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Structural Analysis of Asian and African Rice Panicles via Transfer Learning

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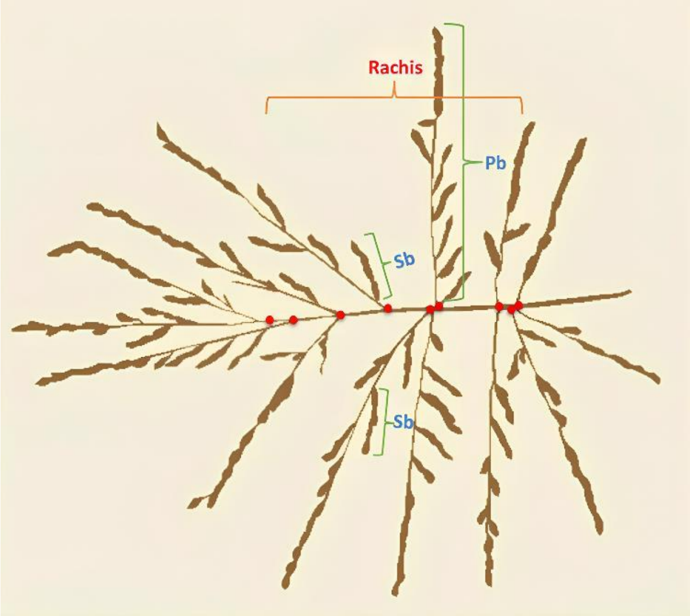
Motivation

- In the face of continuous climate change, sustainable genetic improvement through breeding is essential for maintaining rice yield and quality.
- However, breeding progress is **hindered** by manual, low-throughput phenotyping activities, which are **inaccurate and non-repeatable** [1].
- By leveraging the visual similarities between **pavement cracks and rice panicles**, we propose a cross-domain method to fully automate the **junction detection process**.
- Comprehensive experiments are conducted to test whether a general approach is applicable to both **Asian and African rice panicles**.



Structure of a rice panicle.

Method

Step 1 (Segmentation)

Seven pre-trained segmentation models on CFD dataset [2] are fine-tuned with our dataset.

Step 2 (Skeletonization)

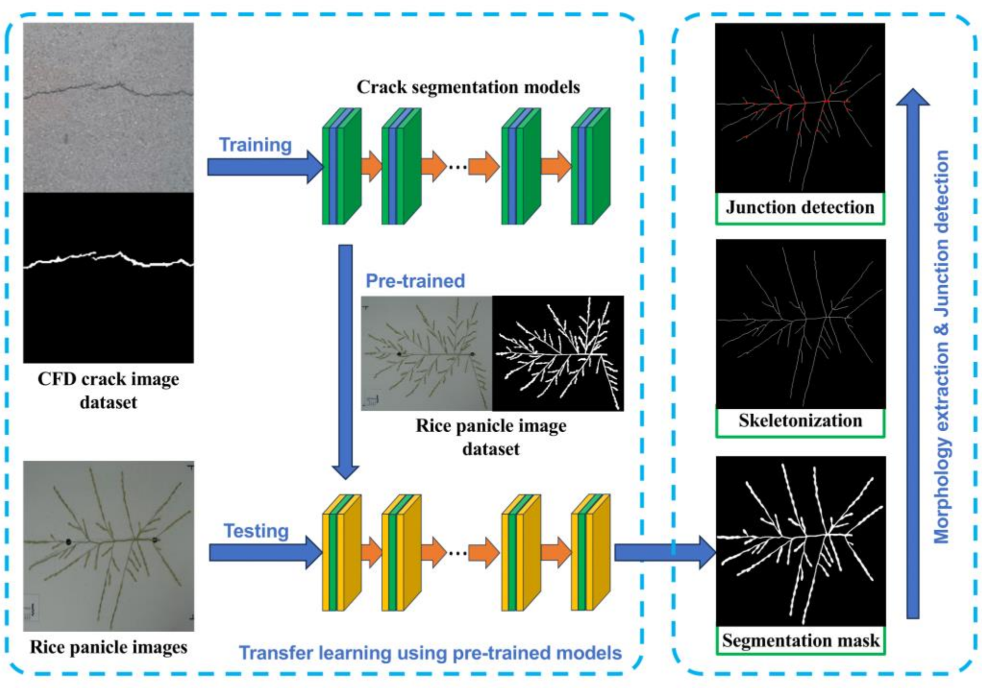
Resulting binary images are transformed into unitary thickness skeletons.

Step 3 (Junction detection)

Various clustering algorithms are used to locate junction positions.

