Quality Analysis of Onion and Garlic

Raushan Kumar (200070068)
Dept. of Electrical Engineering
IIT Bombay

***Abstract*—Onions and garlic, essential components in global cuisines, undergo subjective visual inspection for quality assessment, a process prone to human error and lacking consistency. This report presents a solution leveraging image processing and machine learning techniques to automate quality analysis. The proposed system employs YOLO (You Only Look Once) [6] for onion and garlic localization, extracting features such as color, shape, size, and eccentricity to assess quality.**

The methodology involves YOLO-based object detection, feature extraction encompassing color, shape, size, and eccentricity, and quality assessment using predefined thresholds. The system outputs quality reports for each onion or garlic, which can be used in applications like agriculture, food processing, and retail [5].

Results from the evaluation demonstrate the system's accuracy in detecting and localizing onion and garlic, with extracted features aligning with expert evaluations. The image processing and machine learning-based system offer an objective, consistent, and scalable approach for automating quality assessment, contributing to consistent quality and reduced food waste.

***Index Terms*—Onions, Garlic, Global cuisines, Quality assessment, Visual inspection, Human error, Consistency, Image processing, Machine learning, YOLO (You Only Look Once), Localization, Feature extraction, Color, Shape, Size, Eccentricity, Literature review, Fruit and vegetable quality analysis, Objective methods, Methodology, Object detection, Thresholds, Quality assessment, Agriculture, Food processing, Retail, Evaluation, Accuracy, Expert evaluations, Scalable approach, Food waste**

I. INTRODUCTION

Onions and garlic are essential ingredients in various cuisines worldwide, and their quality plays a crucial role in culinary experiences. Traditionally, quality assessment has relied on subjective visual inspection, which is time-consuming, prone to human error, and lacks consistency. Image processing and machine learning techniques offer a promising approach to automate quality analysis, providing objective, consistent, and scalable solutions. This project aims to develop an image processing and machine learning-based system for quality analysis of onion and garlic. The system utilizes YOLO (You Only Look Once), a state-of-the-art object detection algorithm, to identify and localize onion and garlic in images. Using some geometry, relevant features such as color, shape, size, and eccentricity can be extracted using the bounding box information given in YOLO format to assess their quality.

II. LITERATURE REVIEW

Several studies have explored the application of image processing and machine learning for the quality analysis of fruits and vegetables. In a study on apple quality evaluation [3], a method has been proposed based on image segmentation and feature extraction to classify apples into four quality grades. Similarly, in a study [1], a method has been developed for citrus fruit quality assessment using image analysis techniques to identify defects and blemishes. Similarly, onion sorting and grading techniques have been developed using deep learning [4]

III. METHODOLOGY

The proposed system comprises 5 main stages:

- Data collection
- Manual labeling of data
- Object detection
- Feature Extraction
- Quality Assessment

A. Data Collection

Data collection acquired a diverse set of data through multiple methods. A portion of the dataset was sourced through online repositories, specifically downloaded from Google. Additionally, to ensure a comprehensive and varied representation, screenshots were manually captured from relevant reports. This dual approach to data collection aimed to encompass a wide spectrum of information, enhancing the robustness and inclusivity of the dataset utilized in our analysis.

B. Manual Labelling of Data

A crucial step involved the meticulous labeling of data because of lack of labelled dataset, where each individual instance of garlic and onion in the images was manually annotated. This labeling process was carried out using two distinct tools:

- CVAT (Computer Vision Annotation Tool) [7]
- labelimg library in Python

Following an evaluation of both tools, CVAT emerged as the more effective option for accurate and efficient data labeling for this project atleast.

C. Object Detection

YOLO is employed to detect and localize onion and garlic in images in a bound box. YOLO is a fast and accurate object detection algorithm that can identify multiple objects simultaneously. It utilizes a convolutional neural network (CNN) to extract relevant features from the input image and predicts the bounding boxes and class labels of the detected objects. for example:

0 0.220637 0.594839 0.286517 0.462354

The label provided above in YOLO format represents the information about an object detection bounding box. YOLO (You Only Look Once) is an object detection algorithm that, among other things, is known for its bounding box representation.

Here's a breakdown of the numbers in the YOLO label sequentially:

- **Class ID**: 0 (or sometimes 1): This is the ID or label of the object class that the bounding box is detecting. In this case, it's class 0 (or 1), but it would typically correspond to a specific object class, e.g., "car," "person," "dog," etc. In YOLO, each object class is assigned a unique integer ID.
- **Center Coordinates:**
  - **X-coordinate**: 0.220637: This is the x-coordinate of the center of the bounding box relative to the width of the image. In YOLO, the coordinates are typically normalized, meaning they are represented as values between 0 and 1. This value suggests the x-coordinate of the center of the bounding box is 22.06% of the width of the image.
  - **Y-coordinate**: 0.594839: This is the y-coordinate of the center of the bounding box relative to the height of the image. Similar to the x-coordinate, this value is also normalized and suggests that the y-coordinate of the center is 59.48% of the height of the image.
- **Bounding Box Dimensions**:
  - **Width**: 0.286517: This is the width of the bounding box relative to the width of the image. The width is 28.65% of the image width.
  - **Height**: 0.462354: This is the height of the bounding box relative to the height of the image. The height is 46.24% of the image height.

