ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

DISI

Master in Artificial Intelligence

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Visual Inspection of Motorcycle Connecting Rods

IPCV Project Report

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Abstract

This project aims to robustly process images of motorcycle's connecting rods, taken under different settings, distinguish between different types of rods, and compute several metrics (length, width, barycenter, width at barycenter, position(s) of the hole(s) and corresponding diameter(s)). In particular, variations of lighting conditions, noise and distractors' presence, and the possibility of partial overlapping between objects are possible scenarios. By exploiting standard Computer vision Algorithms, and simple ideas from Machine Learning, a completely automated pipeline, capable of dealing with all aforementioned obstacles, is implemented.

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Chapter 1

First Task

This first set of images presents neither overlapping between objects nor distractors or noise, the only possible variation is in the backlighting's source power.

In such a setting it's crucial to employ a robust algorithm to automatically select a correct threshold for binarization.

Even though images have a bimodal histogram, foreground and background pixels have significantly different variances, and the application of Otsu's method for segmentation results in the wrong classification of rods' shadows, which in turn leads to the computation of inaccurate metrics.

I tried to employ a variation of the so-called "valley-emphasis method", proposed by Hui-Fuang et al.[1], with poor results.

Therefore I employed a more sophisticated, time-consuming method, which achieves the desired outcome.

After approximating the probability density function of the pixels' intensity through gaussian kernel density estimation, the second zero-crossing of the first derivative of the pdf is found (the first zero-crossing corresponds to the first mode), which is the binarization's threshold.

For simplicity, I make use of a function provided by the library Scipy for relative

minima computation after performing kernel density estimation.

The only parameter which has to be tuned is the bandwidth, which acts as a smoothing parameter controlling the bias-variance tradeoff (the higher the bandwidth, the smaller the variance), and which has been set to 6 for all the images in the dataset. An example of binarization both with this method and with Otsu's method, can be seen in 1.1.

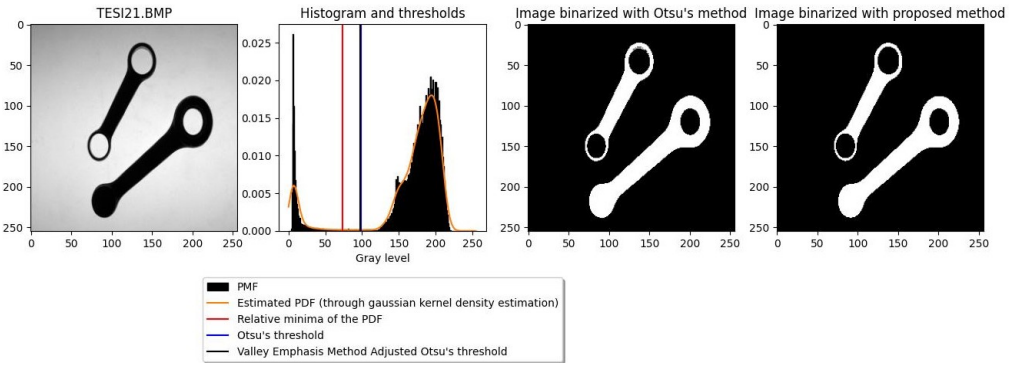

Figure 1.1: A comparison of the different thresholding methods.

After binarization, the following operations are performed:

1. Identification of connected components,
2. Computation of minimum enclosing rectangles,
3. Computation of descriptive statistics for the blobs, and the required metrics,
4. Visualization of analysis results.

Chapter 2

Second Task

2.1 Presence of distractors

To discriminate between rods and distractors, I filtered blobs based on their area. In particular, I computed a reasonable confidence interval for this statistic based on the images of the first task (from 1280 to 6000).

I considered Haralick's circularity and Hu's moments as possible alternatives but eventually decided to go for the area as it was easier to construct a confidence interval without having to use discriminative algorithms as isolation forests to separate the two classes.

2.2 Partially overlapping rods

As a first attempt, I tried to separate touching rods by applying morphological operators and the Watershed segmentation algorithm.

Unfortunately, due to the particular shape of the rods, I was not able to correctly tell apart the different rods.

Therefore I decided to opt for a more complex approach, involving the identi-

fication of points of discontinuity in the shape of the rods, to eventually draw the smallest possible line to reconstruct the original boundaries.

Since by definition convexity defects are the deepest points between convex hulls where convexity is violated, the points of contact between the rods will always be among them.

Clearly, these two points are not the only convexity defects in the image, therefore they must be somehow identified among all the others.

Given the particular smooth shape of the rods, by performing Harris corner detection on the image, we can easily tell apart the cluster of corner points around the points of contact between the rods.

This way, after having found the center of these clusters, the exact points of contact can be described as the pairs of convexity defect points closest to the centers of the clusters.

This can be visually understood by looking at 2.1.

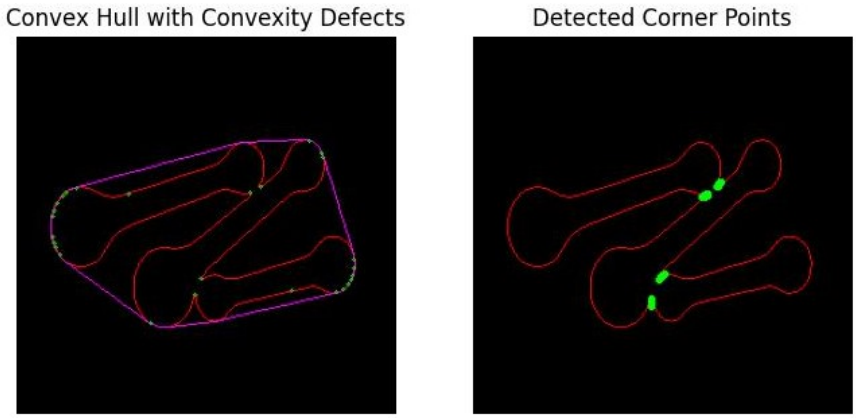

Figure 2.1: Convex hull with convexity defects highlighted and points detected by Harris corner detection algorithm.

2.3 Presence of iron powder over the inspection area

While on one hand the iron powder could be handled as if it was salt and pepper noise, through application of a median filter, on the other hand, the distribution of the pixels' intensity of the dust particles closely resemble that of the rods' pixels, making it difficult to filter them when in close contact with the rods.

In addition, repeated application of a median filter, even with a small kernel size (equal to 3) would result in a degradation of the contours of the rods in those areas where the they are particularly thin (e.g. around the holes).

For these reasons I decided to test two different methodologies: applying a bilateral gaussian filter, and sharpening the image after the repeat application of a median filter.

Since the first approach failed at removing most of the dust particles from the image (leaving this task to the filtering stage over the connected components), I eventually decided to opt for the second approach.

In particular, the sharpened version of the image is obtained by adding to the image the difference between the image itself and its smoothed version (through application of gaussian filtering).

Bibliography

[1] Hui Fuang Ng. A weighting scheme for improving otsu method for threshold selections. *Journal of Computers (Taiwan)*, 27:12–21, 07 2016.