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Mask R-CNN and multifeature clustering model for catenary insulator recognition and defect detection

Ping TAN, Xu-feng LI, Jin DING, Zhi-sheng CUI, Ji-en MA,
Yue-lan SUN, Bing-qiang HUANG, You-tong FANG

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The Overall Algorithm Model

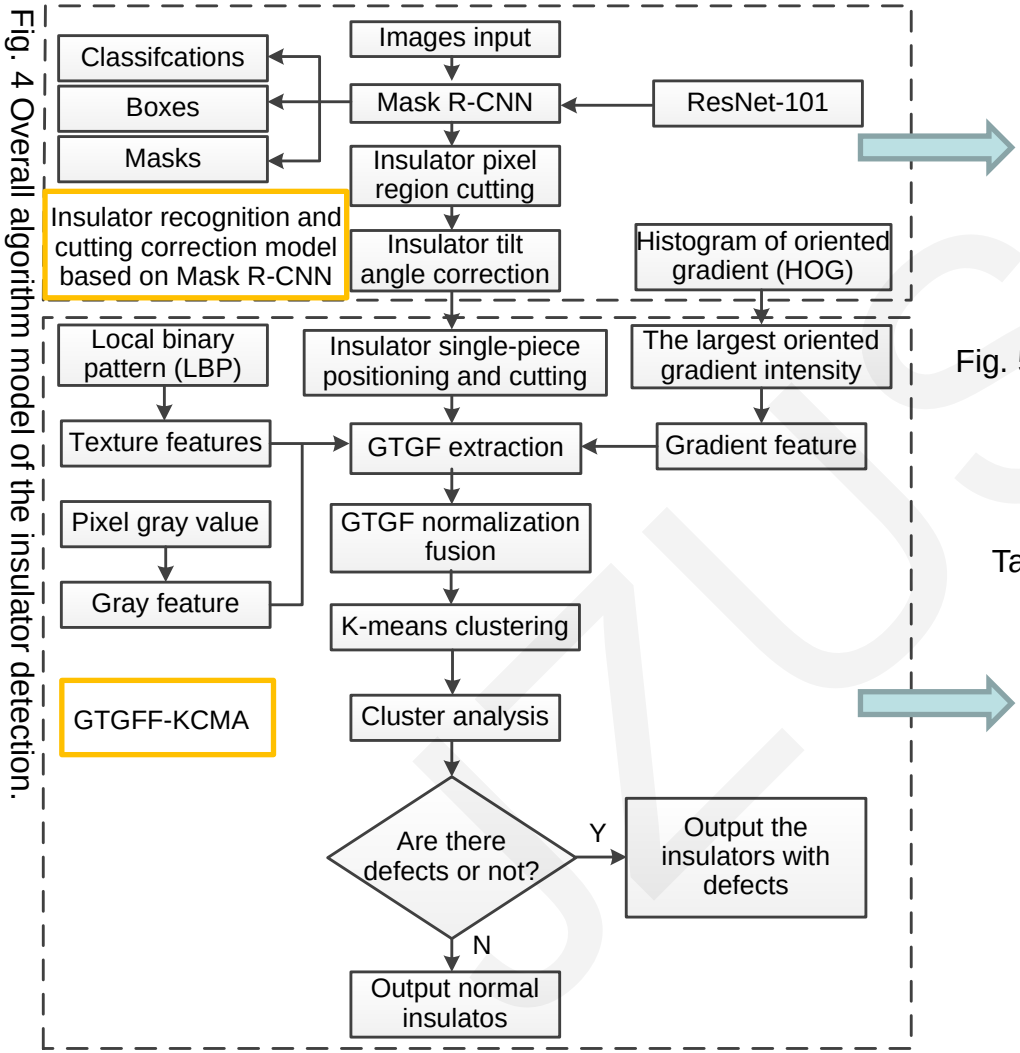


Fig. 4 Overall algorithm model of the insulator detection.

