AN ADAPTIVE FITTING APPROACH FOR THE VISUAL DETECTION AND COUNTING OF SMALL CIRCULAR OBJECT IN MANUFACTURING APPLICATIONS

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INTRODUCTION

- **Existing circle detection methods and drawbacks**:

(1) Methods based on Circular Hough Transform (CHT)[1]: fail in detecting a large number of small circles in noisy images due to the limited number of edge points available.

(2) Stochastic techniques such as Random Sample Consensus[2]: make implementation complicated for noisy background.

(3) Line Segment Approximation(LSA) [3] :fail to detect small circles due to difficulty in performing low-curvature arc segmentation along a circle perimeter.

(4) Dominate deep learning approaches like Faster R-CNN perform poorly for small object detection due to the difficulty of region proposal networks to localize small objects accurately.

- **Our approach**:

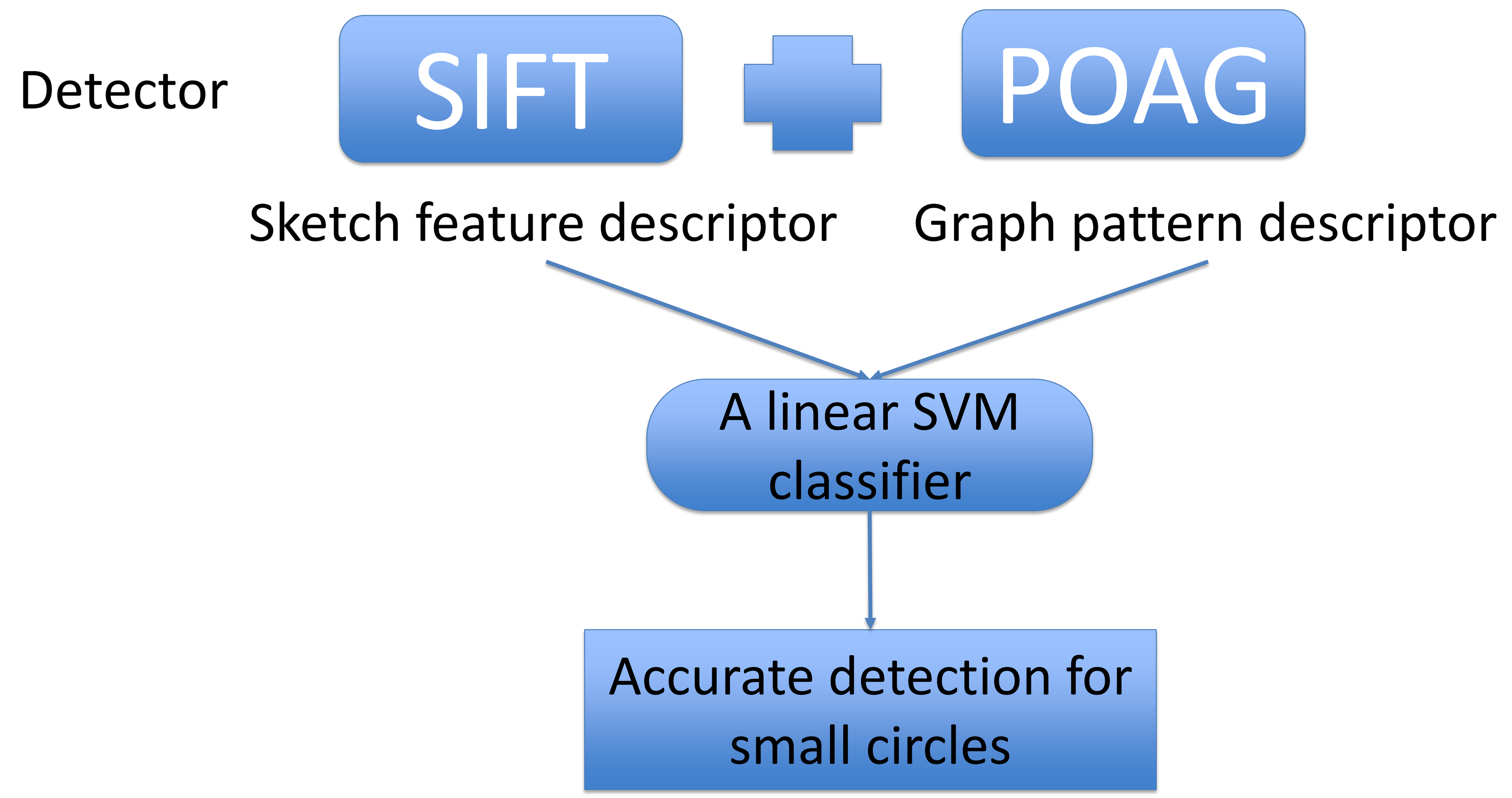
We propose a novel two-stage circle detection method:

