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Automatic soil desiccation crack recognition using deep learning

JIN-JIAN XU* HAO ZHANG† CHAO-SHENG TANG* QING CHENG* BO LIU* BIN SHI*

Abstract

This study proposes a new automatic soil cracks recognition method based on U-Net Convolutional neural network (CNN) architecture for segmentation on soil desiccation crack images. The backbone of the U-Net encoder is selected as ResNet and a new loss function combing both BCE loss and dice loss is used during training stage to fit imbalance problem. Subsequently, the U-Net with an encoder based on ResNet and a decoder part is trained from end to end on a subset of 524 labeled crack images with 224×224 pixels for semantic segmentation. The U-Net architecture achieves 94.38%, 74.43%, 81.13% for precision, recall and dice scores on test sets, which are better than all results using Otsu threshold method employed in traditional crack image processing technique. Experimental results reveal that deep learning can reach higher accuracy than traditional method (binarization by thresholding) in quantifying surface crack ratio, average crack width, total crack length and crack number. Moreover, deep learning can not only accurately identify cracks or spots by means of crack edge features, but also can accurately separate cracks and clod areas under bad photographing condition (such as uneven illumination, field environment or poor photographing angle). It may also be applied to other materials with cracks.

Significance and Impact

Soil desiccation cracking is a common natural phenomenon. The existence of cracks can negatively impact both mechanical and hydraulic properties of soil (Figure 1). Accurate acquisition of soil crack networks is not only the basis for obtaining the relevant geometrical parameters of crack networks, but also an important foundation and premise for further study about formation mechanism of shrinkage and desiccation cracking. However, the digital image processing method requires a high quality of the original image and can be significantly influenced by some disruptive factors like uneven lighting environment and uneven surface of the soil or noise. Thus, it is necessary to put forward a new method for crack recognition which is accurate and convenient especially for images with distractions.

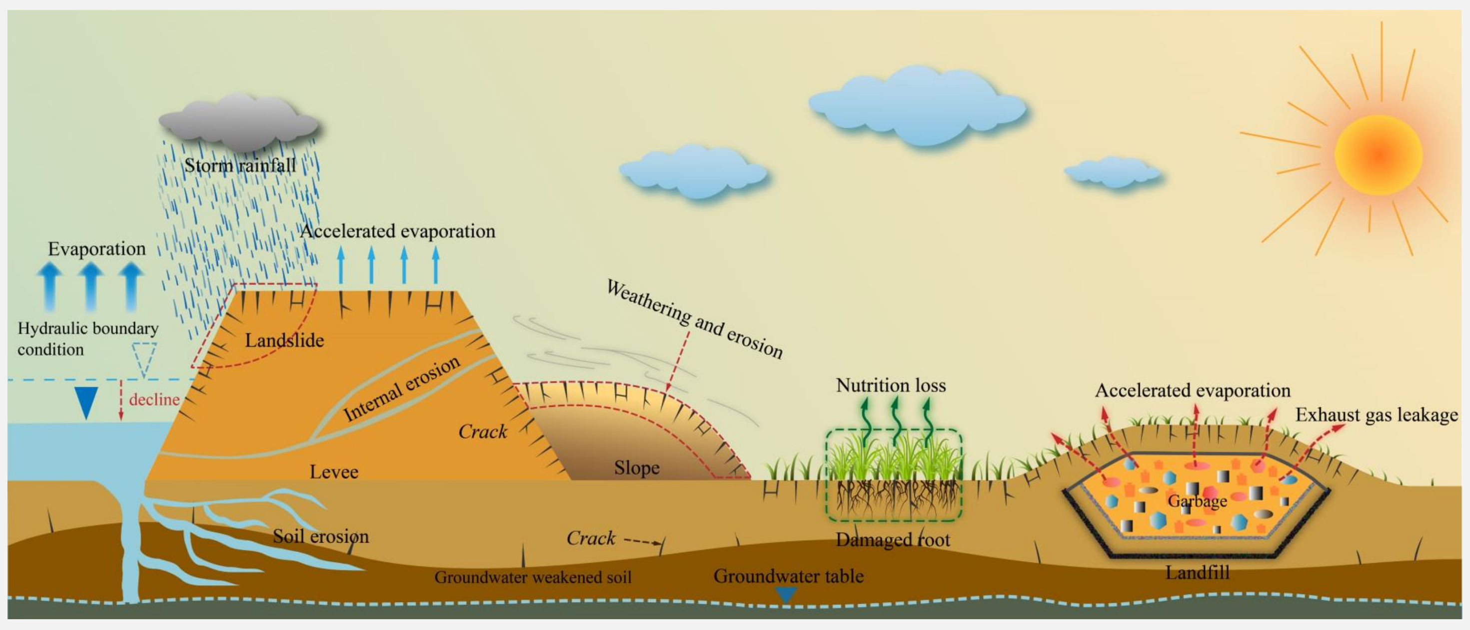

***Figure 1**. Impacts of drought-induced soil desiccation cracking*

Methods and Materials

All soil cracking images are labelled with binary mask manually as ground-truth. It should be noted that we annotated a crack image (Figure 2(a)) with Labelme. In Figure 2(b)-(c), crack area is annotated with polygonal line and the result which is named as label or ground truth is shown in Figure 2(d), where the white area is represented by 1 and background is 0. The architecture of U-Net for soil crack image segmentation is shown in Figure 2(e). The backbone of the U-Net encoder is selected as ResNet and a new loss function combing both BCE loss and dice loss is used during training stage to fit imbalance problem. Subsequently, the U-Net with an encoder based on ResNet and a decoder part is trained from end to end on a subset of 524 labeled crack images with 224×224 pixels for semantic segmentation.

