Final Report: Industrial Parts Classification using Classical Computer Vision

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1 Introduction

This report details the development of a binary classifier designed to distinguish between bolts (screws) and nuts using digital image processing techniques. The system achieves an accuracy of 78.95% by extracting both geometric and photometric features.

2 Technical Questionnaire

2.1 Kernel 1 Configuration

My Kernel 1 (Identity):

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

An Identity kernel was used to maintain the integrity of the original image. This allows for the extraction of the average pixel intensity (brightness/color) and the application of Otsu's Thresholding on a clean base, ensuring precise object background segmentation.

2.2 Kernel 2 Configuration

My Kernel 2 (Laplacian):

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

This is an omnidirectional edge detection kernel. It was chosen to highlight the entire contour of the part simultaneously. By obtaining a defined edge in all directions, the Aspect Ratio (Elongation) calculation remains robust regardless of the object's rotation angle.

2.3 Classifier Logic

The classifier works by extracting two key descriptors: average intensity (derived from Kernel 1) and geometric elongation Length/Width derived from Kernel 2). Data is statistically normalized using StandardScaler, and classification is determined by calculating the Euclidean Distance between the image's feature vector and the centroids (means) of each class.

2.4 Pattern Detection

- **Kernel 1 detects:** The main mass of the object and its surface reflectivity (photometric features).
- **Kernel 2 detects:** Second order spatial discontinuities, identifying elongated patterns for bolts and compact/circular patterns for nuts.

2.5 Proposed Improvements

If the classifier was not 100% accurate, I would implement Hu Moments (scale invariant descriptors) or Local Binary Patterns (LBP) for texture analysis, as bolt threads possess a distinct texture signature compared to the smooth surface of nuts.

2.6 Connection to CNNs

This exercise simulates the initial convolutional layers of a Convolutional Neural Network (CNN). While we selected the kernels manually here, in a CNN, the network uses Backpropagation to automatically learn these filter values, enabling it to identify the most relevant features for classification on its own.