Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

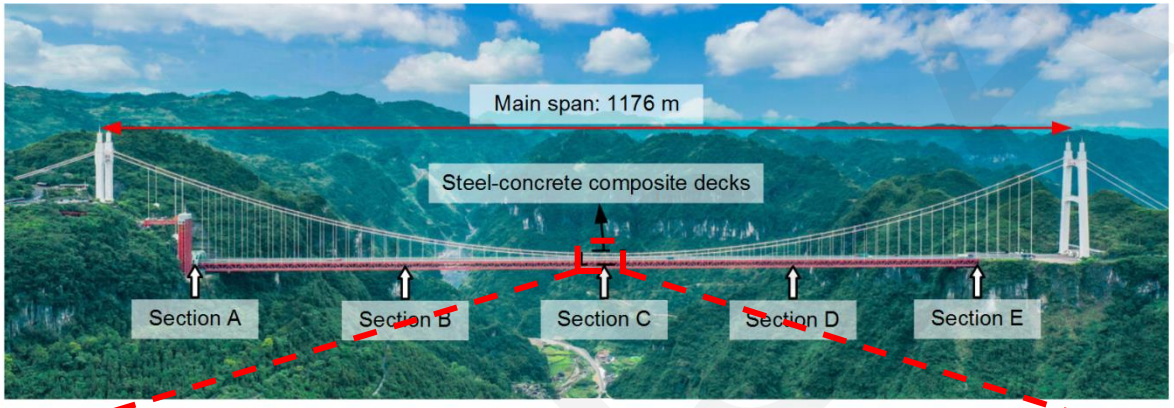
Temperature field prediction of steel-concrete composite decks using TVFEMD-stacking ensemble algorithm

Benkun TAN, Da WANG, Jialin SHI, Lianqi ZHANG

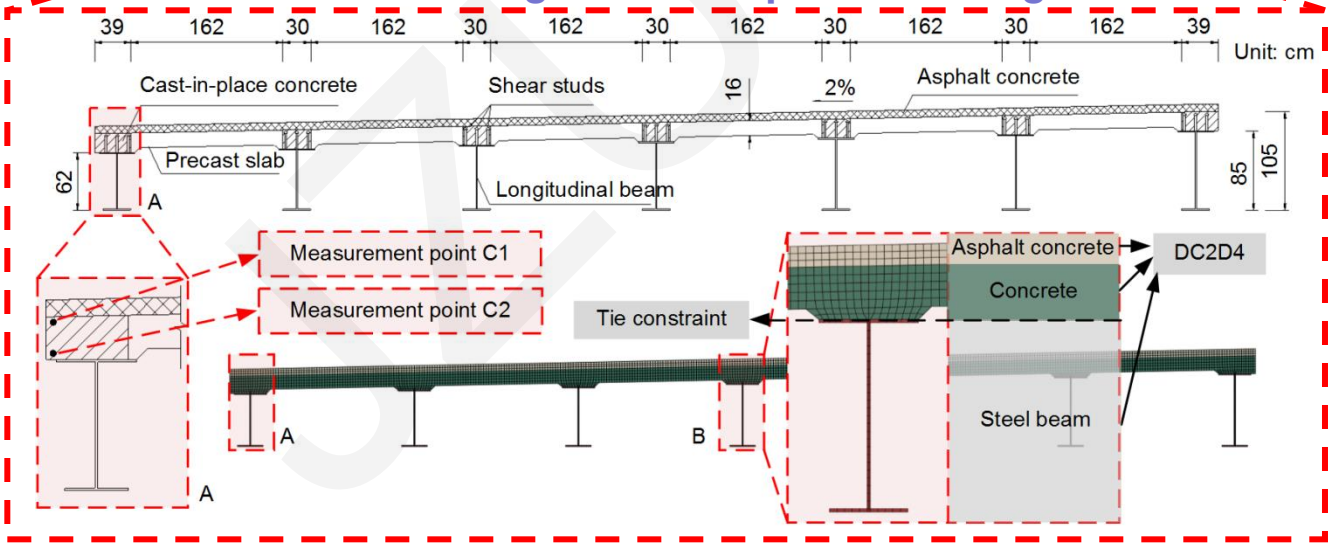
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Research subjects

