FoodPAL: A Method to Ensure Food Allergens Free Diet in Smart Healthcare Framework

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Abstract

The immune system plays a critical role protecting the body from pathogens and foreign substances. Food allergies produce disorders in the immune system. Young children (between one to three years old) start exploring the world by consuming any object that comes to their attention. Exploration skills being underrecognized pose a primary threat to a child's life. Children with allergies require increased oversight in the growth stage. This paper proposes a smart surveillance device called "FoodPAL" that can monitor toddlers' consumption. A hybrid approach for object detection is employed to optimize performance efficiency and resource utilization. A high-quality dataset was developed and used to train two state-of-the-art algorithms for the purpose of identifying allergenic foods. The objective of this research is for protecting the immune systems of children from dietary allergies.

Keywords: Smart Healthcare, Diet Monitoring, Healthcare Cyber-Physical System (H-CPS), Machine Learning.

1 INTRODUCTION

The curiosity of a child is a substantial factor for continuous learning throughout their life. Food allergies are a common type of immune system response that affects children. Around 5% of children under 5 years have food allergies from eggs, wheat, and peanuts [1]. Food allergies may be diagnosed by feeding small quantities of several kinds of food. Within a short period of time, ranging from minutes to an hour, the immune system initiates a response, leading to the emergence of certain symptoms in the child. Some symptoms are visibly evident, such as changes in the skin, while others may be recognized as soreness. Fig. 1 displays the different symptoms of food allergy. Death also can occur when an individual's immune system has an inappropriate reaction to a certain foods [2]. The child has to be sent to the emergency room without delay if such symptoms occur. As children grow, supervising them becomes more challenging due to their innate curiosity and willingness to explore everything.

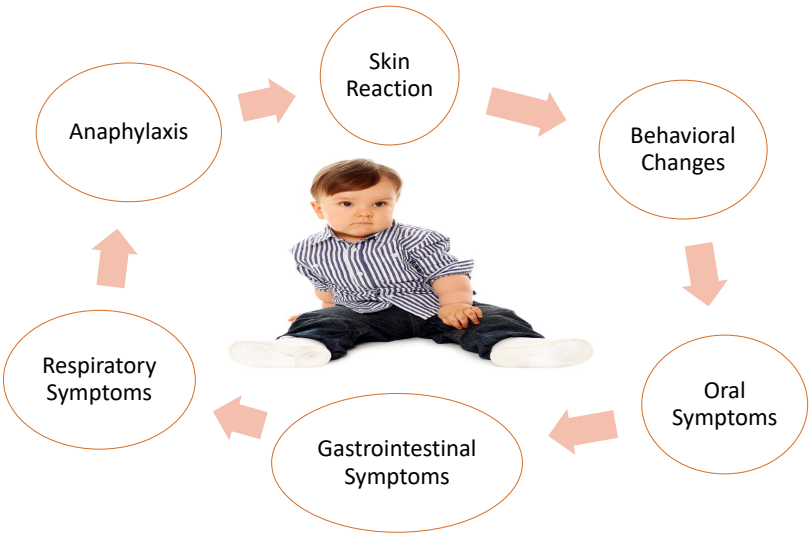

Fig. 1 The Symptoms Of Food Allergies

The children lack the ability to perceive the potential harm of objects without physically interacting with or consuming them. After the children experiences dangerous objects, they begin to avoid them. For instance, they do not understand the hot water without physically touching it. However, the allergic foods might have sweet taste, so they will face difficulty recognizing the danger. Moreover, the allergic reactions to food have a systemic impact on the entire body, making it challenging for children to discern the source of the error. As long as they find the flavor enjoyable, they will persist in their attempts to consume the meal.

The paper introduces "FoodPAL", a state-of-the-art device for monitoring toddlers' food. This aims to assist parents in monitoring their children and safeguarding them from allergenic foods. Hybrid methodologies are used to construct real-time

systems for object detection. The system leverages both edge-based and cloud-based processing techniques to enhance performance efficiency and optimize resource utilization. YOLOv8 (You Only Look Once) was used to train the collected dataset, and it is hosted on the cloud. YOLOv8 is a powerful and efficient tool that was utilized to detect the collected image. The SSD-MobileNetV2 model is a lightweight model designed for edge-based to deploy on the captured images. The lightweight model can help reduce the load on the cloud infrastructure. A high-quality dataset consisting of the six most common types of allergenic foods is used to create the models. FoodPAL is surveillance to ensure the food allergens is free diet.

