FruitPAL 2.0: A Smart Healthcare Framework for Automatic Monitoring of Fruit Consumption

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***Abstract*—Consuming a wide variety of fruits can provide a multitude of health benefits. Fruits provide healthy nutrition, including vitamins and dietary fiber, that contribute to the promotion of human health. Consuming a diverse range of fruits, including all sorts and hues, is essential for providing the body with a comprehensive array of essential nutrients [1]. Having fruit every day could provide numerous advantages to the human body such as losing weight, providing vitamins, and reducing the risk of diseases. This paper proposes a real-time device that can monitor the level of intake of fruits, which is called FruitPAL 2.0. FruitPAL 2.0 issues a daily report on fruit consumption, which includes detailed information on the many benefits associated with each type of fruit that is consumed. YOLOv5, the most popular iteration of the YOLO family, has been used as the core of FruitPAL 2.0. The main objective of the proposed device is to increase the regular consumption of fruits.**

***Index Terms*—Smart Healthcare, Diet Monitoring, Healthcare Cyber-Physical System (H-CPS), Deep Learning.**

I. Introduction

Consumption of fruits supplies the human body with a diverse range of vitamins, which could boost the immune system. For instance, oranges and bananas are examples of fruits that contain vitamin C [2]. Consumption of fruits has been shown to help lower disease risk such as cardiovascular and metabolic syndrome [3]. However, many individuals fail to incorporate the consumption of a sufficient quantity of fruits into their daily dietary routine. 76% of Americans, according to a 2015 report by the Centers for Disease Control and Prevention, do not consume enough fruit daily [4].

This paper proposes FruitPAL 2.0 (automatic monitoring of fruit consumption), a novel method for encouraging consumers to consume fruit daily. The many health perks of fruit can be achieved with FruitPAL 2.0. The primary aim of FruitPAL 2.0 is to provide valuable insights into fruit nutrients.

Fig. 1 illustrates the various vitamins and minerals that can be promoted by FruitPAL 2.0.

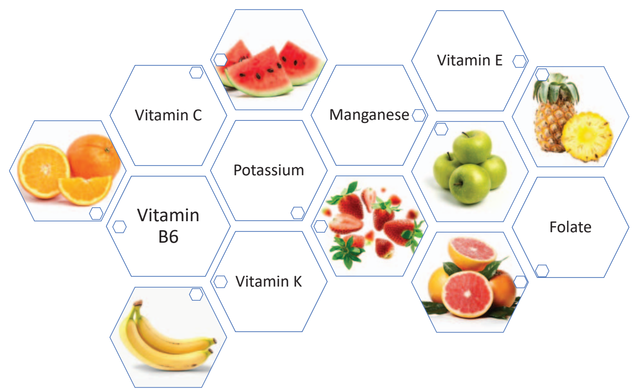

Fig. 1. The vitamins FruitPAL 2.0 promotes

II. NOVEL CONTRIBUTIONS

A. Problems Addressed in Current Paper

Many vitamins and minerals are found in fruit. Since fruits have healthy nutrients, we should eat them every day. Reduction in eating fruit can cause vitamin deficiency, weight gain, and cardiovascular disease. Numerous studies advise people to add fruit in their daily intake because of their nutrients [1], [2], [4], [5]. So, encouraging the community to eating fruit can increase public health.

B. Novel Solutions Proposed

Fifteen different fruit types can be accurately detected by using the proposed FruitPAL 2.0. It is a real-time device that can detect and analyze fruit intake. Then, it notifies the user about the nutrients of the fruit they ate.

- The proposed work automatically detects and analyzes the fruits that were eaten.
- FruitPAL 2.0 has the ability to classify fifteen types of fruit.

- The nutrient information message is automatically sent to the consumer on time.

C. *FruitPAL vs FruitPAL 2.0*

FruitPAL 2.0 represents an updated iteration of FruitPAL [13]. The main objective of FruitPAL 2.0 is to encourage individuals to consume fruit. On the other hand, FruitPAL refers to the automated identification of fruit allergens. Both devices utilize the Allergic-fruit dataset [6]. However, FruitPAL 2.0 has improved metrics in comparison to FruitPAL.

