Journal of Zhejiang University-SCIENCE A

Novel robust cross-modal integration fusion model for rapid moisture content detection in concrete sand

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Cite this as: Zhijian CAI, Jun ZHANG, Xiaoling WANG, Jiajun WANG, Kehao ZHAO, Guohua WU, 2026. Novel robust cross-modal integration fusion model for rapid moisture content detection in concrete sand. *Journal of Zhejiang University-SCIENCE A*, 27(7):711-729. https://doi.org/10.1631/jzus.A2500545

Methods for moisture content detection



Oven-drying method



frying method



Near-infrared spectroscopic method





Image analysis method



Dielectric constant method

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Advantages and limitations of existing methods for determining moisture content of fine aggregate

Oven-drying and frying method

- High accuracy
- High time cost

Near-infrared spectroscopic method

- Rapid
- Significant noise interference

Dielectric constant method

- Rapid
- Significantly influenced by mineral composition.

Image analysis method

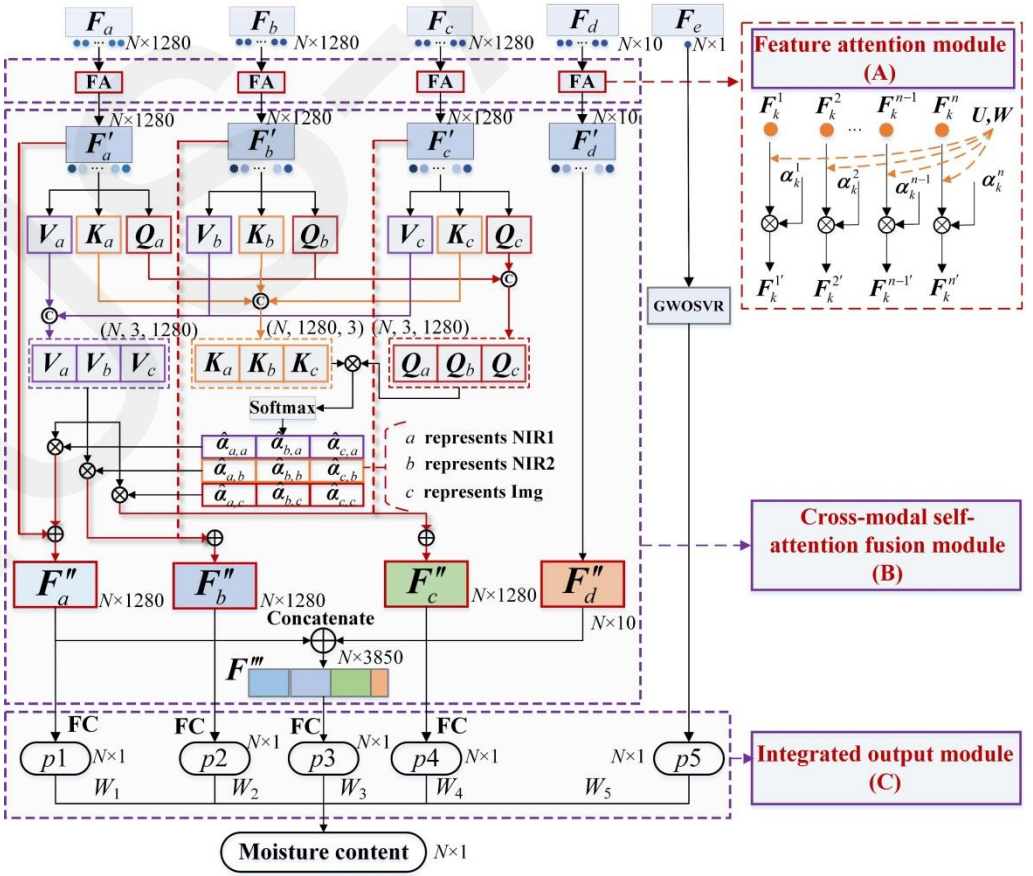
- Rapid
- High susceptibility to noise interference and inadequate accuracy

Advantages of the cross-modal integrated fusion strategy

Effectively extract the interactions between multimodal features, thereby improving the accuracy and robustness of moisture content detection.