The current paper was structured in the following sections. Novel contributions section 2 has disuses the problem 2.1, proposed solution 2.2, and novel solutions 2.3. Various studies on related work are discussed in detail 3. The strategy described in section 4 has been thoroughly explained, providing detailed information regarding the method. The experimental results were explained on section 5. The final section, section 6, offers a concise overview of the primary themes discussed, and also discusses future work.

2 NOVEL CONTRIBUTIONS

2.1 Problems Addressed in Current Paper

Numerous children experience food allergies, necessitating close monitoring. Monitoring children became challenging due to growth stage. The life-threatening allergic reaction can limit child exploration. Food allergies should not hinder the daily development of new abilities. Human surveillance is subject to limitations due to limited ability for continuous observation.

2.2 Proposed Solution

A real-time surveillance device has the capability to precisely identify allergic foods both via device-based and cloud-based procedures. Device-based use a lightweight model to deploy the captured image by smart camera. Once it detects a object, the image will be transferred to the cloud. A powerful model in the cloud will determine whether or not to send an alarm.

2.3 Novel Solutions Proposed

The novelties of the proposed FoodPAL:

- A hybrid approach for object detection enables FoodPAL to accomplish a significant degree of accuracy in its detection capabilities.
- The proposed work is fully automatic and functions to protect children.
- Lower latency connection between the cloud and edge device technique is involved.
- Lower load on the cloud will reduce the cost of the cloud.
- The system is adapting modifications through the cloud.
- The notification is received through the smartphone.

3 RELATED WORK

Different approaches under smart healthcare have been employed to take care of children. The table 2 presents an explanation of the various approaches used in smart healthcare for children. Assistive, entertainment, and monitoring devices has been adopt in prior works. However, predicting the danger is the objective of the current work to increase the child's wellness.

Table 1 Different Approaches in Smart Healthcare for Children

Category	Device/Technology	Purpose
Assistive Devices	Humanoid robot [3]	Helps disabled children interact with others
	Robotic hand [4]	Assists children with neurological disorders, improves hand function
	Android terminal [5]	Supports children with hearing loss
	Reading Robot [6]	Enhances the level of learning for Intellectual Disability
Entertainment Devices	Down children game [7]	Enhances physical and intellectual skills
	Library application [8]	Captures children's interests and promotes engagement
	NAO robot [9]	Provides entertainment during the COVID-19 epidemic
	2D game [10]	Developed specifically for educating dyslexic children
Monitoring Devices	Vision and voice recognition [11, 12]	Monitors dietary intake and improves wellness
	Monitoring of food consumption [13]	Enhances children's health by monitoring food intake
	Fruit allergen detection [2]	Real-time device to help caregivers monitor fruit allergens
	Sound monitoring device [14]	Monitors chewing and eating sounds to track food intake

In the term assist apparatus, a human robot has been employed to help the disabled children interacting with other children in [3]. Neurological disorders "can cause weakness hand function" was considered on [4] by creating robotic hand. Android terminal was used to assist the children with hearing loss [5]. A robot has been employed to read the QR code on learning cards in order to assist children with intellectual disabilities [6]. Deploying aid devices is essential to help disabled children; however, predicting their needs should be considered.

Controlling the entertainment of the children is crucial to support the children's mental health. Down children game was designed to enhance their physical and intellectual skill on [7]. A Library application that allows children to capture interest of the children was present on [8]. Reprogramming the NAO robot to do dance routines and kick a ball offers an important solution for children's entertainment during the

COVID-19 epidemic [9]. A 2D game was developed specifically for the purpose of educating dyslexic children, including visually engaging graphics and limited text [10]. Children should adapt physical activity to increase their creative skills.

Computer vision and voice recognition have been operated in different prior work to monitor dietary intake. Monitoring food consummation was handled to enhance wholesomeness in [11, 12]. The relationships between the food intake and level of stress was explained and solved in [13]. Fruit allergens was considered on real time device to help the caregivers in [2]. Two microUsers to record sounds of chewing and eating for monitoring food intake was explained on [14]. However, the prior research forced on monitoring the food consumption before or during the action of consumeing the food. FoodPAL is a state of the art that contains two stages of object detection to predict the danger of the food allergens.