III. Related Work

Most of the studies done before are focused on identifying the quality and nutrition of the food. The objective of prior researches was increasing the wellness of people by reducing food consumption. However, the current paper focuses on the promotion of fruit eating as a way of enhancing general health. One notable advantage is a device that is fully automatic.

The prior researches adopt various methodologies to evaluate the quality of the food. Using image segmentation to classify the quality of Manalagi apple in smart agriculture was discussed in [7]. The Dietary Intake Monitoring System was proposed in [8] to quantify the temperature of food and monitor changes in weight for the contents of a patient's plate. Fruit in storage was evaluated for quality via laser diagnostics in [9].

The detection of food consumed can be achieved through the classification of sound. Monitoring food consumption using two microUsers to capture sounds of swallowing and eating was presented in [10]. A wearable device on the neck that can detect sound of solid and liquid food and keeps track of eating habits was presented in [11]. A wearable sensor level with a microphone and a camera is made to identify the chewing activity based on the sound features and video sequence analysis and the recording of the order in the consumption rate [12]. Nevertheless, the analysis of sound was inefficient and led to the dissemination of inaccurate information.

An automatic approach can enhance convenience and efficiency. FruitPAL, a real-time device to detect fruit that causes allergies, was presented in [13]. A wearable device to detect food nutrition automatically is discussed in [14]. [15] discusses the food intake related to stress whereas a smart mobile application to automatically analyze images and show the food's nutritional value was proposed in [16]. A smartphone app called DiaWear that tracks calories for people who need to control their dietary habits is given in [17]. However, these approaches alert people about unhealthy nutritional intake, but the proposed device encourages consumption of fruits that are high in nutrients.

Various researchers documented different approaches under the umbrella of smart healthcare, and they addressed various challenges. Our work is an automatic device that encourages people to consume healthy nutrition.

IV. The Proposed Work: FruitPAL 2.0

A. *Overview*

Three levels are illustrated in Fig. 2 to explain FruitPAL 2.0's architecture. The camera captures a photo when the power supply is turned on. The photo will be detected by the YOLOv5m model. The results can be analyzed and sent to the next level, which is the cloud Level. The feature of the cloud Level is to send a text message to phone at the user Level at a specific time. The text message contains a list of all the vitamins in the fruit that was eaten. Wireless commutation is applied between levels. Most work is done at the device Level to reduce the cloud cost. The cloud Level is a communication station between the device and user levels.

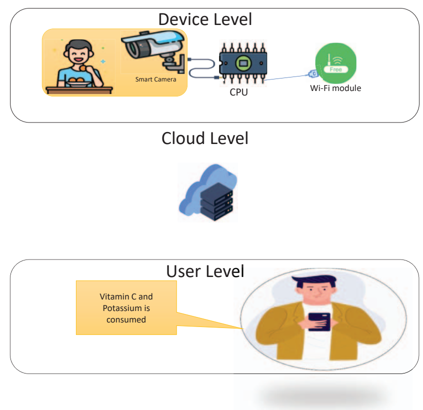

Fig. 2. FruitPAL 2.0's architecture shows three different computing Levels: Device Level, Cloud Level, and User Level

Fig. 3 illustrates how each level works to identify the fruit being consumed and to deliver a text message. All functions are automatic. The image capture, detection, and analysis are done at the device level. Once the message is issued, it is sent to the user by the cloud level. The message is sent every day at a specific time to avoid annoying the users. System restart is done at the user level when new fruits are added to the plate.

