Anchor-based Detection and Height Estimation Framework for Particle Defects on Cathodic Copper Plate Surface

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INTRODUCTION

Particle defects on the cathodic copper plate surface always happen due to the immaturity of electrolytic copper processing. The removal of defects mainly depends on their height exceeding the plate and current removal requires manual measurement and operation, which is time-consuming and laborious. To automate the removal process, machine vision-based defect detection methods need to be developed. However, copper defects are of very small size, which increases the difficulty of feature extraction and prediction. Therefore, this paper proposes a novel Anchor-based Detection and Height Estimation (ADHE) framework, to locate the defect out and estimate the height of the defect in an end-to-end way. Large-scale raw images are transformed into several image blocks as input. Defect features are obtained by Defect Region Extraction Network and then sent into Height-RCNN for defect detection and height prediction. Dataset of cathodic copper plate surface defects has been collected from a real-world manufacturing factory. Experimental results show that the proposed ADHE method can effectively address the small size problem of copper defects and achieve excellent results in detection and height estimation.

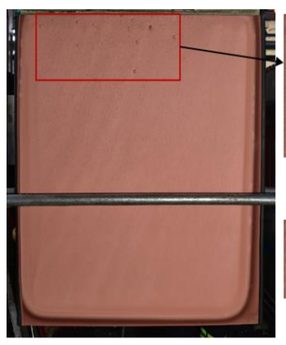


Fig. 1 Examples of Particle Defects

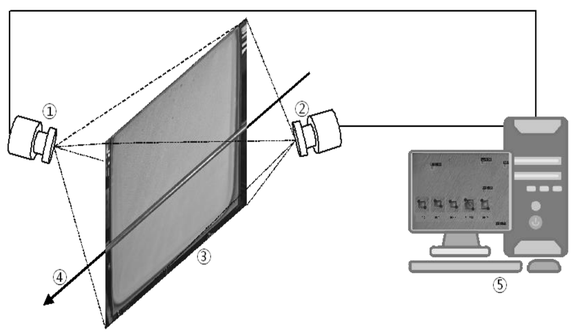


Fig. 2 Automated Inspection System

PROPOSED ADHE METHOD

■ The proposed logit adjusting transformer method (LAT)

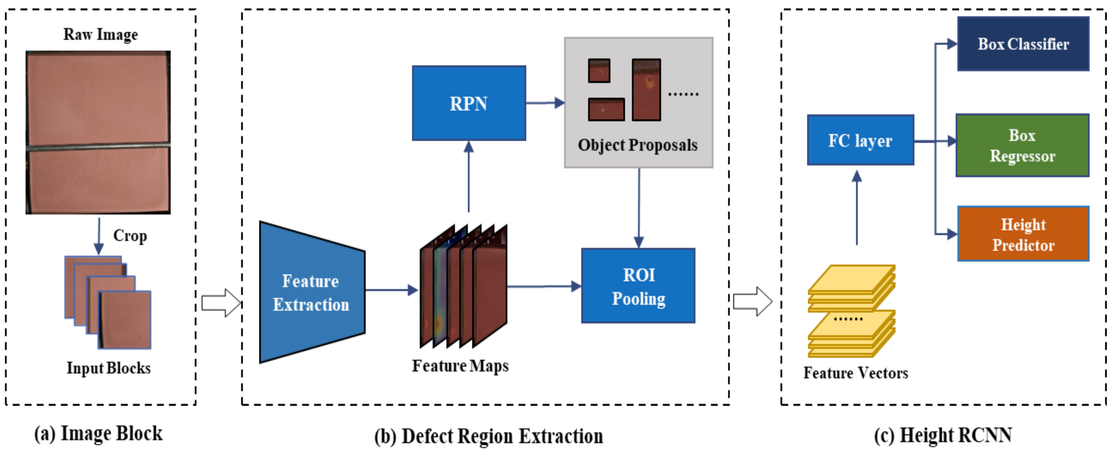
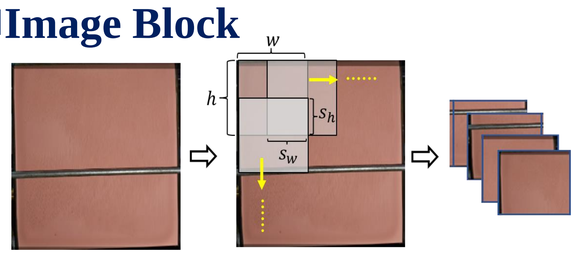