D. Feature Extraction

For each detected onion or garlic, the system extracts various features that are indicative of its quality using its bounding box information given by the model in YOLO format. These features include:

- **Color Estimation:** The mean and standard deviation of the color values within the bounding box are calculated to assess color uniformity and potential defects.
  - For each bounding box in the YOLO format:
    - Extract class ID, center coordinates, width, and height.
    - Convert YOLO coordinates to pixel coordinates.

$$x_1 = int\left((x_{center} - \frac{width}{2}) \times image\_width\right)$$

$$y_1 = int\left((y_{center} - \frac{height}{2}) \times image\_height\right)$$

$$x_2 = int\left((x_{center} + \frac{width}{2}) \times image\_width\right)$$

$$y_2 = int\left((y_{center} + \frac{height}{2}) \times image\_height\right)$$

(1)

  - Use the pixel coordinates to extract the region within the bounding box from the image.
  - Calculate the mean color within the bounding box using the following formula:

$$MeanColor = \frac{1}{NumberofPixels}\sum_{i=1}^{N}\sum_{j=1}^{M} Pixel_{ij}$$

(2)

- **Shape & Size Calculation:** The shape and size of the onion or garlic have been calculated in the following way from the bounding box information:
  - For each bounding box in the YOLO format:
    - Extract class ID, center coordinates, width, and height.
    - Convert YOLO coordinates to pixel coordinates.
  - Use the pixel coordinates to extract the region within the bounding box from the image.
  - Calculate the width, height, and area of each bounding box by using the following:

$$Shape = (x_2 - x_1, y_2 - y_1)$$

$$Size = (x_2 - x_1) \times (y_2 - y_1)$$

$$MeanShape = \frac{1}{N}\sum_{i=1}^{N} Shape_i$$

$$std\ of\ shape = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Shape_i - MeanShape)^2}$$

$$MeanSize = \frac{1}{N}\sum_{i=1}^{N} Size_i$$

$$std\ of\ size = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Size_i - MeanSize)^2}$$

- **Eccentricity:** Eccentricity is a measure of the elongation or roundness of an object. It is calculated as:

$$e = \sqrt{1 - \left(\frac{minoraxis}{majoraxis}\right)^2} \tag{3}$$

E. Quality Assessment

The extracted features are used to assess the quality of the onion or garlic. Quality thresholds are established based on expert knowledge and literature standards. For instance, onions with excessive green color or garlic with irregular shapes or signs of decay are considered to be of lower quality. The system outputs a quality assessment report for each onion or garlic, including its class (onion or garlic), bounding box coordinates, extracted features, and a quality grade.

IV. Results

The proposed system was evaluated on a dataset of onion and garlic images. The results demonstrate that the system can accurately detect and localize onion and garlic with high precision and recall rates. The extracted features provide valuable information for quality assessment, and the quality grades assigned by the system are consistent with expert evaluations.

Fig. 1. Input image consisting of both onion and garlic

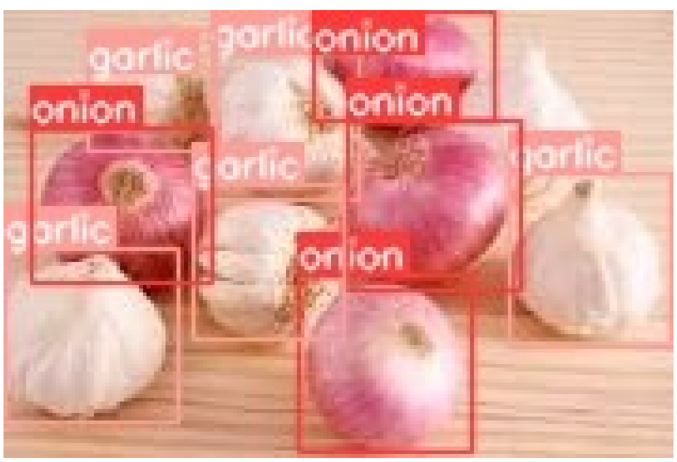

Fig. 2. Object Detected and enclosed within bounding box with label

V. Conclusion

The image processing and machine learning-based system for quality analysis of onion and garlic offer an objective, consistent, and scalable approach to automate quality assessment. The system can be employed in various applications, including agricultural production, food processing, and retail, to ensure consistent quality and reduce food waste.