- **Temperature field database is established by combining health monitoring data with numerical simulations**



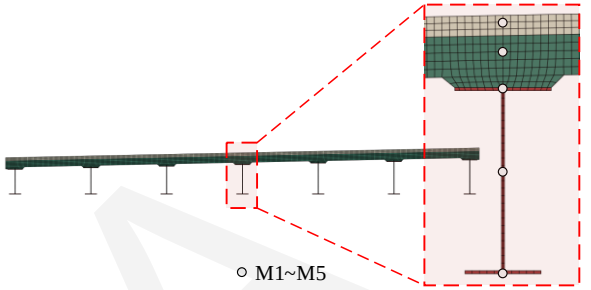
➢ **Overall diagram of suspension bridge**



➢ **Cross-sectional dimensions and FE model of the SCCDs**

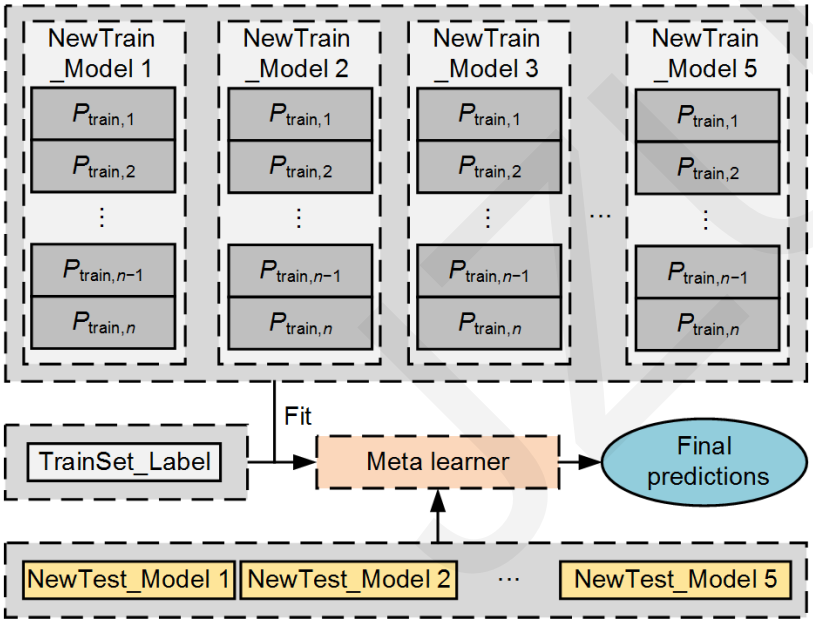
Research method

- Utilize time delay analysis and time-varying empirical mode decomposition (TVFEMD) methods for feature engineering to enhance prediction accuracy
- Develop a temperature field prediction model based on stacking ensemble learning