4 THE PROPOSED METHOD - FOODPAL

4.1 Overview

The proposed work is a surveillance device that can be installed in a children's play area. Fig. 2 explains the different levels of FoodPAL's architecture, which are Edge Level, FoodPAL Cloud, User Level, and ER (Emergency Room) Level. Fig. 3 illustrates the progression of data across each stage. The high-quality camera captures and analyzes the images on a lightweight model. When the system identifies food allergies, it automatically transfers the images to the cloud. The cloud deploys a highly accurate model on the transferred image to identify the types of allergic foods. Furthermore, the cloud level enables notifications to be delivered to the caregiver or ER. Users use the app to receive notifications and dismiss them as needed. If there are any problems with delivering notifications or if the notifications are being silenced, the system will automatically contact the emergency report. Food allergies were the reason for the death.

4.2 Edge Level

The Edge Level's purpose is to protect the child from food allergies. At this level, the primary element consists of a smart camera that collect pictures and transmit them to the model. The lightweight model classifies each item inside the pictures. Once the specific food that causes an allergic reaction is identified, the picture that was recognized will be sent to S3 (Simple Storage Service) via an Internet connection. On the other hand, the empty picture will be eliminated. Fig. 4 displays the hardware setup which Raspberry Pi, and EMEET-HD-1080P camera. Raspberry Pi employed as processing unit that handle capturing frame and deploy the lightweight model on them. The equation below explains the number of the image the EMEET-HD-1080P camera can capture per second.

$$IPS = FPS * S \tag{1}$$

The EMEET-HD-1080P camera can capture 30 frames per second (FPS). S stands for the amount of time, measured in seconds, that the camera is taking pictures.

