AUTOMATIC ELECTRONIC SYSTEM FOR EXTRACTION OF MORPHOLOGICAL CHARACTERISTICS OF CROPS

Renan O. Fersura, Rafael G. Alves, Fabio Lima, Italo M. R. Guedes and Salvador P. Gimenez
FEI University Center
e-mail: unierfersura@fei.edu.br

1. Abstract

Population growth and technological advances require an increase of 50% in food production by 2050, according to the United Nations (UN). In this context, urban food production through vertical farms emerges as a solution to ensure food supply in cities. These vertical farms control environmental conditions, but few studies monitor the morphological characteristics of plants. This project aims to develop a system to extract these characteristics using sensors and nanoprocessors, with data sent to an Internet of Things (IoT) platform, assisting in decision-making to optimize cultivation. The main results of this work reveal that crop growth capture using an ESP32-CAM and a color filter is applicable and promising.

Keywords - Vertical farm, morphological characteristics extraction, computer vision.

2. Introduction

According to the organization of the United Nations (2013), agriculture has maintained its share of 4% of the global Gross Domestic Product (GDP) since 2000, despite an 84% increase in added value. In 2022, approximately 735 million people faced hunger, while agricultural land use decreased, and many countries suffered from high levels of water stress [1]. In this context, food production in urban centers emerges as a crucial strategy for global food security through the so-called vertical farms or plant factories [2],[3]. In these facilities, multiple layers of crops are arranged in vertical beds, where they receive artificial lighting that, due to its characteristics such as the photoperiod, quality, quantity, homogeneity, and pulsation, directly influences crop growth performance [4], [5]. Traditionally, crop evaluation, considering morphological and physiological aspects, is performed manually after the harvest. However, applying automatic systems based on computer vision enables near real-time analysis, although few studies have explored this technology in vertical farms [5]. Sensors, such as cameras and load cells, integrated with microcontrollers, can obtain the essential data for this evaluation. This data can be stored and used for decision-making, with Internet of Things (IoT) platforms being a promising solution for real-time monitoring and control of crop systems [6].

3. Methodology and Technologies Used

This Section describes the main methodologies and technologies employed in developing the automated monitoring system for crops in vertical farms.

3.1 ESP32-CAM Data Collection

The ESP32-CAM is an affordable ESP32 nanocontroller that integrates Wi-Fi, Bluetooth, and a megapixel (MP) camera of two megapixels for remote crop monitoring. It captures images to track plant growth and is programmed via Arduino or ESP-IDF, with communication established through Wi-Fi.

Figure 1 –The ESP32-CAM and its essential pins, such as GPIO (for digital signals), power pins, and serial communication pins, which are essential for data control and transmission.

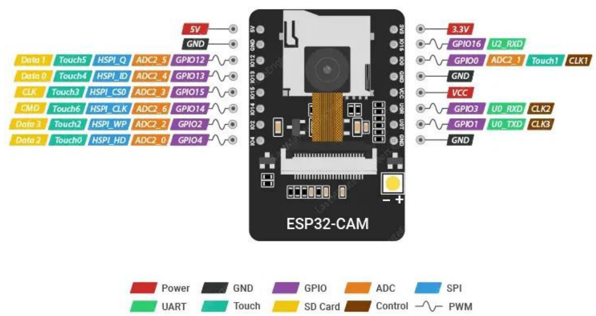

Fig.1. *Last Minute Engineers, 2024*.

The data are collected through sensors such as cameras and load cells, which provide detailed crop information. The captured images are sent for processing, while the load cells measure the total weight of the crop, including shoots and roots (Oliveira, 2019 [7]).

3.2 Image Processing and Computer Vision

The images undergo processing, which converts the color space from RGB (Figure 2.a) to Hue, Saturation, Value (HSV) (Figure 2.b) format, as illustrated in Fig. 2, facilitating hue segmentation to detect the plant area, shoot height, and leaf coloration, using filtering and contour detection technique [8].

Figure 2 – RGB and HSV formats, highlighting how this transformation isolates areas of interest for more precise analysis.

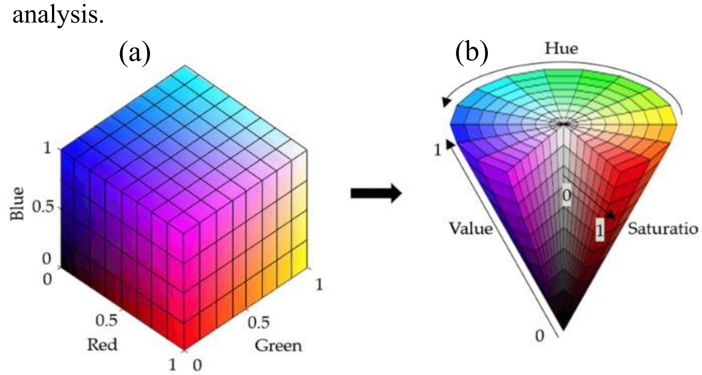

Fig.2. *Researchgate, 2024*.