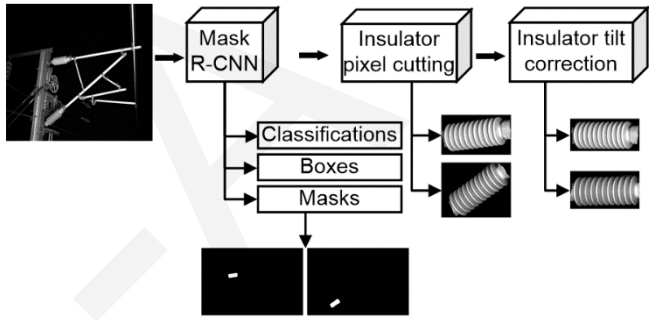
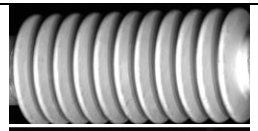
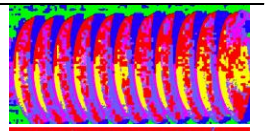
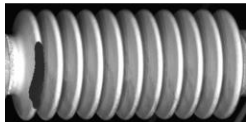
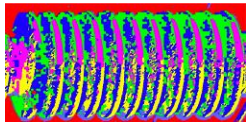
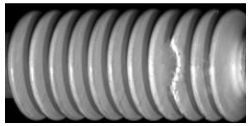
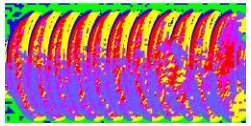


Fig. 5 Insulator recognition and region cutting correction model

Table 3 Partial test results of insulator defect detection

Number	Cutting correction image	GTGFF-KCAM results
Insulator 1		
Insulator 2		
Insulator 3		

Insulator recognition and region cutting correction based on deep learning

- Insulator recognition based on Mask R-CNN
- Insulator pixel region cutting algorithm
  - Information about the bounding boxes of the insulators is stored in the branch output boxes of Mask R-CNN.
- Insulator tilt correction algorithm
  - With the coordinate information of these points, straight line fitting is performed by the least squares method. The slope of the fitted straight line is converted into an angle with the horizontal direction according to a trigonometric function. Then the image rotation operation is performed to correct the tilt angle of the insulator.

Insulator defect detection algorithm based on GTGFF-KCAM

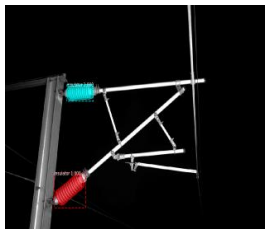
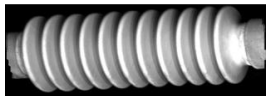
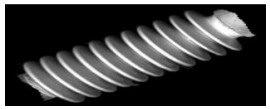
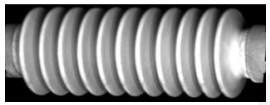
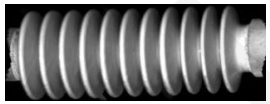
- Projection method to locate the single shed of the insulator
  - Here, binarization and projection methods are used to determine the position information of each insulator shed.
- Gradient, texture, and gray features (GTGF) extraction
  - the edge gradient, texture, and pixel gray features of the defective portion are quite different from those of normal insulators. Combined with the pixel gray feature, research on the HOG and LBP is carried out for GTGF.
- K-means clustering and analysis model

Insulator defect detection algorithm based on GTGFF-KCAM

- Major innovations
  - Insulator recognition and region cutting correction based on Mask R-CNN
  - Projection method to locate the single shed of the insulator
  - Gradient, texture, and gray features (GTGF) extraction and normalization fusion
  - Clustering analysis model improves the accuracy of insulator defect detection

Experimental testing and analysis

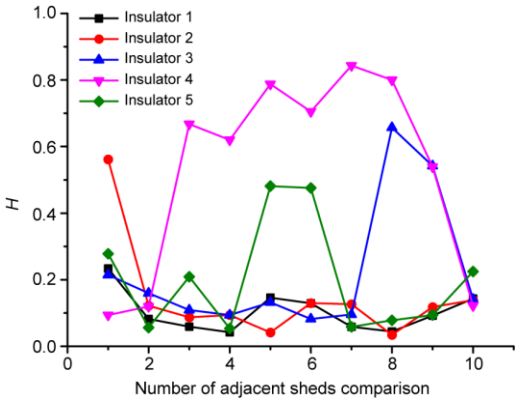
Insulator recognition and region cutting correction model based on Mask R-CNN:

Result of Mask R-CNN	Before tilt correction	After tilt correction	Tilt correction error (°)
	 	 	1.09 and 1.49