Step 1: Bottom-up coarse detection

Step 2: Top-down circle fitting

OUR APPROACH

Step 1: Bottom-up circle detection: A coarse detector to detect small circles in an image with sliding window mode.



OUR APPROACH

Step 2: Top-down circle fitting: A hierarchical Bayesian model performs a top-down adaptive circle fitting, with the ability to achieve a maximum a posteriori probability to fit circles to local image features.

$$(\mathbf{x}_c^*, r^*) = \max_{(\mathbf{x}_c, r)} P(C(\mathbf{x}_c, r)|\mathbf{I}) = \max_{(\mathbf{x}_c, r)} (P(\mathbf{I}|\mathbf{x}_c, r)P(\mathbf{x}_c|\mu_c, \sigma_c)P(r|\mu_r, \sigma_r))$$

where $C(\mathbf{x}_c, r)$ represents a circle centered at $\mathbf{x}_c$ with radius r, $P(\mathbf{I}|\mathbf{x}_c, r)$ is the likelihood of finding a circle centered at $\mathbf{x}_c$ with radius r in image I, $P(\mathbf{x}_c|\mu_c, \sigma_c)$ is the prior of the circle centered at $\mathbf{x}_c$ given the initial center location at μ_c with potential spatial variation σ_c, and $P(r|\mu_r, \sigma_r)$ is the prior of the radius r given the initial estimation μ_r with potential variation σ_r. The problem formulation can be represented as a Hierarchical Bayesian Model.

