_9) or capacitor (C_7) change of the value of the sensitivity. The higher and lower limits of responsiveness can be established based on the given equation. The highest point of responsiveness and lowest point of responsiveness can be expressed as:

$$T_i = 24 \times 1m * 0.01\mu F = 2.4 \quad seconds \tag{2}$$

$$T_X = 24 \times 1m \times 0.05\mu F = 12 \quad seconds \tag{3}$$

B. Datasets

All classes in the Allergic-fruit dataset are annotated into different approaches based on:

1- Whole fruit.
2- Cutting fruit.
3- Fruit with rot.
4- Fruit inside boxes.
5- Fruit max with others.

The pre-training model is a proficient approach employed for annotating fruits in the allergic-fruit dataset. At the beginning of creating the dataset, the MS COCO model which has 55.8% mAP (Mean Average Precision) is used. However, the MS COCO model has only three different kinds of fruit which are apple, banana, and orange. Three versions of the pre-trained model have been built at our end. The first version was trained based on the pictures annotated by the MS coco model. The second and third versions relied on the previous versions' pre-trained model. Fig. 4 illustrates that each version's improvement mAP, precision, and recall were dominated by the number of annotated images in the version of the allergic-dataset. Increasing the number of images that have been duplicated in the dataset has been done by image augmentation, generating synthetic images to enhance the model [14]. The overall quantity of the images in our dataset is 12000, split into training, validation, and testing sets.

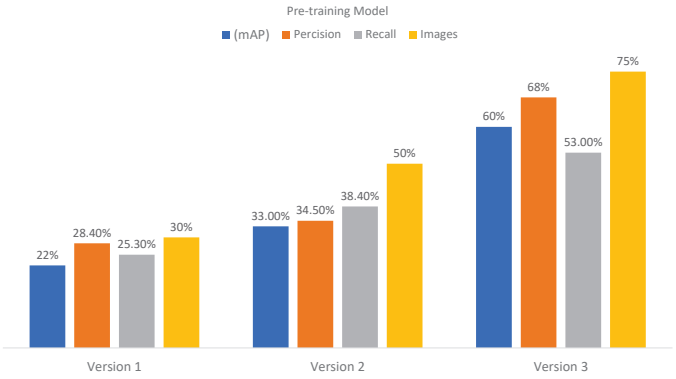

Fig. 4. Pre-trained Model used to annotated the allergic dataset.

C. Experiments

FruitPAL is a portable electronic device that can be positioned in any location. The computational performance of the model was assessed on a computing system equipped with an Intel Core i7-7700 processor operating at a clock speed of 3.60 GHz and 16 GB of RAM. For the implementation processes, we use a Raspberry Pi 4 with 4GB RAM in the end platform, as shown in Fig. 3. The model was trained on an A100 GPU a Google Colab GPU) with high RAM (40GB), and it has consumed around 16 hours to complete 100 epochs. Fig. 5 displays the model evaluation for the object detection model and interpreting into train box loss, class loss, and DFL loss. Also, the same image illustrates the validations as val box loss, class loss, DFL loss. Precision, recall, and mAP50 and 50-95 are metrics considered in our research work. The data is presented in two distinct formats in Fig. 5 and Table I. The confusion matrix in Fig. 6 presents the synopsis performance for each class of the model. As a summary of the FruitPAL model, we see how FruitPAL detects the fruit among the other objects in the captured picture (Fig. 7) while the FruitPAL device can detect the danger accurately. By combining the FruitPAL model part with the FruitPAL device, the allergic person has the possibility to avoid the fruit that jeopardizes his life.

TABLE I
METRICS

Precision	Recall	mAP50	mAP50-95
86%	77%	84%	66%

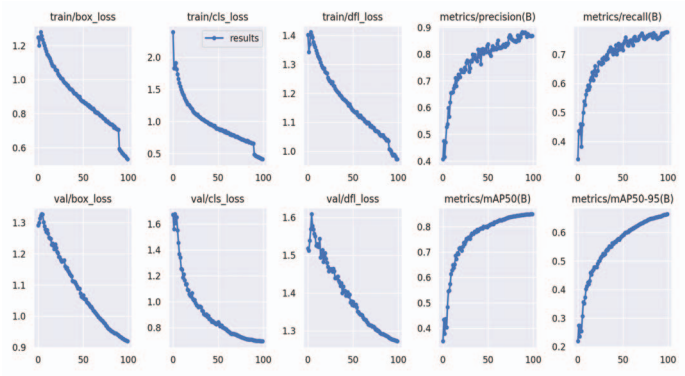

Fig. 5. Model Evaluation

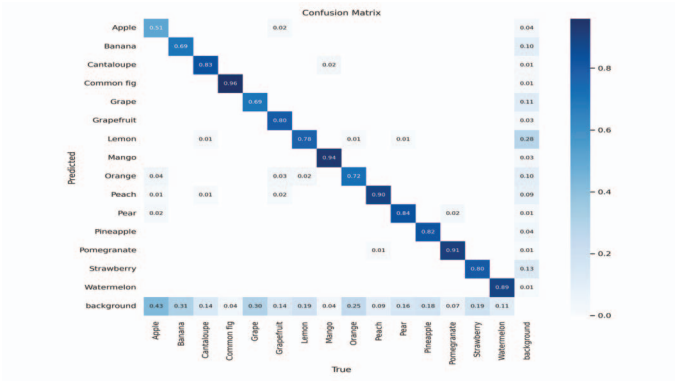

Fig. 6. Confusion Matrix

VI. Conclusion and Future Work

Fruit allergens could cause a significant harm for the allergic people. Previous research works discuss different ways to protect the humans form the allergic-causing fruits [4], [15], [16]. FruitPAL is a device that proposes to keep the allergic people monitored by the caregiver as a part of smart healthcare. One of the FruitPAL characteristics is to protect the people who suffer from health issues and eat fruit that cause allergies automatically.

Forthcoming research will delve into the system that caters to individuals with fruit allergies, without any proposed solutions being put forth. There is a need to improve the metrics.

Fig. 7. Fruit detection by FruitPAL

The proposed system is intended to use better hardware as well as classes of fruit will be added into the system. An initial version of the next phase of this ongoing research has been communicated to [17].

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