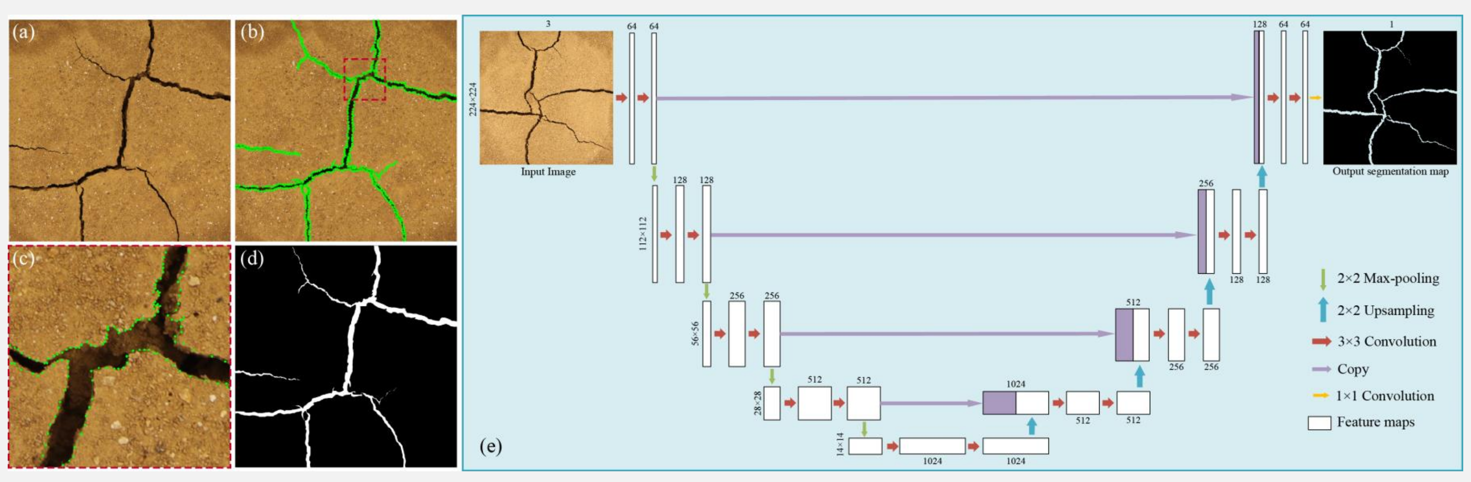

***Figure 2**. Procedures of annotating crack image and the architecture of U-Net for soil crack image segmentation*

Results and Discussion

A series of crack patterns obtained from different sources and photographing conditions were recognized by the two methods (Figure 3). It is found that the crack recognition effectiveness of the traditional method significantly depends on image quality. Generally, deep learning presents much better performance on crack recognition than traditional method. It can not only accurately identify cracks or spots by means of crack edge features, but also can accurately separate soil cracks and clods under bad photographing condition (such as uneven illumination, field environment or poor photographing angle). As shown in Figure 4, the procedure of the new crack recognition method includes data collection, annotation of images, model training, model testing and crack analysis.