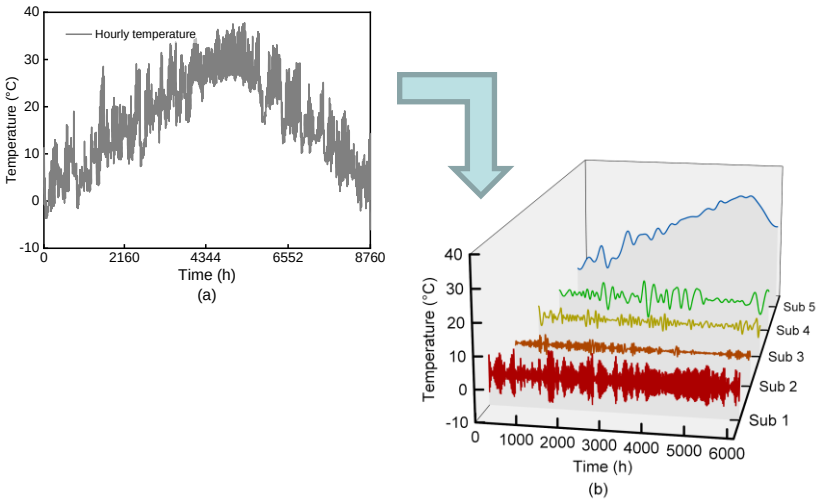


	t	*t*-1	*t*-2	*t*-3	*t*-4	*t*-5	*t*-6
M1	0.59	0.28	0.03	0.01	0.01	0.01	0.01
M2	0.00	0.00	0.04	0.74	0.22	0.00	0.01
M3	0.03	0.93	0.03	0.00	0.00	0.00	0.01
M4	0.67	0.33	0.00	0.00	0.00	0.00	0.00
M5	0.67	0.33	0.00	0.00	0.00	0.00	0.00

