CP303: Capstone project II

Apple Volume Prediction

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Problem Statement

Objective: To calculate the volume of an apple from the images captured from a single camera source, using image processing and machine learning models.

Use Case

- **Food Processing Industry:** This model optimizes sorting, grading, and packaging processes, enhancing efficiency and reducing waste by categorizing apples precisely based on their size and volume.
- **Agricultural Technology:** Analyzing apple volume enables optimization of harvesting techniques, real-time fruit growth monitoring, and more accurate crop yield estimates.
- **Quality Control:** Integration of this model into quality control systems ensures consistent product quality for retailers and distributors. This leads to increased customer satisfaction and fewer product returns.

Dataset : Apple Images

- We began with a dataset containing **200** apples.
- Each apple was carefully photographed from **10** different angles to provide a comprehensive view.
- This approach resulted in a total of **2000** images, each showcasing the apple from various perspectives.

Dataset : Apple Images

Dataset : Volume Reading

- The volume of 200 apples is provided in milliliters (ml) in CSV format.
- The volume of the apple is measured using the water displacement method.

Apple No.	Volume
1	80
2	300
3	130
4	200
5	250
6	240
7	230
8	130
9	170
10	160

Approach: Overview

1. **Boundary Point Extraction**

   Obtain boundary points from the edges of the apple fruit in the single-view images using edge detection techniques.

2. **2D Curve Fitting**

   Perform 2D curve fitting on the extracted boundary points to generate a mathematical representation of the apple fruit surface.

3. **Eccentricity Calculation**

   Calculate the eccentricity of the fitted ellipse, representing the shape of the apple fruit, as determined by the curve fitting process.

Approach: Overview

4. **Volume Calculation by Eccentricity**

   Utilize the eccentricity of the fitted ellipse to determine the volume of each shape category (e.g., circular, elliptical, parabolic) using shape-specific volume formula.

5. **Volume Averaging and Scaling**

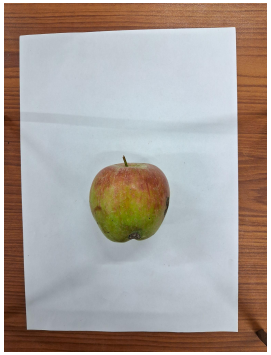
   Average the volumes obtained from each view to obtain the final volume estimation of the apple fruit.

Circular, Elliptical, Parabolic Apple

Figure 1. a) Circular apple b) Elliptical apple c) Parabolic apple

Boundary Point Extraction

- **Cropping A-4 Paper:** Crop the A-4 paper to isolate the apple.
- **Enhance Contrast:** Convert yellow pixels and low red to high red for better contrast.
- **Grayscale:** Convert to grayscale
- **Blur:** Apply Gaussian blur to reduce noise.
- **Edge Detection:** Use Canny edge detector to find edges.
- **Dilation:** Dilate edges for stronger boundaries.
- **Contour Extraction:** Extract boundary points using contours.



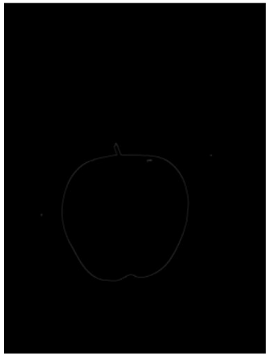
1. Original Photo

2. Cropped Photo

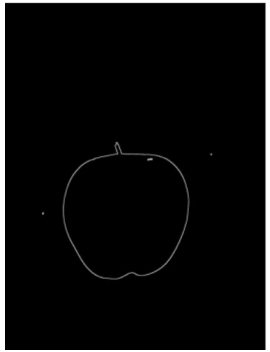
3. Better Contrast

4. Grayscale image

5. Blurred image



6. Canny Edges



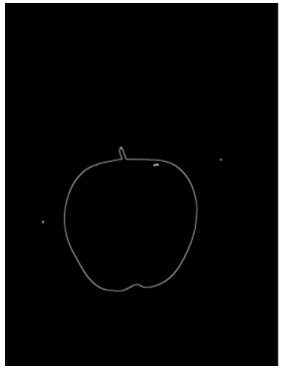
7. Dilated Edges

8. Boundary points

2-D Curve Fitting

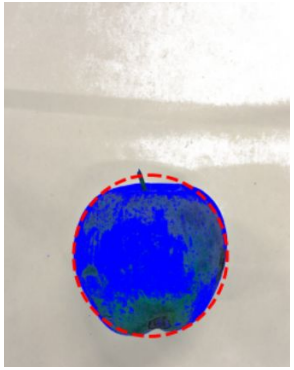
- Employ 2d curve fitting techniques to generate a 2D curve that closely matches the boundary points extracted from the apple fruit's contour.
- By fitting an 2d curve to the boundary points, a smooth and continuous 2D curve is obtained, providing a mathematical representation of the apple fruit shape for further analysis.