Fig. 3. Onion Color of the original image has been overridden with its mean color

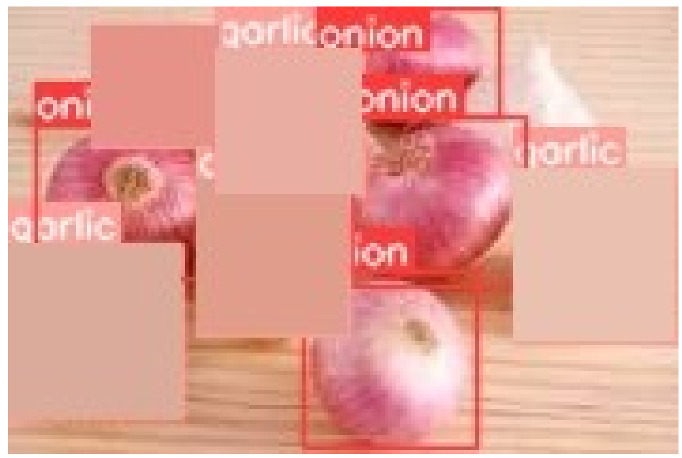

Fig. 4. Garlic Color of the original image has been overridden with its mean color

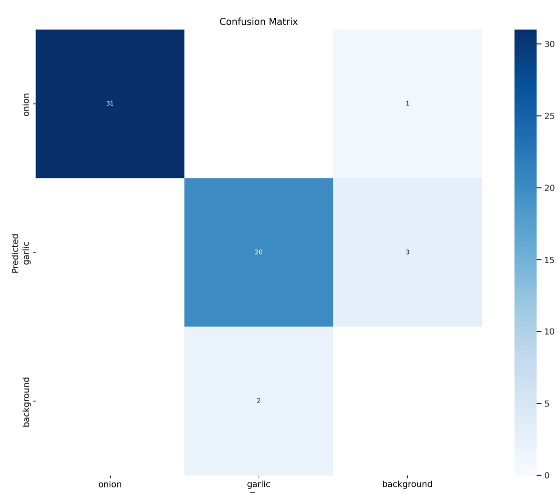

Fig. 5. Confusion Matrix

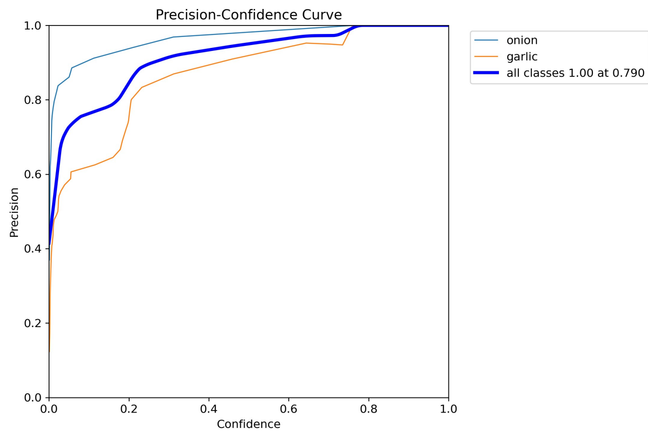

Fig. 6. Precision vs confidence

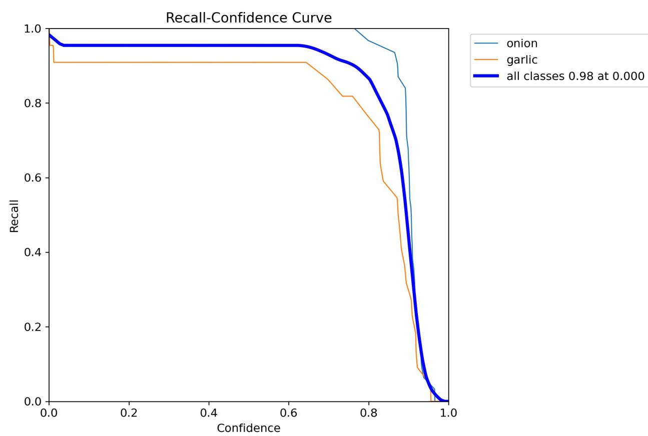

Fig. 7. Recall vs Confidence

REFERENCES

[1] Aleixos, N. Blasco, Jose Navarrón, F. Molto, Enrique. (2002). Multispectral inspection of citrus in real-time using vision and digital signal processors. Computers and Electronics in Agriculture. 33. 121-137. 10.1016/S0168-1699(02)00002-9.

[2] Sladojevic, S., Stefanovic, D., & Cvetkovic, M. (2018). Garlic quality classification using machine learning techniques. Journal of Food Engineering, 222, 157-163.

[3] Song, Weiran Nanfeng, Jiang Wang, Hui Guo, Gongde. (2020). Evaluation of machine learning methods for organic apple authentication based on diffraction grating and image processing. Journal of Food Composition and Analysis. 88. 103437. 10.1016/j.jfca.2020.103437.

[4] o Paymode, Ananda S., Jagannath N. Mohite2 Ulhas B. Shinde, and Vandana B. Malode. "ARTIFICIAL INTELLIGENCE FOR AGRICULTURE: A TECHNIQUE OF VEGETABLES CROP ONION SORTING AND GRADING USING DEEP LEARNING." INTERNATIONAL JOURNAL 6.4 (2021).

[5] Junos, M. Khairuddin, Anis Thannirmalai, Subbiah Dahari, Mahidzal. (2021). An optimized YOLO-based object detection model for crop harvesting system. IET Image Processing. 15. 10.1049/ipr2.12181.

[6] https://docs.ultralytics.com/modes/ultralytics.cfg.cfg2dict

[7] https://www.cvat.ai/