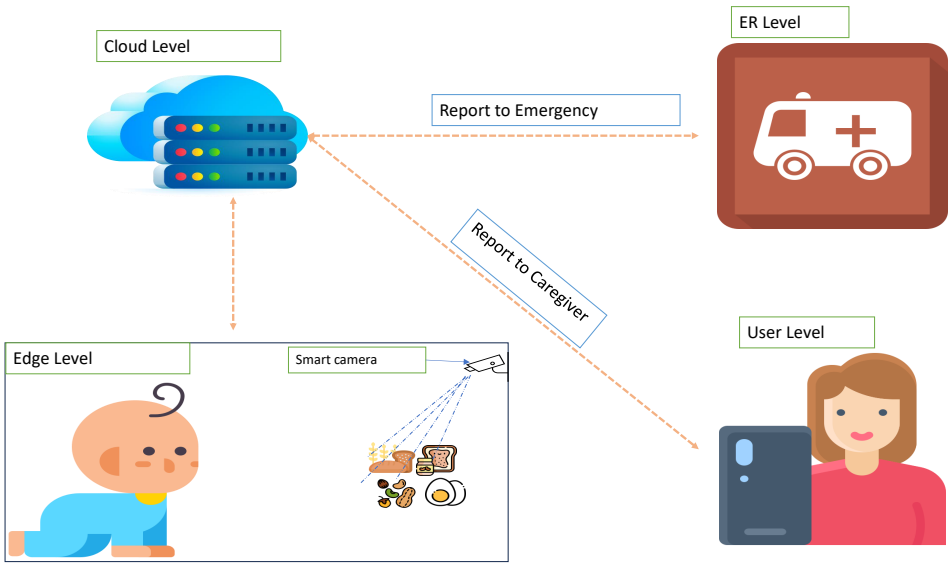

Fig. 2 FoodPAL's architecture

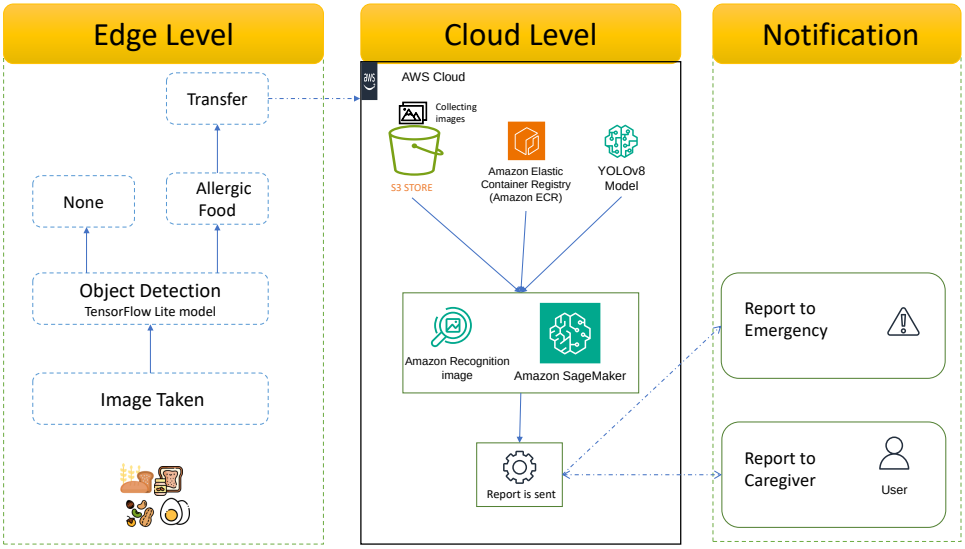

Fig. 3 FoodPAL's Pipeline

4.3 FoodPAL Cloud

Amazon Web Services (AWS) is used to analyze the reviving data that was provided from the Start Level. The buckets host the detected images and YOLOv8 model. Fully managed container Amazon Elastic Container (ECR) host Ultralytics Docker Images [15]. SageMaker deploys the YOLOv8 model on the transferred images. Additionally,

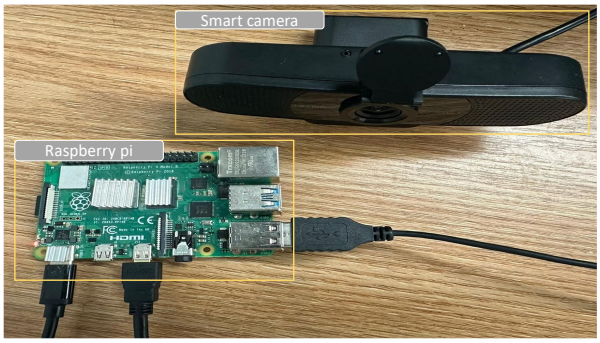

Fig. 4 FoodPAL's Hardware Setup

the Cloud Level serves as a channel for communication between the Edge Level and the Notification Level. The caregivers will be alerted through their smart phones. If there is a failure or missing delivery, an alarm will be sent to the emergency room along with location information. The caregiver can choose the allergic food that might affect the child through the Cloud Level.

4.4 User Level & ER Level

The purpose of the User Level is to promptly get notifications when a child may be in contact with allergenic foods. The caregiver should immediately react to the alarm. Alternatively, if not done, the report will be sent to the Emergency Room to ensure the protection of children's lives from allergic food.

5 EXPERIMENTAL RESULTS

5.1 Model

FoodPAL was build with integrated approach for detecting allergenic foods. On the Edge Level, the Raspberry Pi is used by a lightweight model to carry out first detection. The SSD-MobileNetV2 is a lightweight object detection model designed to be highly efficient for processing resources with limitations, such as embedded systems. In order to improve the level of detection, the powerful object detection model YOLOv8 was used on the Cloud Level.

AWS SageMaler endpoint "powerful cloud" hosts the YOLOv8 model to detect allergenic foods. YOLOv8 was trained on GPU that provide by Google Colab. The duration for completing one hundred epochs was roughly three hours. mAP50 (mean average precision at 50% IoU), mAP50-90 (mean average precision from 50% to 90% IoU), precision, and recall over the iterations are presented in Fig. 5. The Table. 2 summers ever metrics for YOLOv8 model. Figure 6 shows the box_loss, cls_loss, and dfl_loss during training. Both the box_loss and cls_loss decreased over the epochs. Additionally, Figure 6 illustrates these same losses—box_loss, cls_loss, and dfl_loss—on the validation set.

The Fig. 7 displays different detection for the 6 classes using YOLOv8. The classes stare form 0 to 5 as (milk, sea food, egg, wheat(rice and bread), and peanut butter).