Fig. 3 The framework of Anchor-based Defect Detection and Height Estimate network (ADHE) is proposed which consists of Image Block, Defect Region Extraction, and Height-RCNN (H-RCNN) three modules.

■Image Block



- **Operation Parameters:**
  - h: the height of a image block;
  - w: the width of a image block
  - s_h: the step between blocks in height direction
  - s_w: the step between blocks in width direction

Fig. 4 The process of image block process

■ Defect Feature Extraction

As shown in Fig 3, defect region extraction network, which follows a two-stage network structure as an overall framework, including feature extraction network, Region Proposals Network (RPN), and Region of Interest (ROI) pooling.

■ Height RCNN

Height-RCNN takes fix-size vectors as input and conducts defect classification, location, and height estimation tasks simultaneously.

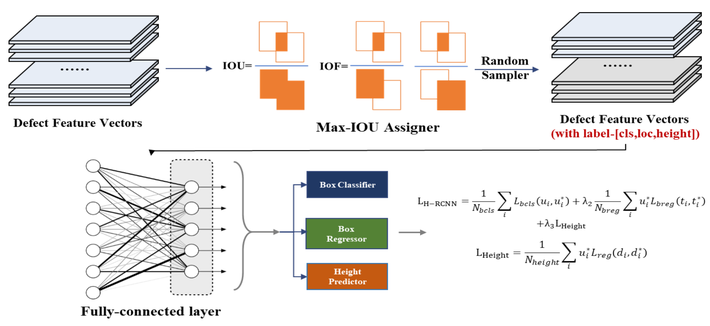


Fig. 5 The Framework of Height RCNN

EXPERIMENTS

■ Dataset Description

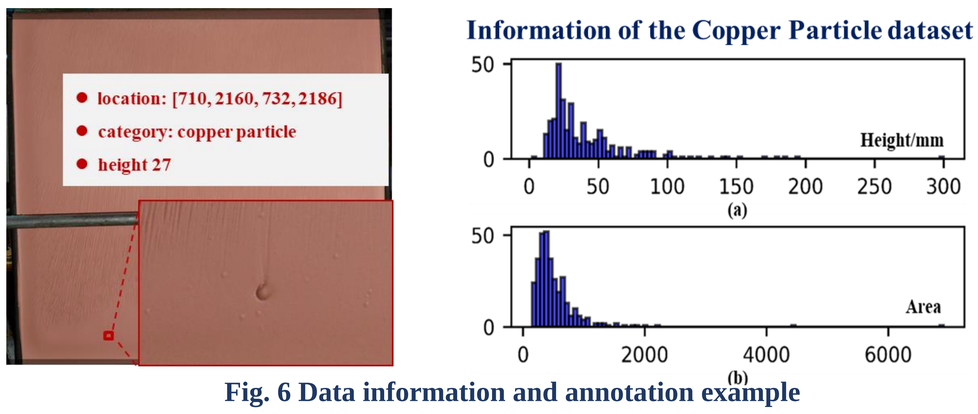


Fig. 6 Data information and annotation example

■Comparison with Conventional Feature Extraction

TABLE I Comparison with Conventional Feature Extraction Network

Method	Params	Detection			Height Estimation
		Precision↑	Recall↑	AP_{50}↑	RMSE↓
ResNet-50	26.63M	0.372	1.000	0.949	9.135
ResNet-101	45.62M	0.383	1.000	0.955	9.640
HRNet-w32	32.38M	0.379	1.000	0.951	10.016
HRNet-w40	48.63M	**0.393**	**1.000**	**0.956**	**8.572**

The detection performance gets better when models go bigger. ADHE with HRNet-w40 achieves the best AP value and RMSE value.