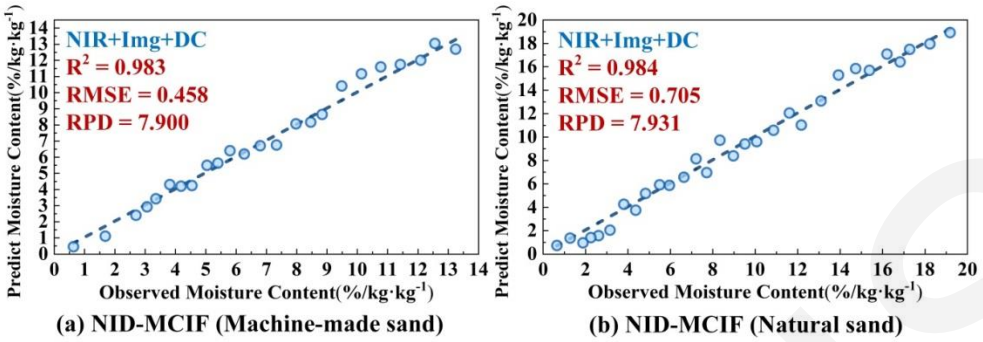


Multimodal data collection process

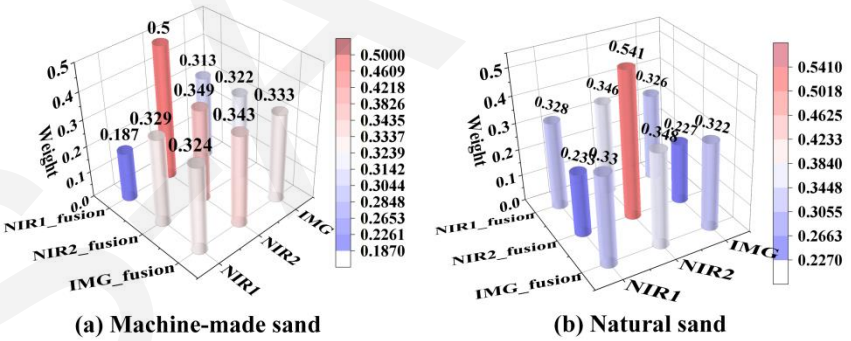


Flowchart of the multilevel cross-modal integration fusion model

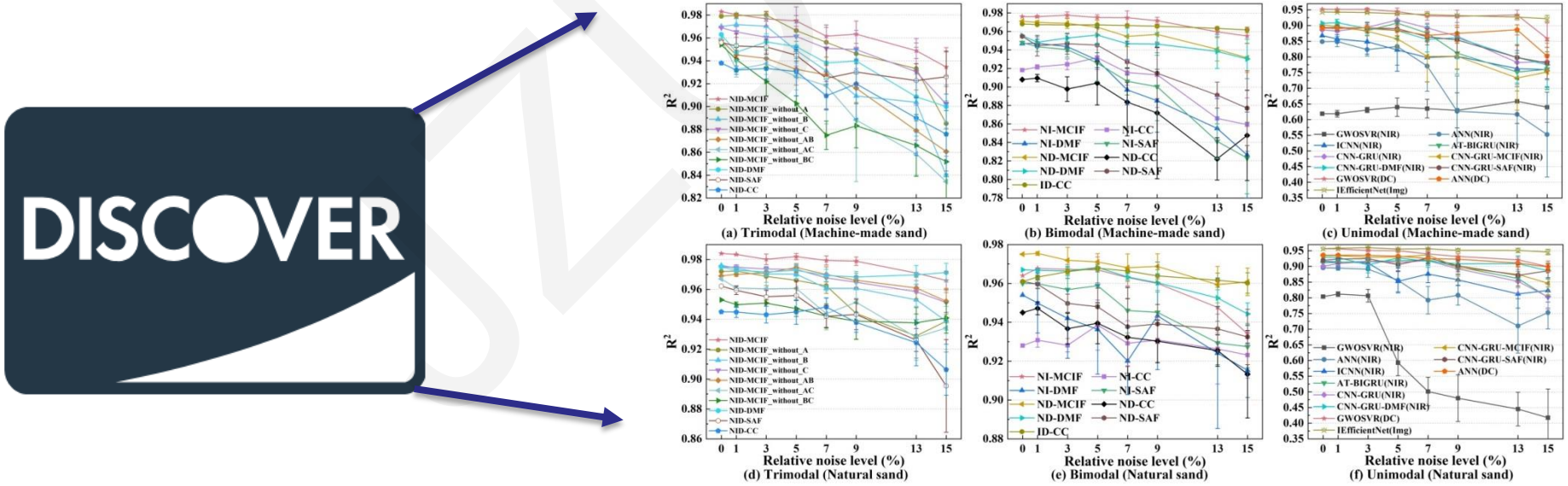
Detection results of the cross-modal fusion model (NID-MCIF)



Prediction results of the MCIF model for the MC of concrete sand



Cross-modal fusion weight distribution of the MCIF model



Model performance under varying levels of image, NIR, and DC noise intensity

Conclusions



- The proposed NID-MCIF model achieves high-precision accuracy in moisture content detection for both types of concrete sand materials, with $R^2 > 0.98$.
- Under the corresponding modalities, the model based on the MCIF fusion strategy significantly outperforms both the model employing a simple concatenation fusion strategy and unimodal models in terms of accuracy and robustness, providing a novel and reliable solution for rapid determination of moisture content in concrete sand materials.

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