Image Defect Detection and Classification Project

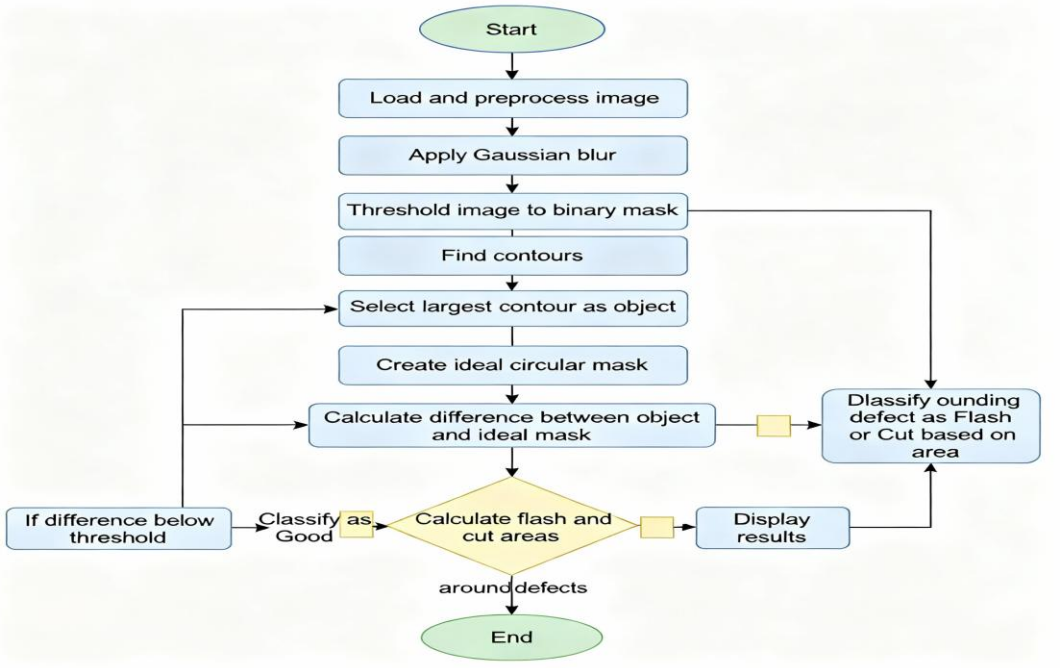
Introduction

This project aims to develop a general algorithm capable of detecting and classifying defects in circular objects imaged under varying conditions such as different diameters and positional translations. The defects of interest include flashes (extra material outside the expected shape) and cut marks (missing material inside the expected shape). The algorithm processes each input image to identify these defects, localizes them, and classifies the defect types effectively.

Problem Statement

The challenge is to create a robust image analysis system that can handle variations in the object's size and position during image acquisition. The system must detect deviations from an ideal circular shape, accurately localize those anomalies, and classify them into defect categories like flashes or cut marks. This approach needs to be generalizable to various image inputs with minimal dependence on fixed thresholds tied to specific image conditions.

Flow Chart:



The flow chart illustrates the step-by-step process of the image defect detection and classification system. It begins with loading the input image, which is then converted to grayscale to simplify analysis. Next, Gaussian blur is applied to reduce noise and minor variations, improving the accuracy of subsequent processing. The blurred image undergoes thresholding to create a binary mask that separates the object from the background. Contour detection is performed, and the largest contour is chosen as the object of interest, assuming it is the main feature to analyze. An ideal circular mask is generated around this contour, representing the perfect shape of the object without any defects. The difference between the actual object mask and this ideal mask is calculated, highlighting deviations from the perfect shape. If the difference area is below a predefined threshold, the object is labeled as 'Good,' indicating no significant defects. If not, the system measures the areas of excess or missing material: the flash area (extra material outside the ideal shape) and the cut area (missing material inside the ideal shape). Based on which area is larger, the defect is classified either as a 'Flash' or a 'Cut.' The system then locates the defect precisely by drawing bounding boxes around the identified defect regions on the original image, which is subsequently displayed with labels indicating the classification. Finally, the process concludes, providing visual and analytical results to assess the defect status of the object in the image.

Algorithm Used

The detection and classification process is performed using the following steps:

1. **Image Acquisition and Preprocessing**
   Convert the input image to grayscale, apply Gaussian blur to reduce noise, and apply a binary threshold to separate the object from the background.

2. **Contour Detection**
   Find external contours in the binary image. Select the largest contour assuming it represents the object of interest.

3. **Ideal Mask Creation**
   Fit a minimum enclosing circle around the largest contour to create an ideal circular mask representing the perfect, defect-free object shape.

4. **Difference Calculation**
   Calculate the absolute difference between the actual object mask and the ideal mask to highlight discrepancies.

5. **Defect Classification**
   Measure areas of difference outside the ideal mask as flashes and inside the ideal mask as cuts. Classify based on which area dominates or mark as generic defect if unclear.

6. **Localization and Visualization**
   Extract contours from the difference image and draw bounding boxes around significant defects on the original image.

Output

The output consists of a labeled image where detected defects are highlighted by bounding boxes colored differently based on defect type: flashes or cuts. Additionally, the model prints the classification result ("Good," "Flash," "Cut," or "Defect") and displays images at intermediate steps (mask, ideal mask, difference) for understanding and validation.

Explanation of the Entire Process

The process begins with pre-processing the input image for consistent segmentation regardless of image conditions. The largest contour detection assumes the target object is the prominent shape in the image. Using a minimum enclosing circle abstracts the expected perfect geometry, enabling computation of deviations. The pixel-wise difference between the object and this ideal shape quantifies defects spatially. Analyzing difference areas inside and outside the ideal mask helps differentiate defect types. Final defect localization via bounding boxes aids visualization and practical interpretation. This modular approach ensures adaptability and accuracy in a wide range of scenarios, fulfilling the need for a general defect detection system.