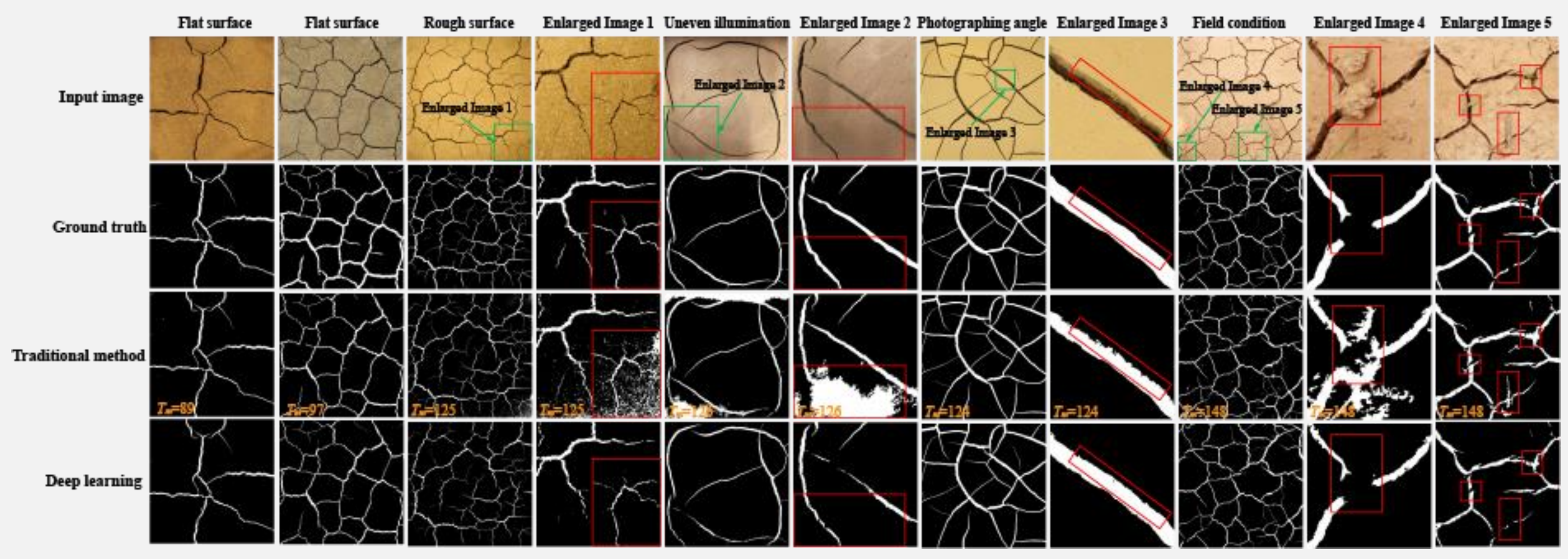

***Figure 3**. Example results on the test set of typical soil cracks dataset including traditional method and deep learning*

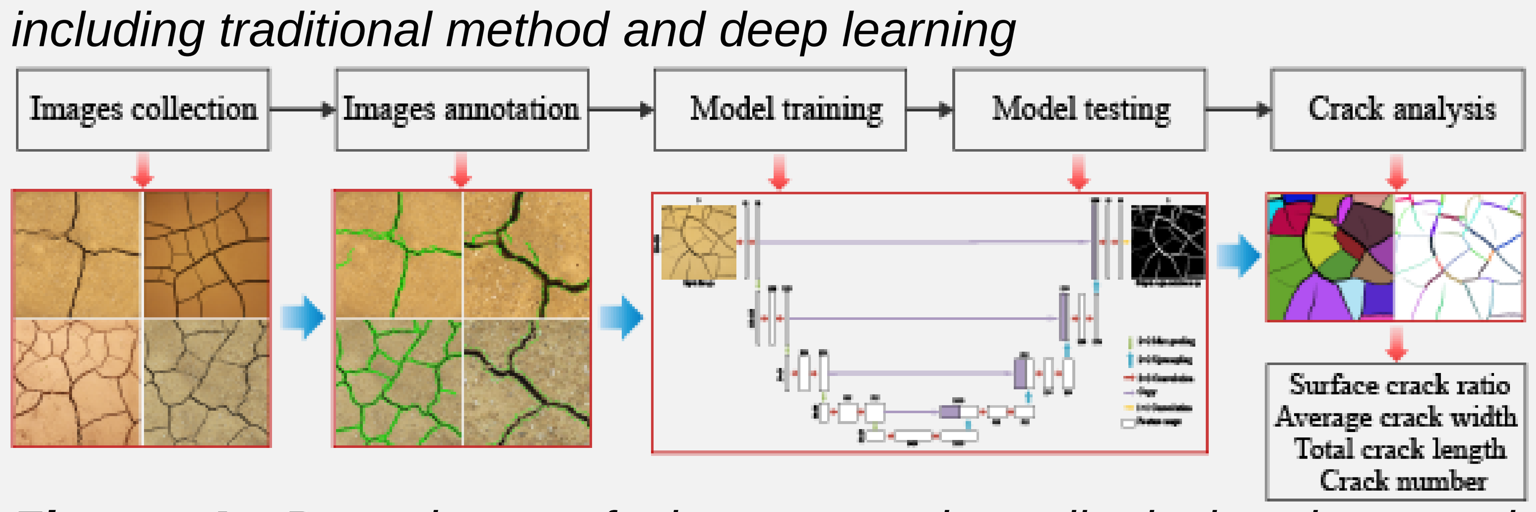

***Figure 4**. Procedures of the automatic soil desiccation crack recognition method based on deep learning*

Conclusion/Remarks

In the present study, a new deep learning-based automatic soil cracks recognition method using U-Net architecture is proposed for segmentation on soil desiccation crack images. The results of traditional method (binarization by thresholding) in precision, recall and dice scores are 81.74%, 66.56%, 68.48%, while those of deep learning are 94.38%, 74.43%, 81.13%. Moreover, deep learning method can not only accurately identify cracks or spots by means of crack edge features, but also can accurately separate soil cracks and clods under bad photographing condition. In addition, purely from a methodological perspective, the deep learning-based crack recognition method proposed in this study is not limited to soils. It may also be applicable in other materials with cracks.

Acknowledgements

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*School of Earth Sciences and Engineering, Nanjing University, Nanjing, China.
†School of Information Engineering, Nanchang University, Nanchang, China.