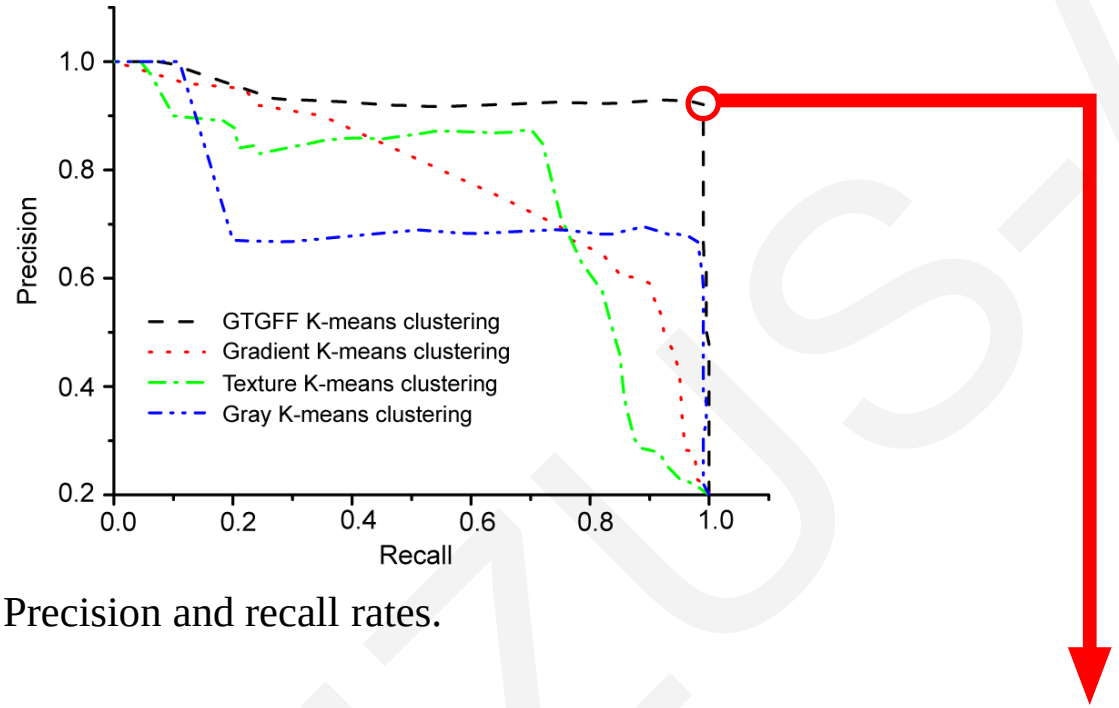
The pixel region can be accurately separated and the tilt correction error is very low.

Insulator defect detection based on GTGFF-KCAM:

The characteristics of defective insulators are very obvious.



Insulator defect detection model evaluation



The GTGFF clustering performed better than the other three single-feature clusters.

Fig. 13 Precision and recall rates.

Table 4 Insulator defect detection based on GTGFF-KCAM test results

Image item	Amount of insulator images	Amount of defect images detected	Amount of defect images correctly recognized	Recall (%)	Precision (%)
Insulator	800+200	214	198	99.0	92.5

Conclusions

- Based on the Mask R-CNN and GTGFF-KCAM, we carried out studies on HSR catenary insulator recognition and defect detection. Mask R-CNN is an outstanding deep learning model for object recognition and instance segmentation, and achieves high accuracy for insulator recognition. Based on the Mask R-CNN detection results, the cutting and tilt correction of the insulator pixel region are presented. For insulator defect detection, the proposed GTGFF-KCAM was applied and tested on a realistic image dataset and achieved high precision insulator defect detection.

Conclusions

Published articles

- Tan P, Li XF, Wu ZG, et al., 2021. Multialgorithm fusion image processing for high speed railway dropper failure-defect detection. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 51(7):4466-4478.
  https://doi.org/10.1109/TSMC.2019.2938684
- Tan P, Li XF, Xu JM, et al., 2020. Catenary insulator defect detection based on contour features and gray similarity matching. Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering), 21(1):64-73.
  https://doi.org/10.1631/jzus.A1900341
- Ping TAN, Ji-en MA, et al., 2016. Sustainability Development Strategy of China's High Speed Rail [J]. Journal of Zhejiang University-SCIENCE A, 17(12): 923-932.
  http://dx.doi.org/10.1631/jzus.A1600747