1. Original Image



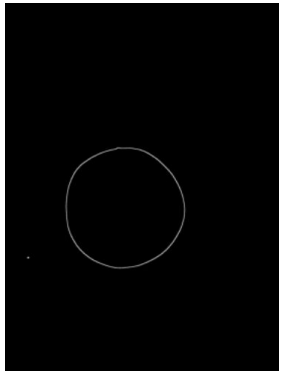
2. Dilated Canny Edges

3. Boundary Points



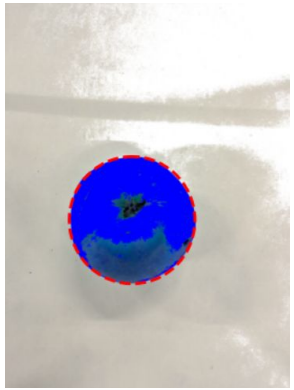
4. Fitted Ellipse

1. Original Image



2. Dilated Canny Edges

3. Boundary Points



4. Fitted Ellipse

Eccentricity Calculation

- Following the ellipse fitting process, the major and minor axes are derived as essential parameters of the ellipse.
- These parameters facilitate the calculation of the eccentricity, a measure of the deviation of the ellipse from a perfect circle.
- The eccentricity value obtained aids in classifying the apple fruit into circular, elliptical, parabolic, or hyperbolic shapes based on predefined criteria or thresholds

Volume Calculation By Eccentricity

- The figure below illustrates the criteria for classifying shapes as parabolic, elliptical, or spherical based on eccentricity.

Shape models	Eccentricity	b/a ratio	Position of ED with respect to mid. of PD
Circular	< 0.3	0.95 – 1.05	± 5% of PD
Elliptical	0.3 – 0.7	0.7 – 0..95	± 5% of PD
Parabolic	-	-	> 5% of PD

- Volume of circular apple: $V = 4 * \pi * r^3 / 3$
- Volume of Elliptical apple: $V = 4 * \pi * a^2b / 3$
- Volume of Parabolic apple: $V = \int (\pi * x^2)\, dy$