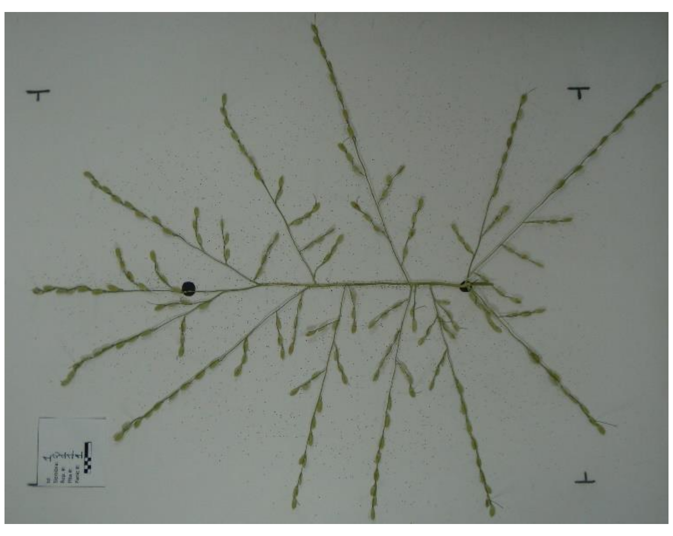
Step 4 (Evaluation)

Located junctions are compared to pre-labelled junctions for evaluation.



The proposed pipeline.

Data



Asian rice panicle.

- Asian panicles: 100 images.
- African panicles: 100 images.
- Settings: Laboratory, secured in place against a white background.
- Format: RGB.

Results

Segmentation

- **U-net** [5] achieves the highest average $F1$ score across 3 datasets, reaching nearly **90**% accuracy.
- **SegNet** [6] excels in Recall (Rc) but underperforms in Precision (Pr), indicating possible **over-segmentation**.
- **U²CrackNet** [7] showcases strong performance, particularly in Precision (Pr).

For balanced performance, **U-Net** is the best choice.

Performance (%) of fine-tuned models.

Model	DeepCrack	FCN	SegNet	U-Net	U^{2}CrackNet	ACS	RUC-Net
Asian rice panicles							
Pr	89.46	86.80	77.78	89.60	**91.61**	88.21	86.02
Rc	89.73	88.35	**94.95**	90.18	86.81	90.23	92.07
F_1	89.53	87.41	85.26	**89.85**	89.10	89.18	88.89
African rice panicles							
Pr	89.14	86.09	77.18	89.26	**90.93**	87.95	86.00
Rc	89.24	88.49	**94.72**	89.78	86.72	89.89	91.40
F_1	89.08	87.04	84.84	**89.42**	88.69	88.83	88.52
Mixed Asian and African rice panicles							
Pr	90.10	86.95	77.80	89.05	**91.72**	88.26	86.38
Rc	88.73	89.13	**95.41**	90.91	86.66	90.22	91.68
F_1	89.34	87.86	85.51	**89.91**	89.05	89.17	88.88

Junction Detection

Performance in $F1$ score (%) of different algorithm combinations.

Skeletonization	ZS			GBO		
Clustering	DBSCAN	FINCH	CN	DBSCAN	FINCH	CN
Main axis junctions						
Asian	73.94	41.71	82.02	77.16	49.96	**82.56**
African	68.17	44.43	78.61	73.79	54.20	**81.44**
Combined	69.27	34.62	**78.85**	72.75	41.23	78.63
High-order junctions						
Asian	53.18	13.48	**54.63**	51.64	13.64	52.23
African	72.25	11.10	**72.54**	66.68	11.88	67.79
Combined	59.58	12.18	**60.61**	56.58	13.19	57.11
All junctions						
Asian	60.09	16.91	**62.60**	59.01	18.78	60.59
African	72.04	14.68	**75.31**	69.54	16.67	72.59
Combined	64.49	15.78	**67.91**	63.21	18.11	65.45

- The combination of **Zhang-Suen** thinning [3] and **Crossing Number** [4] (ZS-CN) consistently detects main axis junctions with approximately **80**% accuracy.
- Further refinements are needed to enhance the accuracy of high-order junction detection, particularly in complex structures like Asian's.

Conclusion

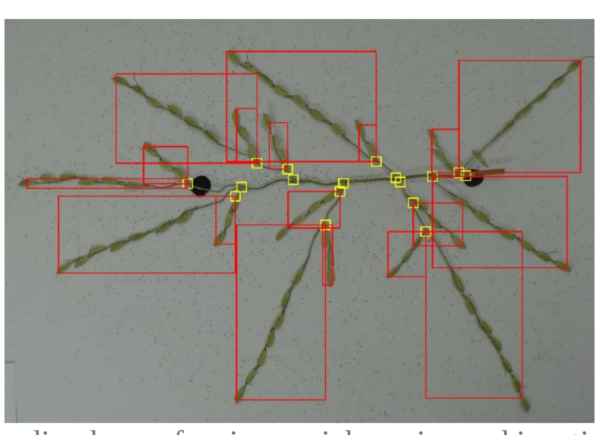
Contributions

- A novel method to **fully automate** the detection of rice panicle junctions.
- Comprehensive experiments to test whether a **general approach** is applicable to both Asian and African rice panicles.

U-Net – Zhang-Suen – Crossing Number can serve as a general approach for panicles structural analysis.

Future Works

- Develop a robust method with fewer steps.
- Employ detection models for grain and junction identification.



Bounding boxes for rice panicle grains and junctions.

References

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