

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

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Methods for moisture content detection



Oven-drying
method



frying method



Near-infrared
spectroscopic method



Image analysis method



Dielectric constant
method

...

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

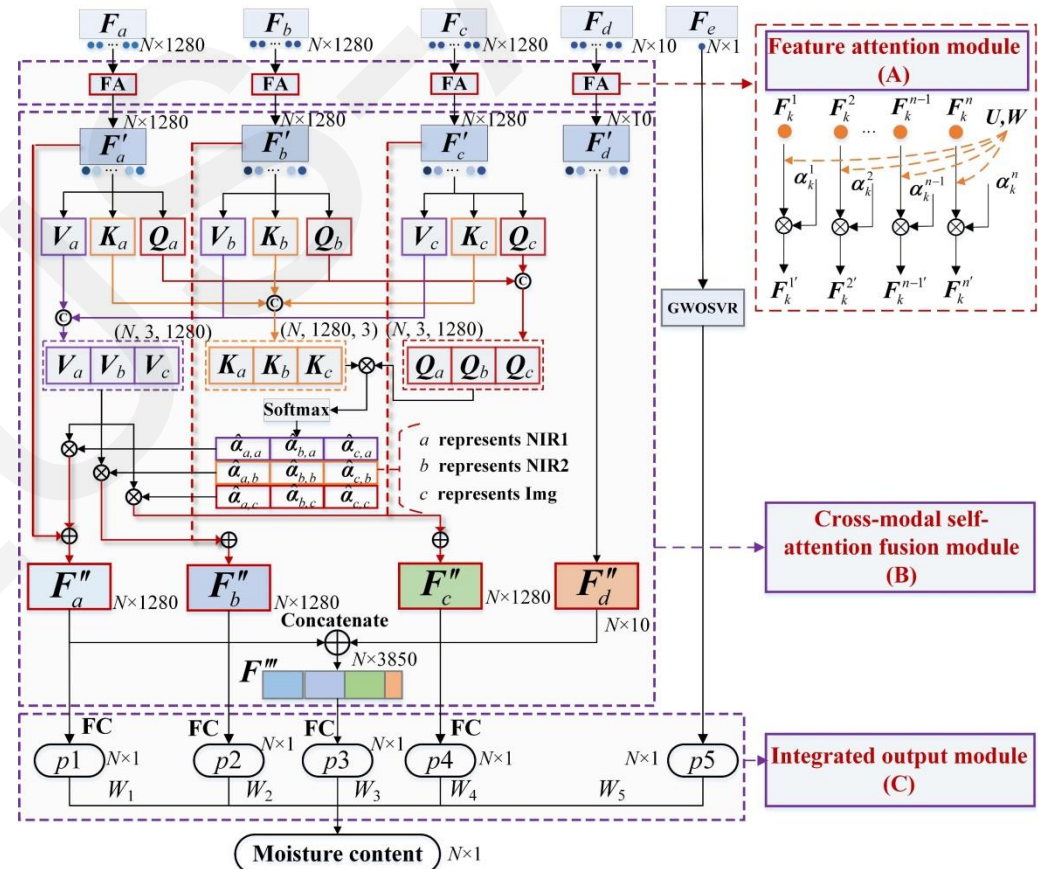
- **Rapid**
- **High susceptibility to noise interference and inadequate accuracy**

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.