EVALUATION

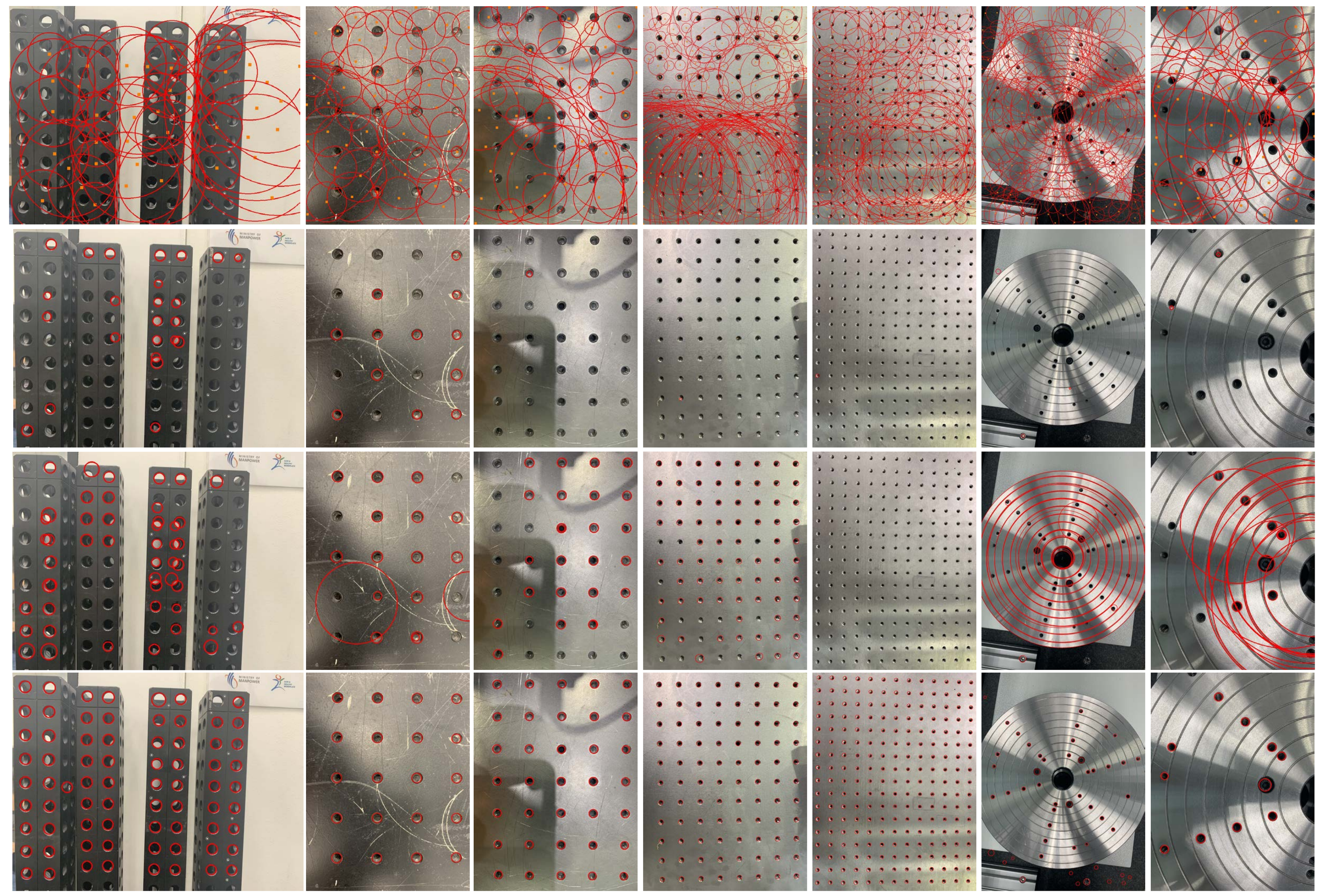


Fig. 1. Comparison of Circular Hough Transform (CHT) without setting parameters (first row), CHT with setting parameters (second row), Line Segment Approximation (LSA) results (third row) and our method (fourth row) on sample images.

EVALUATION

Method	Precision	Recall	F1 score	Average time (sec)
CHT[1]	0.91	0.23	0.37	8.03
LSA[3]	0.96	0.67	0.79	3.12
Our	0.97	0.94	0.95	0.84

Table 1. Method performance comparisons

CHT method performs poorly when the parameters of the circle scale were not present. LSA method performs better than CHT, especially for circles with diameters over 40 pixels. Our algorithm can obtain faster and more accurate results than the tested CHT and LSA methods for small circle detection.

CONCLUSION

- We propose a novel method for circular object detection, which combines bottom-up coarse detection and top-down circle fitting.
- We designed a SVM-based approach for circle detection to obtain coarse estimates of the location and scale of small circles.
- A model-driven method based on a hierarchical Bayesian model is used to get precise positions and scales of small circles.
- Evaluation on manufacturing images demonstrate the advantage of the proposed method on circle detection, localization and counting.
- For future work, we aim to test our algorithm on larger datasets, with the intention of commercial deployment.

REFERENCE

[1] "Hough circle transform," https://docs.opencv.org/4.0.0/d4/d70/tutorial_hough_circle.html/, 2018.

[2] M. Fischer and R. Bolles, "Random sample consensus: A paradigm to model fitting with applications to image analysis and automated cartography," CACM, vol. 24, no. 6, 1981.

[3] C.S. Lu, S.Y. Xia, W.M. Huang, M. Shao, and Y. Fu, "Circle detection by arc-support line segments," IEEE International Conference on Image Processing, 2017.