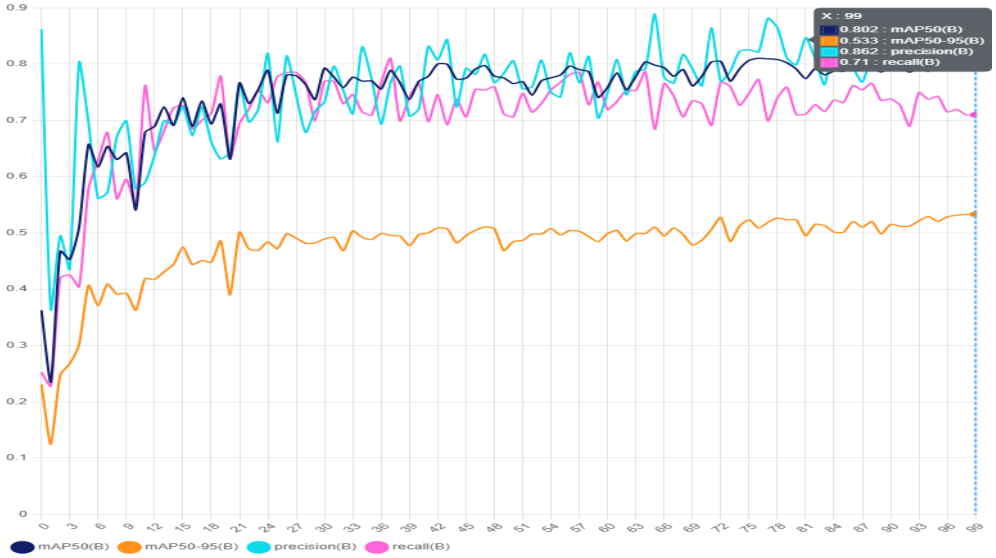

Fig. 5 mAP50, mAP50-90, percision, and recall over the iterations

Table 2 Performance Metrics of YOLOv8

Epochs	Precision	Recall	mAP50	mAP50-95
100	86%	71%	80%	53%

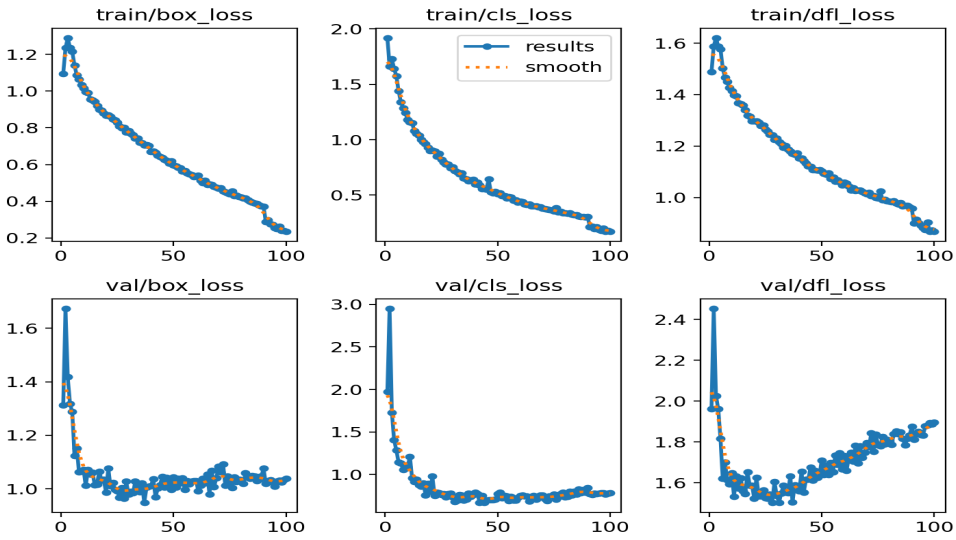

Fig. 6 YOLOv8 model evaluation

Fig. 7 Object detection using YOLOv8

Lightweight model was hosted in embedded system. It is concerned as first step to filtering the images before sending them to cloud level. The SSD-MobileNetV2 model was trained on a Google Colab GPU, and the training process took around 6 hours. The training process consists of a total of 40,000 stages, with each step including a batch size of 16. The Fig. 8 explains the loss Classification, Localization, Regularization, and Total Loss. SSD-MobileNetV2 model detects rice at 61% threshold value in Fig. 9.