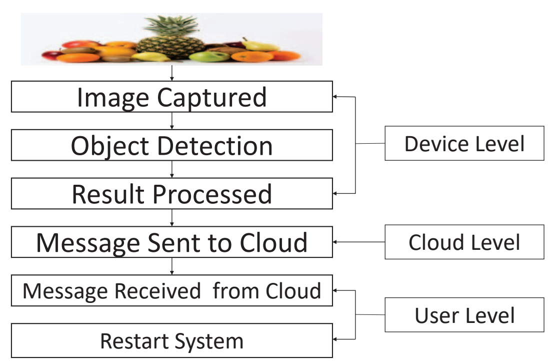

Fig. 3. FruitPAL 2.0 Workflow

B. *Device Level*

The image is taken by the smart camera once the device is active. YOLOv5m mode is applied on captured images as in [18]. The initial fruit list is stored after the fruit has been identified. Every hour, the fruit in the dish is detected. A new list is created and compared with the original list to show the consumed fruits. The nutrient value from each eaten fruit is provided based on Table I. The consumed nutrients is written on a text message, and it is provided at a specific time. Table I shows the nutrition for each fruit group [2]. The message provides a summary of the nutrition that was consumed throughout the day. However, the system automatically restarts every morning to update the original list.

TABLE I
FRUITS NUTRITIONAL

Group	Nutrients	Fruits
Citrus Fruits	Vitamin C and Potassium	Grapefruit, Lemon, and Orange.
Tropical Fruits	Vitamin B6 and C	Banana, Mango, and Pineapple.
Pome Fruits	Vitamin C and Manganese	Apple, Common fig, and Pomegranate.
Stone Fruits	Vitamins A, C, and E	Peach and Pear.
Melons Fruits	Vitamins A and C	Cantaloupe and Watermelon.
Berries Fruits	Vitamin K and Folate	Grape and Strawberry.

1) Dataset: The model uses the Allergic-fruit dataset [6]. Allergic-fruit dataset images were collected from Open Images Dataset V7 [19]. The collected images contain 3173 annotated images, based on whole or cut fruits. To increase the accuracy of the dataset, image augmentation has been applied on the collected images, which are:

- Grayscale: Applied to 3% of images.
- Saturation: Between -5% and +5%.
- Brightness:Between -10% and +10%.
- Exposure: Between -10% and +10%.
- Blur: Up to 0.5px.
- Noise: Up to 1% of pixels.
- Mosaic: Applied.

Image augmentation increased the number of the images in the dataset to 12061 images. The images were split into Training, Validation, and Testing sets. Fifteen fruits: Apple, Banana, Cantaloupe, Common fig, Grape, Grapefruit, Lemon, Mango, Orange, Peach, Pear, Pineapple, Pomegranate, Strawberry, and Watermelon, can be detected.

C. Cloud Level & User Level

The link between device level and user level is the cloud level. The text message is created by the device level. It is sent to user level by the cloud level. Users do not need an Internet connection to receive the message due to GSM.

V. EXPERIMENTAL RESULTS

A. Model

FruitPAL 2.0 is a mobile electronic device that can be placed in the dining room to monitor fruit consumption. YOLOv5m has been utilized as the object detector in FruitPAL 2.0. High timer response and accuracy were achieved. A T4 GPU with 40GB of RAM was used for training the model. The model was evaluated on a Microsoft Surface Pro 7 that has Intel I5-1035G4 CPU, 8GB RAM, and 256GB SSD. Fig. 5 illustrates the model evaluation process for the object detection model, focusing on the analysis of the train box loss, class loss, and DFL loss. It serves to exemplify many forms of validation, such as val box loss, class loss, and DFL loss. The metrics of precision, recall, mAP50, and mAP50-95 are displayed in Fig. 6. The performance for each class of the model is illustrated in Fig. 7. Open Neural Network Exchange (ONNX) is involved to exchange YOLOv5 model from PyTorch to TensorFlow lite. TensorFlow lite is suitable for end devices [20].

B. Hardware

A Raspberry pi 4 with 8GB RAM and pi camera is used at the device level, as shown in Fig. 4. Fig. 8 shows test results. With a high performance model and fast end device, FruitPAL 2.0 can encourage users to increase fruits consumption.

