Multi-fidelity fusion for soil classification via LSTM and multi-head self-attention CNN model

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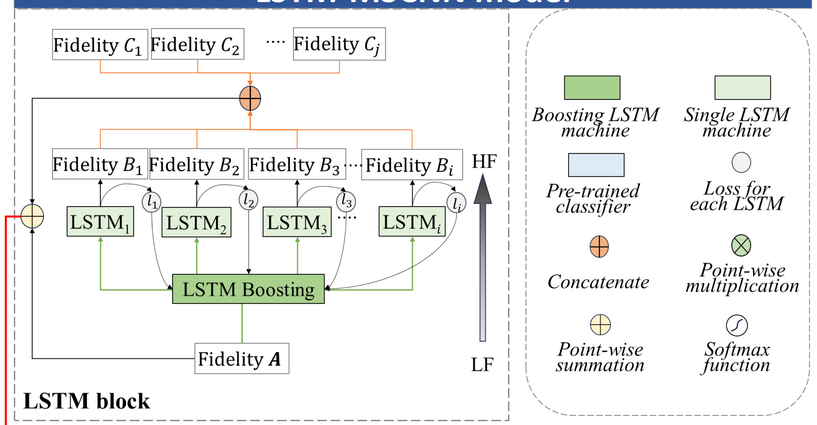
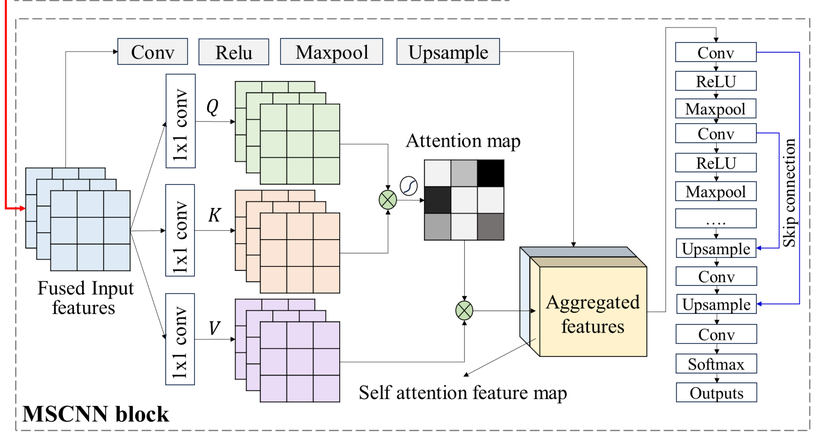
❑ Background & objectives

An effective soil classification method is essential for soil stratigraphy interpretation. Traditional methods rely on classification systems in design codes or empirical formulae based on single source data, which may not be accurate or suitable for every site. This research introduces a novel machine learning architecture using boosting LSTM machine to map low fidelity cone penetration test (CPT) data to high fidelity laboratory test (LT) data which are then fused and fed into a multi-head self-attention convolutional neural network (MSCNN) for soil classification. The experimental results reveal a significant improvement in prediction of true ground profiles using the proposed LSTM-MSCNN model over conventional methods.

❑ Methodology

LSTM-MSCNN model

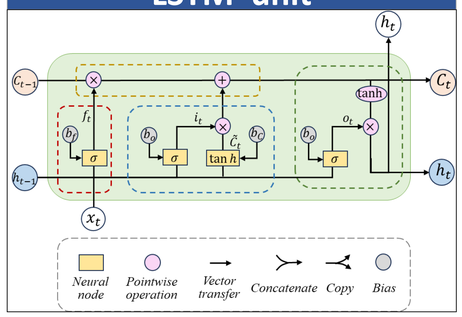




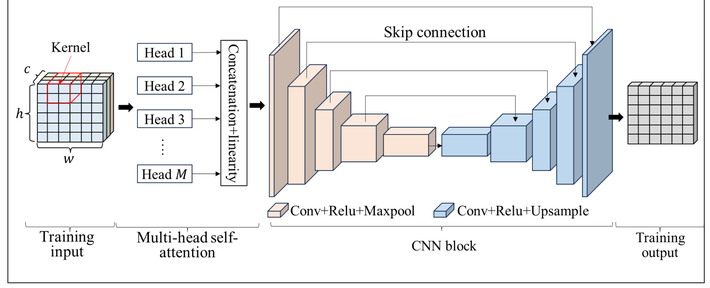
✓ a boosting LSTM is employed to map high-resolution, low-accuracy data into low-resolution, high-accuracy data. This involves utilizing multiple sub-LSTM machines specifically designed to achieve effective data mapping.

✓ The mapped outputs are concatenated with data from other fidelities. In this way, MF data containing valuable information from different sources can be fused into a feature map as an input for the MSCNN classifier.