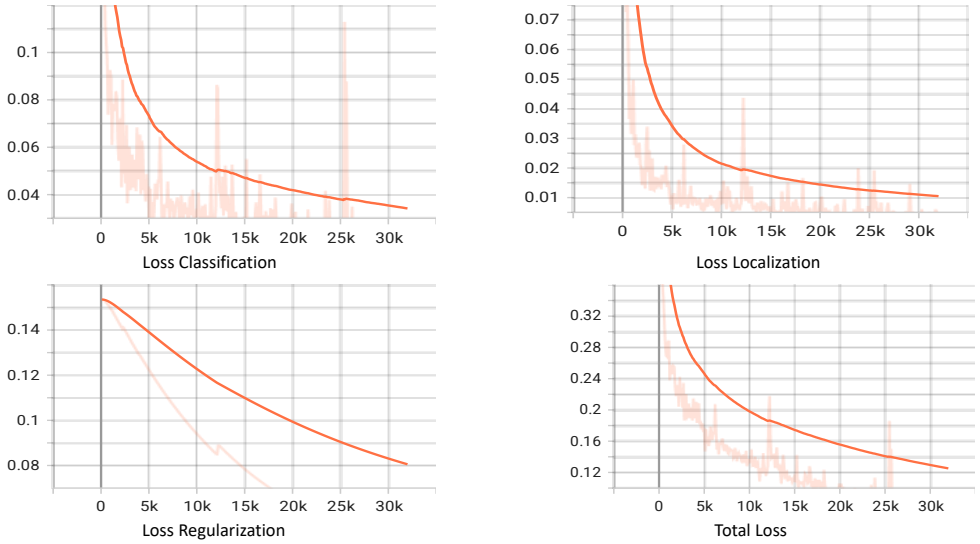

Fig. 8 SSD-MobileNetV2 model evaluation

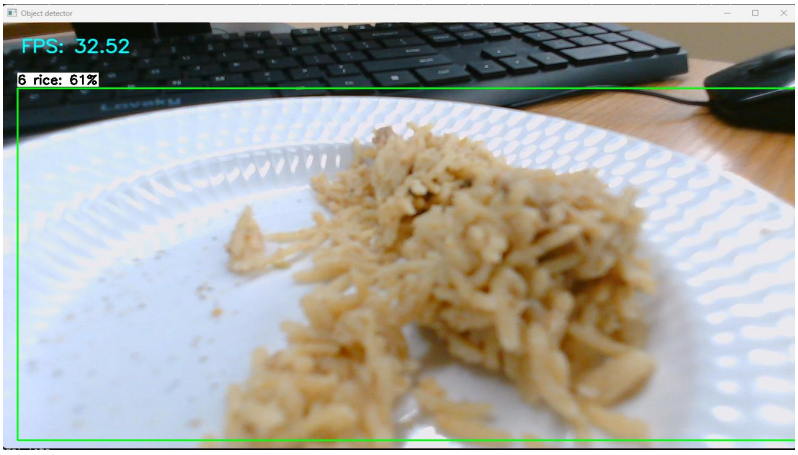

Fig. 9 Object detection using SSD-MobileNetV2

5.2 Dataset

The dataset has the 6 kind of allergic food that most likely cause allergy, which are milk, seafood, egg, wheat(rice and bread), and peanut butter. The food-set dataset contains 1236 images [16]. The images were collected for different datasets [17–20]. The number of the annotations are 2149 boxes, which are 1.7 average per image across 6 classes. The size of the image are 640*640 square. The augmentations Flip (Horizontal and Vertical) and Noise (Up to 0.22% of pixels) are used to increase number of image to 4139 images. The dataset was divided into three parts: a training set, a validation set, and a test set.

6 CONCLUSION AND FUTURE WORK

Food allergies impose a substantial burden on children who are afflicted, resulting in the imposition of dietary limitations, apprehension of inadvertent responses, and a worse overall quality of life. The main motivation for this study is to protect children from allergy-causing foods. The FoodPAL system consists of two components that are designed to provide high accuracy, reduced latency, enhanced flexibility, and cheaper cost. A combination of approaches relies on both the hardware component and the cloud component. The Edge Level utilizes the SSD-MobileNetV2, which is a lightweight model. Lightweight not only decreases latency, but also minimizes the load on the cloud. YOLOv8 model deploys the images that were sent through the internet.

Upcoming research will focus on enhancing children's protection. Expanding the number of classes might be beneficial in order to address a wider range of allergies. Furthermore, it is necessary to enhance the performance metrics for a hybrid approach.

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