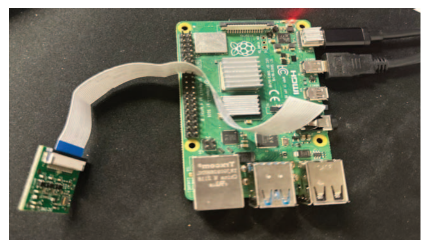

Fig. 4. Device Level

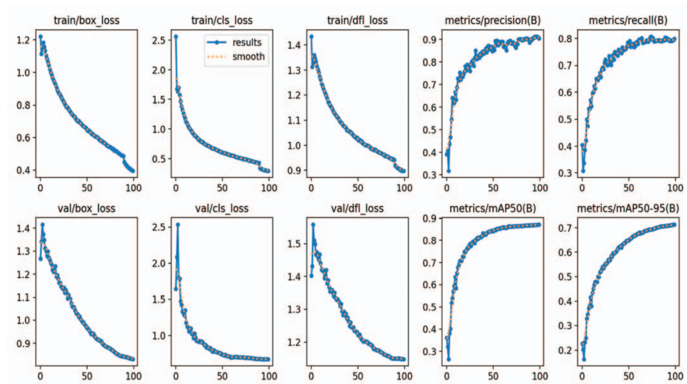

Fig. 5. Model Evaluation

VI. CONCLUSION AND FUTURE WORK

Consuming fruits contributes to the enhancement of overall health through the provision of essential nutrients [2], [3], [21], [22]. Nutritionists encourage the consumption of fruits due to their potential role in preventing diseases [23]. The proposed work is a fully automatic device that can monitor fruit consumption. One of the notable features of FruitPAL 2.0 is to motivate people to consume fruit on every day.

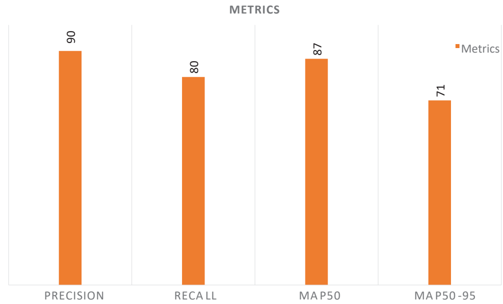

Fig. 6. Performance Metrics of FruitPAL 2.0

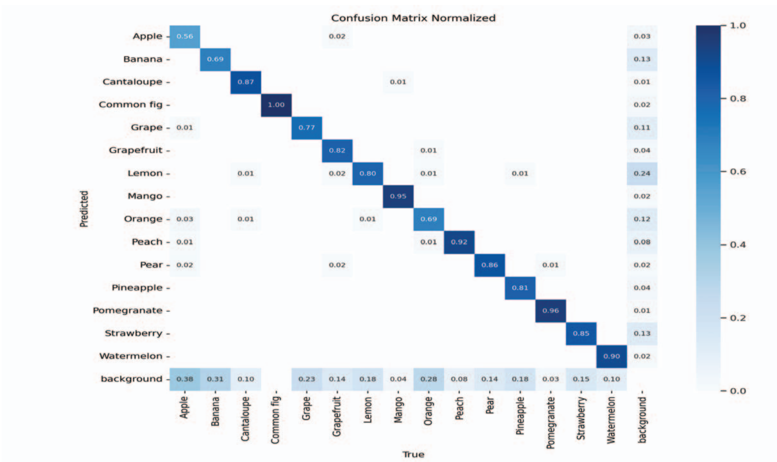

Fig. 7. Confusion Matrix

Monitoring fruit consumption with higher efficiency and versatility will be considered in forthcoming research. The addition of new fruit classes and improved hardware will be incorporated within the system.

References

[1] "Vegetables and fruits." [Online]. Available: https://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/vegetables-and-fruits

[2] K. D. Sade Meeks, "20 healthy fruits that are super nutritious." [Online]. Available: https://www.healthline.com/nutrition/healthy-fruit

Fig. 8. Fruit detection by FruitPAL 2.0

[3] N. Butler, "Soluble and insoluble fiber," 2017. [Online]. Available: https://www.medicalnewstoday.com/articles/319176

[4] T. Calvo, "The truth about the sugar in fruits." [Online]. Available: https://www.consumerreports.org/diet-nutrition/sugar-in-fruit/

[5] L. Natalie Olsen, R.D., "Do you have a citrus allergy? learn the symptoms," *Healthline*. [Online]. Available: https://www.healthline.com/health/citrus-allergy

[6] "Allergic-fruit dataset." [Online]. Available: https://app.roboflow.com/unt-eh3cu/allergic-fruit-a9ixh/15

[7] M. Muladi, D. Lestari, and D. T. Prasetyo, "Classification of eligibility consumption of manalagi apple fruit varieties using backpropagation," in *Proc. of the International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)*, 2019, pp. 75–79.