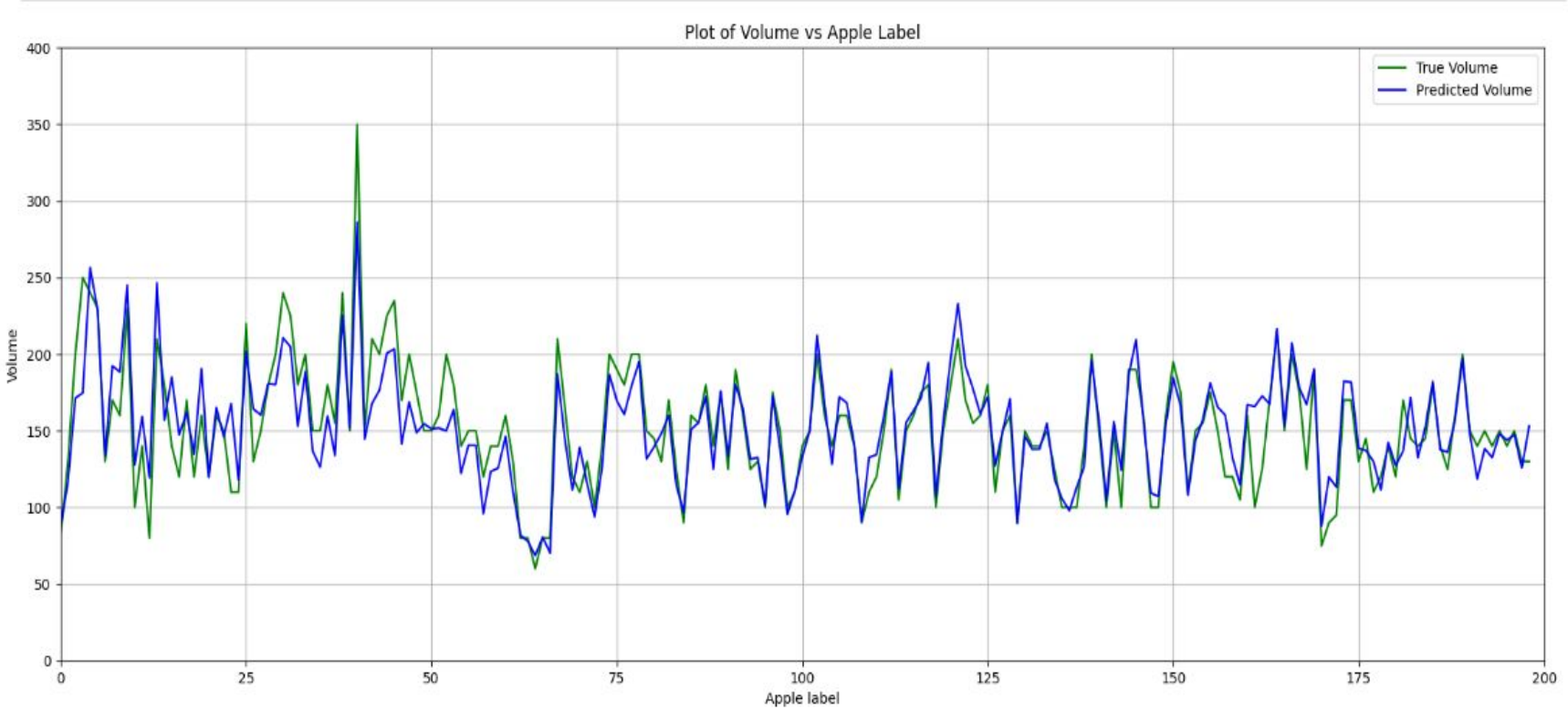
Volume Averaging and Scaling

- To find the predicted volume of the apple, we calculate the average of the volumes obtained from all the views.
- The volume we find, measured in (pixels)^3, is then converted to milliliters using the optimal scale factor.

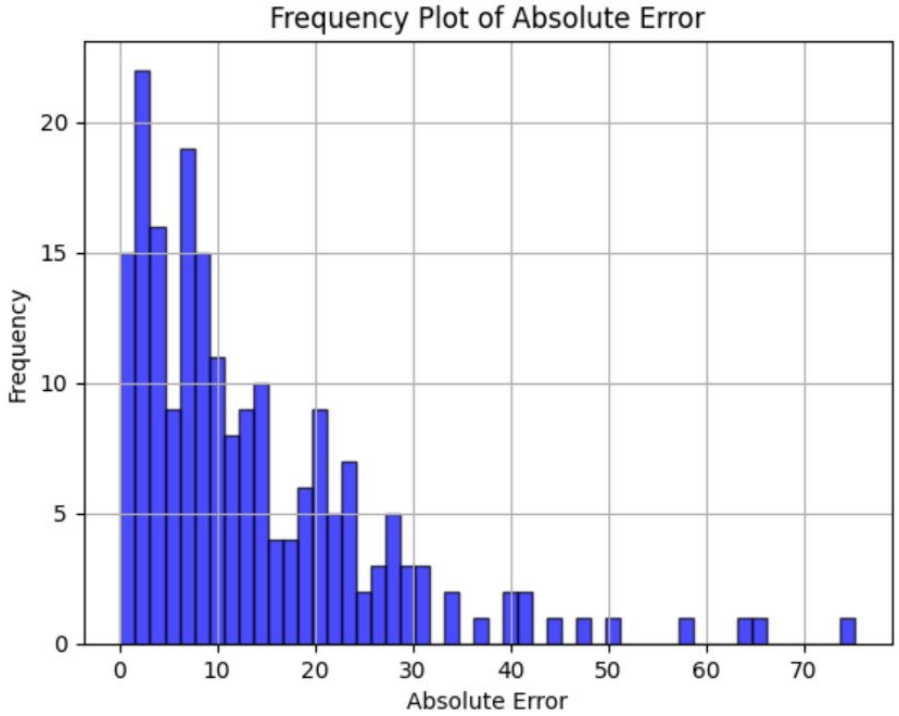
Results

- Mean Squared Error (MSE): 351.79
- Root Mean Squared Error (RMSE): 18.76
- Mean Percentage Error (MPE): 9.35%

Plots: Actual Vs Predicted Volume



Plot: Frequency Plot of Absolute Error



Future Work

- The support vector machine regression (SVMR) modeling technique will be employed to develop a model for estimating the volume of fruit samples based on ellipse parameters.
- Various kernels will be explored, and their performance will be analyzed and compared.

References

- Iqbal, S. Md., Gopal, A., & Sarma, A. S. V. (Year). Volume Estimation of Apple Fruits using Image Processing. Central Electronics Engineering Research Institute (CSIR-CEERI), Chennai – 600113, India. [Link]
- Khojasteh Nazhand, M., Omid, M., & Tabatabaiefar, A. (Year). Determination of orange volume and surface area using image processing technique. Department of Agricultural Machinery, Faculty of Biosystems Engineering, University of Tehran, Karaj, Iran. [Link]
- Forbes, K. A., & Tattersfield, G. M. (Year). Estimating Fruit Volume from Digital Images. Department of Electrical Engineering, University of Cape Town, Private Bag, Rondebosch, 7701, South Africa. [Link]