4. Results

To validate the system, experiments were conducted using the ESP32-CAM to capture and process images in a controlled environment. The nanocontroller was mounted on a stand, while an object was positioned at different angles and locations within the camera's field of view. The lighting remained constant to ensure the accuracy of the analysis. The tests focused on evaluating: I- Image segmentation: HSV masks were applied to isolate the area of interest; II- Centroid calculation: The central position of the object was determined based on geometric moments; III- Maximum distance measurement: The furthest point from the centroid was identified for growth measurement; IV- Object delimitation: The boundary of the cultivated area was detected, and a bounding box was drawn.

Figure 3 illustrates the experiment's results for detecting a green pen using image processing. The image shows four main stages: the original mask (Figure 3.a), where green color segmentation was applied; the identification of the center (Figure 3.b) of the segmented object (figure 3.c); the display of the object isolated from the background; and the Bounding Box (Figure 3.d), which highlights the position and boundaries of the pen. The processing was performed by converting the image to the HSV color space, applying filters to reduce noise, and using OpenCV's findContours function to extract contours. This method will be used in the future for plant detection in smart agricultural systems.

Figure 3 - Experiment's results for detecting a green pen using image processing.

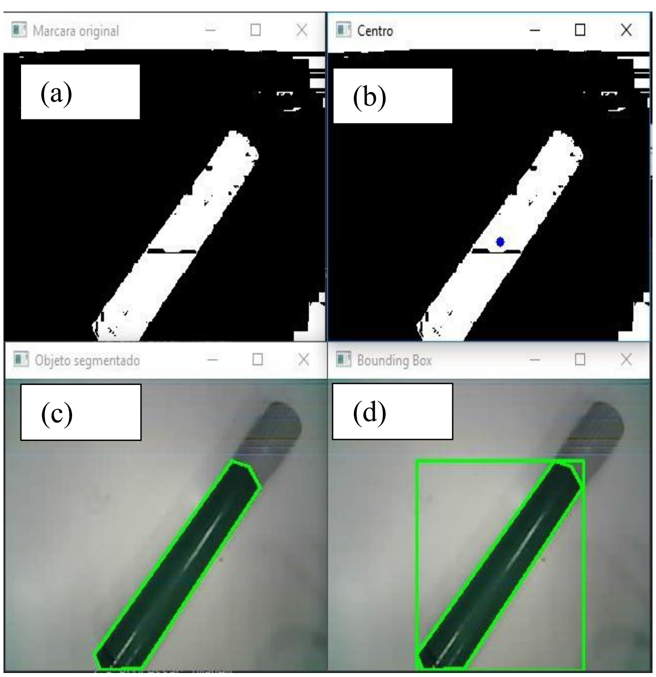

Fig. 3 *– Authors.*

Fig. 3 – Author.

5. Conclusion

In this work, we developed an image processing system to identify green objects, using a green pen as a reference. The process involved image capture, conversion to HSV, green color segmentation, application of noise reduction filters, and contour detection using OpenCV’s findContours. The experiments showed that the system is efficient in image analysis, enabling precise monitoring of crop growth. The integration of computer vision with IoT optimizes agricultural management by reducing manual measurements and increasing data reliability. This improves control over cultivation conditions and boosts productivity in urban environments. In future stages, I will apply this method to plant detection and monitoring, enhancing agricultural automation.

Acknowledgments

Salvador Pinillos Gimenez thanks CNPq (grant number 304427/2022-5) and FAPESP (grant number 2020/09375-0), and INCT Namitec for the financial support

References

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (2013) FAO. The State of Food and Agriculture: Leveraging Food Systems for Inclusive Rural Transformation. Rome: FAO, 2017. Available at: http://www.fao.org/3/a-i7658e.pdf. Accessed on: January 30, 2020.

[2] WEIDNER; YANG; HAMM, 2019. WEIDNER, Till; YANG, Aidong; HAMM, Michael W. Consolidating the current knowledge on urban agriculture in productive urban food systems: Learnings, gaps, and outlook. Journal of Cleaner Production, Elsevier Ltd, v. 209, p. 1637–1655, Feb. 2019. DOI: 10.1016/j.jclepro.2018.11.004.

[3] BENKE; TOMKINS, 2017 BENKE, Kurt; TOMKINS, Bruce. Future food-production systems: vertical farming and controlled-environment agriculture. Sustainability: Science, Practice and Policy, Informa UK Limited, v. 13, n. 1, p. 13–26, Jan. 2017. DOI: 10.1080/15487733.2017.1394054.

[4] KOZAI; NIU; TAKAGAKI, 2020. KOZAI, Toyoki; NIU, Genhua; TAKAGAKI, Michiko. Plant Factory. 2nd ed. [S.l.]: Elsevier, 2020.

[5] BOROS, I. F. et al., 2023. BOROS, I. F. et al. Title of the article or chapter. [Additional information]. 2023.

[6] TAO, Wen et al., 2021. TAO, Wen et al. Review of the internet of things communication technologies in smart agriculture and challenges. Computers and Electronics in Agriculture, Elsevier B.V., v. 189, p. 106352, Feb. 2021. DOI: 10.1016/j.compag.2021.106352.

[7] Oliveira, M. J. dos S. (2019). Dispositivo para monitoramento contínuo de cultura de células dentro de estufas. Universidade Federal do Rio Grande do Sul. Recuperado de (lume.ufrgs.br)

[8] Glaucius, M. PID Processamento de Imagens Digitais. Instituto Federal Sul-rio-grandense – IFSul.