[8] K. T. Ofei, M. Dobroczyński, M. Holst, H. H. Rasmussen, and B. E. Mikkelsen, "The dietary intake monitoring system (dims): an innovative device for capturing patient's food choice, food intake and plate waste in a hospital setting," 2014. [Online]. Available: https://api.semanticscholar.org/CorpusID:32549097

[9] A. Michtchenko, M. Hernandez-Vizuet, and O. Budagovskaya, "Laser diagnostics of fruits in storage," in *Proc. of the 9th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE)*, 2012, pp. 1–3.

[10] S. Päßler and W.-J. Fischer, "Acoustical method for objective food intake monitoring using a wearable sensor system," in *Proc. of the 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops*, 2011, pp. 266–269.

[11] H. Kalantarian, N. Alshurafa, and M. Sarrafzadeh, "A wearable nutrition monitoring system," in *Proc. of the 11th International Conference on Wearable and Implantable Body Sensor Networks*, 2014, pp. 75–80.

[12] J. Liu, E. Johns, L. Atallah, C. Pettitt, B. Lo, G. Frost, and G.-Z. Yang, "An intelligent food-intake monitoring system using wearable sensors," in *Proc. of the Ninth International Conference on Wearable and Implantable Body Sensor Networks*, 2012, pp. 154–160.

[13] A. Alkinani, A. Mitra, S. P. Mohanty, and E. Kougianos, "FruitPAL: a smart healthcare framework for automatic detection of fruit allergens," in *Proc. of the IEEE International Symposium on Smart Electronic Systems (iSES) (IEEE-iSES-2023)*, Ahmedabad, India, Dec. 2023, p. 4.

[14] H. Jiang, J. Starkman, M. Liu, and M.-C. Huang, "Food nutrition visualization on google glass: Design tradeoff and field evaluation," *IEEE Consumer Electronics Magazine*, vol. 7, no. 3, pp. 21–31, 2018.

[15] L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT," *IEEE Transactions on Consumer Electronics*, vol. 66, no. 2, pp. 115–124, 2020.

[16] Mitra, Alakananda and Goel, Sarang and Mohanty, Saraju P. and Kougianos, Elias and Rachakonda, Laavanya, "iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare," in *Proc. of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. 683–688.

[17] G. Shroff, A. Smailagic, and D. P. Siewiorek, "Wearable context-aware food recognition for calorie monitoring," in *Proc. of the 12th IEEE International Symposium on Wearable Computers*, 2008, pp. 119–120.

[18] A. Mitra, S. P. Mohanty, and E. Kougianos, "aGROdet 2.0: An Automated Real-Time Approach for Multiclass Plant Disease Detection," *SN Computer Science*, vol. 4, no. 5, p. 657, 2023.

[19] "Open Images Dataset V7." [Online]. Available: https://storage.googleapis.com/openimages/web/index.html

[20] "TensorFlow Lite." [Online]. Available: https://www.tensorflow.org/lite/guide

[21] S. McMurray, "Sugar content in fruit: Is it damaging to your health and waistline?" [Online]. Available: https://universityhealthnews.com/daily/nutrition/high-sugar-content-fruit-damaging-health-waistline/

[22] N. Butler, "What is nutrition, and why does it matter?" 2020. [Online]. Available: https://www.medicalnewstoday.com/articles/160774

[23] S. Garone, "6 incredible effects of eating fruit every day, say dietitians," 2022. [Online]. Available: https://www.eatthis.com/incredible-effects-eating-fruit-every-day/