■The influence of Image Block operations

TABLE II Comparison with Conventional Feature Extraction Network

Block	Image Size	Image Number	Instance Number	Detection			Height Estimation
				Precision↑	Recall↑	AP_{50}↑	RMSE↓
1x1 (Raw)	**2516×2468**	**160**	**343**	**0.438**	0.767	0.715	13.127
2x2	**1258×1214**	**640**		0.392	0.971	0.927	12.314
3x3	**838×809**	**1440**		0.393	**1.000**	**0.956**	**8.572**

Between different block number: The detection and height estimation results get better when the block number adds

■Detection Visualization under Block 3×3

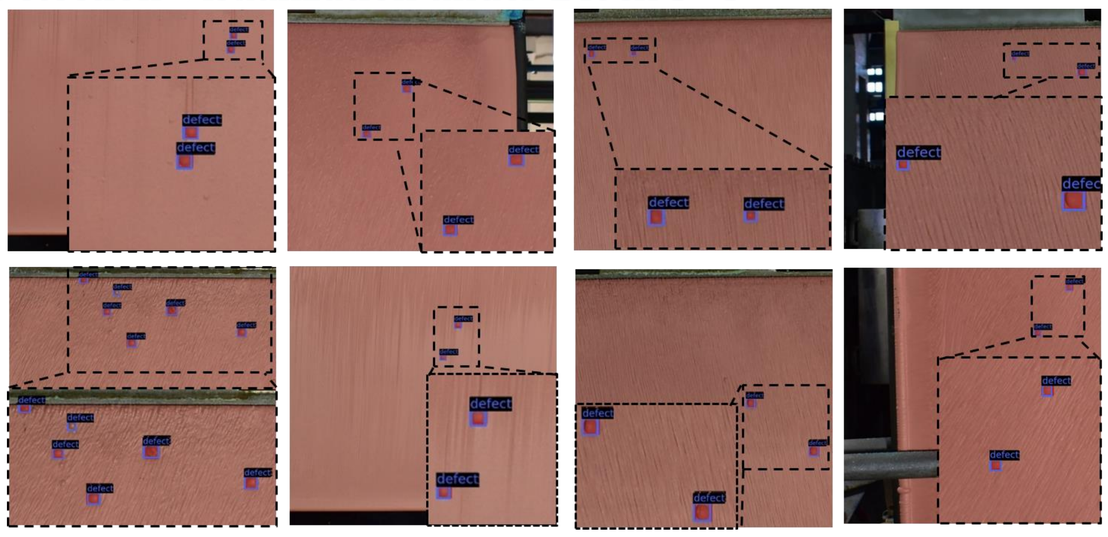


Fig. 7 Data information and annotation example

■The Influence of Loss Hyperparameter λ_3

$$L = L_{RPN} + L_{RCNN} + \lambda_3 L_{Height} = L_{RPN} + L_{RCNN} + \lambda_3 \frac{1}{N_{height}} \sum_i u_i^* L_{reg}(d_i, d_i^*)$$

TABLE III The Influence of Loss Hyperparameter λ_3

λ_3	Detection			Height Estimation
	Precision↑	Recall↑	AP_{50}↑	RMSE↓
0.05	**0.395**	**1.000**	0.944	9.134
0.10	0.393	**1.000**	0.956	**8.572**
0.50	0.350	**1.000**	**0.962**	9.610
1.00	0.244	**1.000**	0.960	10.593
5.00	**0.395**	**1.000**	0.944	9.134

The best result on detection and height estimation cannot be achieved at the same time, a trade-off needs to be taken into consideration. The value of 0.1 is relatively better performance.

CONCLUSIONS

- **Image Block operation is utilized to adjust the receptive fields for small defects and enlarge numbers of the training set (oversampling)**
- **As to small size defects, a defect region network and Height-RCNN network are deployed to conduct feature extraction and detection task. Especially, the proposed method can locate the defect out and estimates the height of the defect in an end-to-end way**

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