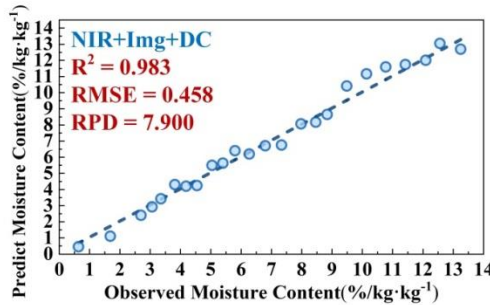


Multimodal data collection process

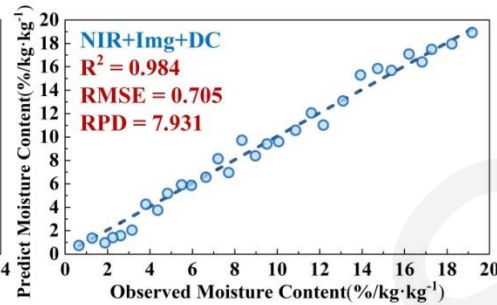


Flowchart of the multilevel cross-modal integration fusion model

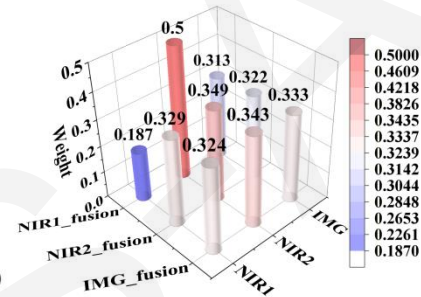
Detection results of the cross-modal fusion model (NID-MCIF)



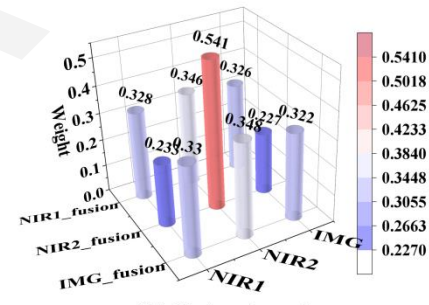
(a) NID-MCIF (Machine-made sand)



(b) NID-MCIF (Natural sand)



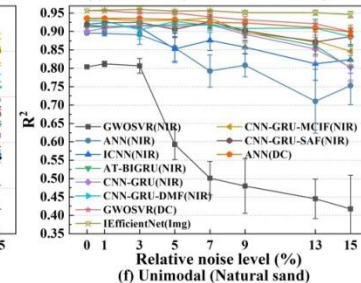
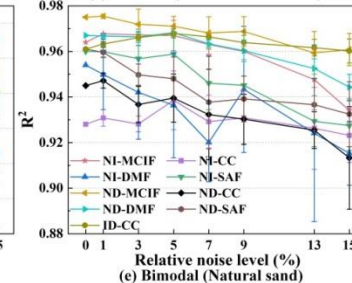
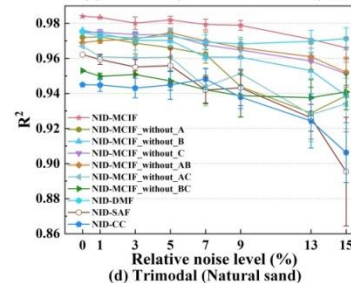
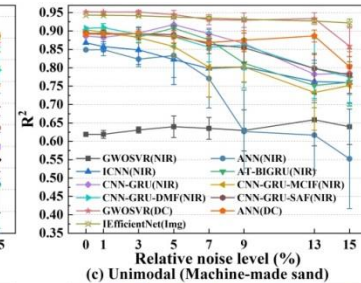
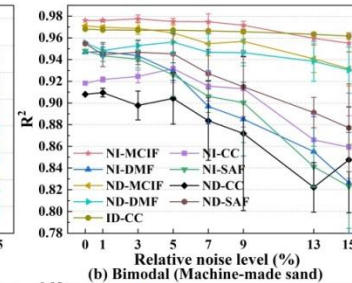
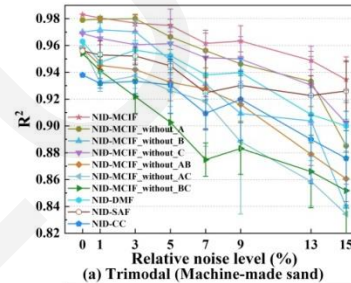
(a) Machine-made sand



(b) Natural sand

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.