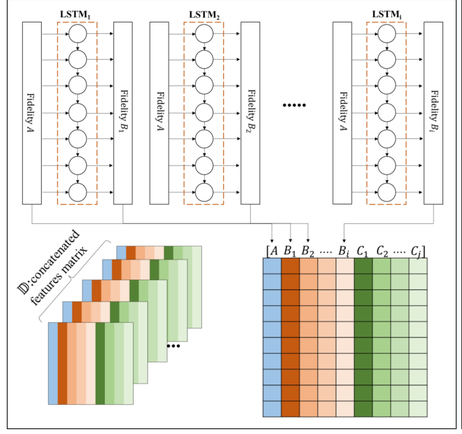
LSTM unit



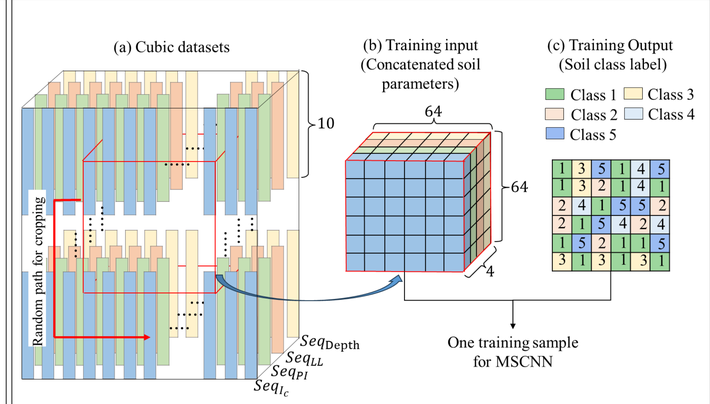
MSCNN model



MF data fusion process

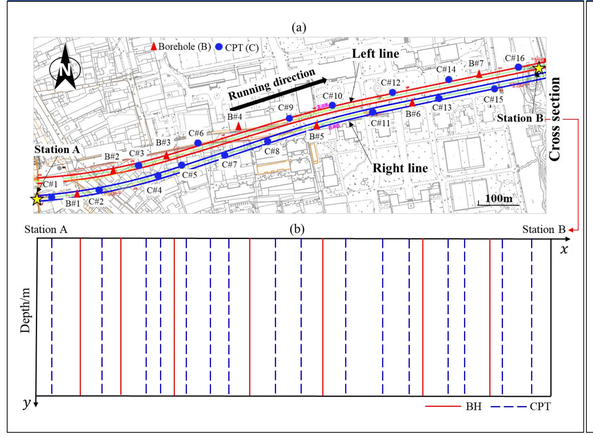


Data augmentation strategy

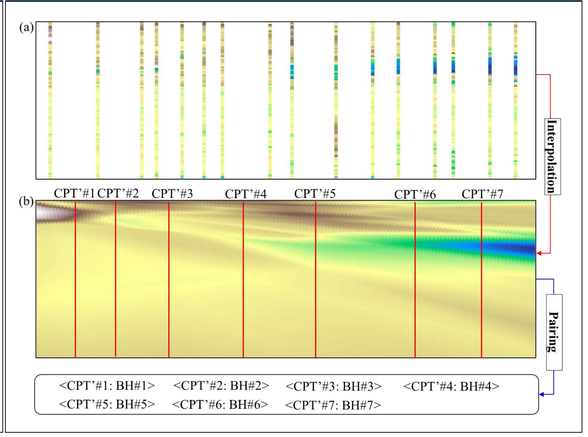


❑ Data samples for LSTM translation:

Plan view and cross sectional view of test locations



Interpolation of the CPT data and pairing exercise



The CPTs and BHs are staggered with approximately 1 BH for every 2-3 CPTs. CPT points are first interpolated to be able to acquire I_c data for any given location, using a simple feed-forward neural network (FNN) with interpolation resolution of 1 m and 0.1 m in the horizontal and vertical directions, respectively.

The interpolation is used to recover I_c records at the locations of real BHs, e.g. CPT'#1 to CPT'#7 in Figure 9. For example, at the location of BH#1, the interpolated I_c data is labelled using CPT' #1 to create the pair {CPT'#1: BH#1}. In this way, 231 pairs are constructed in total.

❑ Results:

✓ Figure 1(a) represents the traditional SBT classification result using CPT data only. Note that the stratum of fill is not correctly identified using the SBT chart, leading to the omission of soil type 1 in the SBT classification,

✓ Compared with the SBT classification, Figure 1(b) depicts the corresponding MSCNN classification results using fusion of CPT data and mapped BH data, which matches the benchmark profile reasonably well.

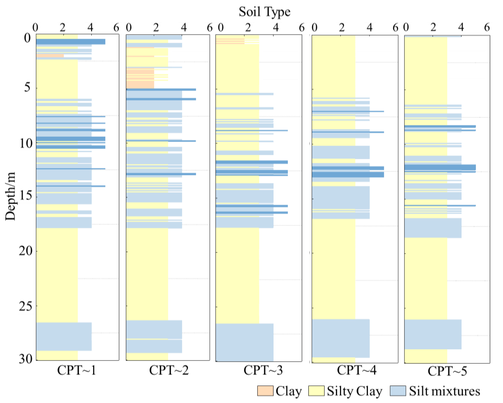


Figure 1(a) The SBT soil classification determined using selected CPTs

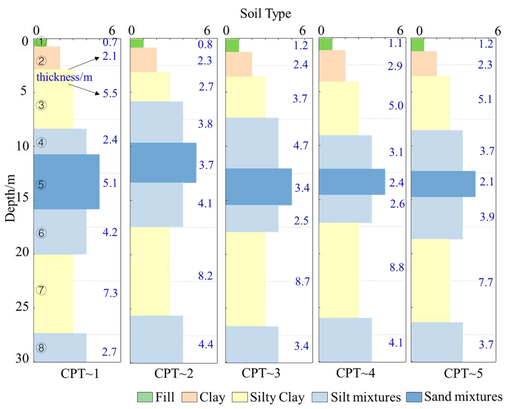


Figure 1(b) The soil classification result on selected test data determined using the updated LSTM-MSCNN model

❑ Conclusions:

- This paper introduced an innovative DL method for soil classification, leveraging LSTM for MF data fusion in conjunction with MSCNN classifiers.
- The predictions are validated on real data from the Suzhou No.5 metro line project, demonstrating substantial potential for application in similar tasks in future projects