➢ The XGBoost model is used for time delay analysis of ambient temperature



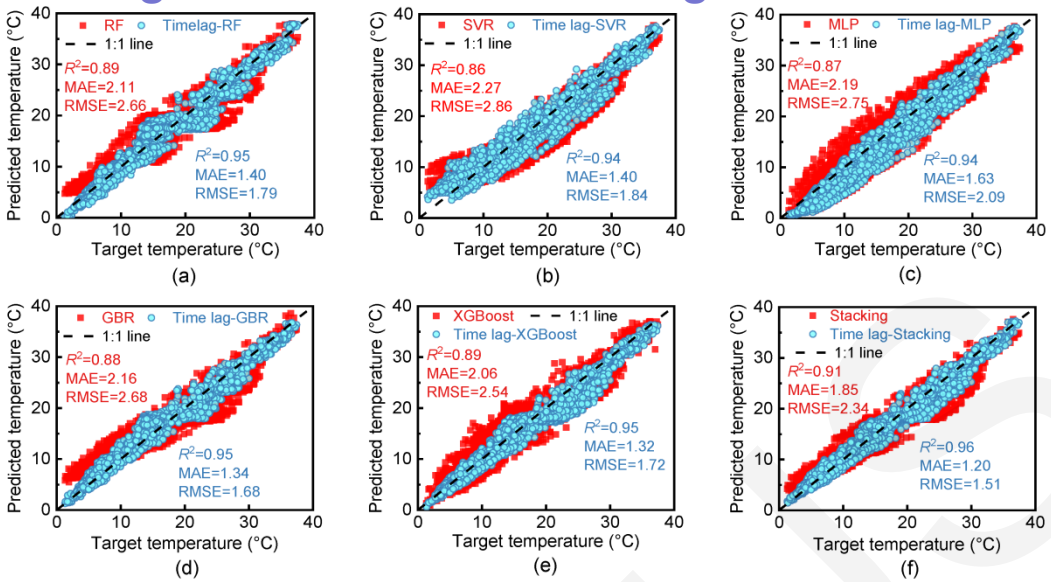
➢ Stacking ensemble model framework



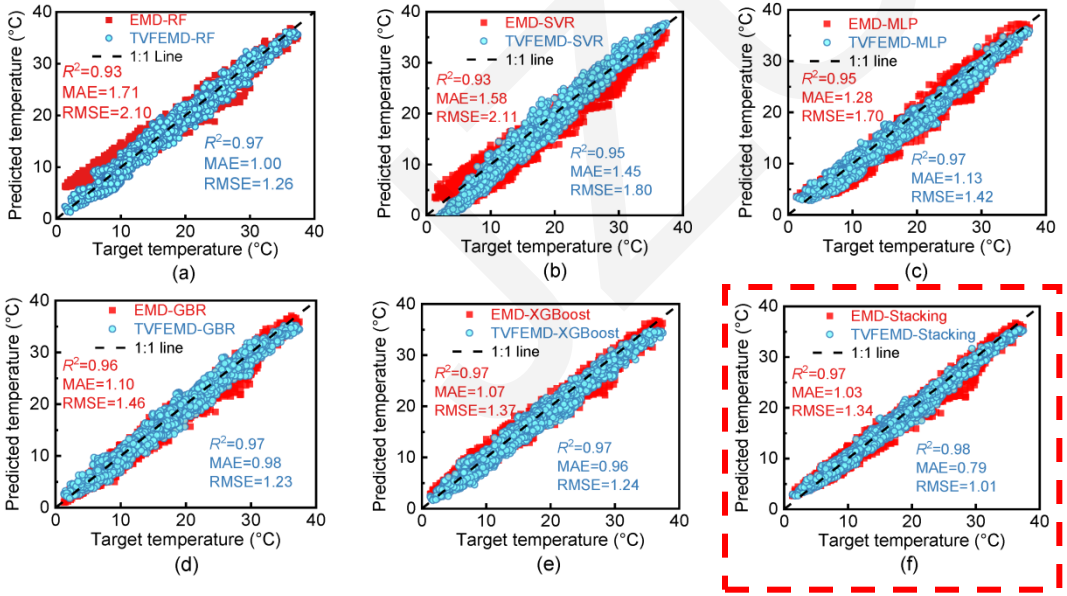
➢ Time-varying filtering-based empirical mode decomposition

Excellent prediction performance

➢ Original model and Time lag-based



➢ EMD-based and TVFEMD-based



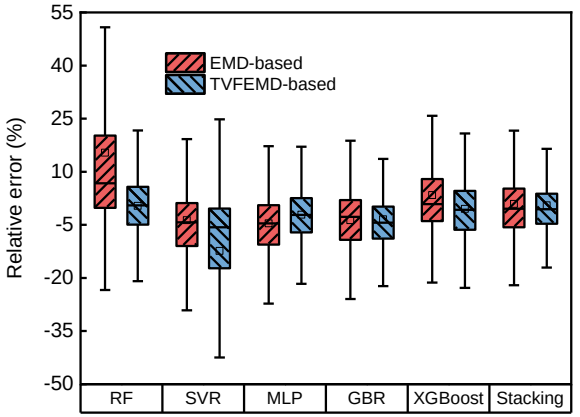
Scatter plot analysis

RF model	SVR model
MLP model	GBR model
XGBoost model	Stacking model

+

Time lag EMD TVFEMD

■ 20 individual models and 4 stacking models were built



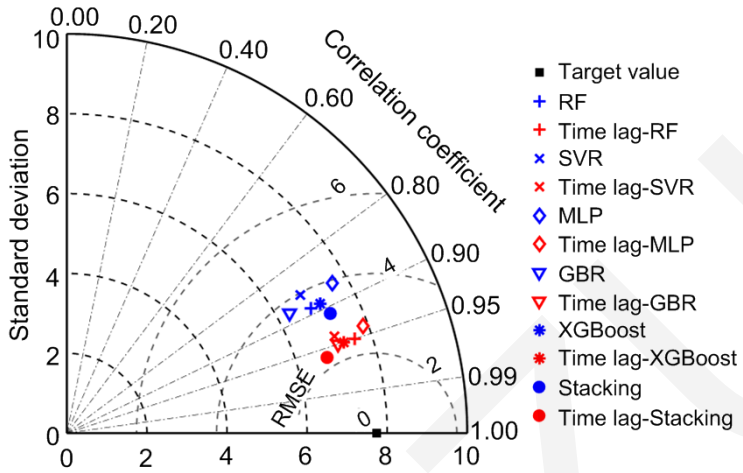
Relative error box plot

Excellent prediction performance

- **The models that combined time lag and feature decomposition had higher prediction accuracy**

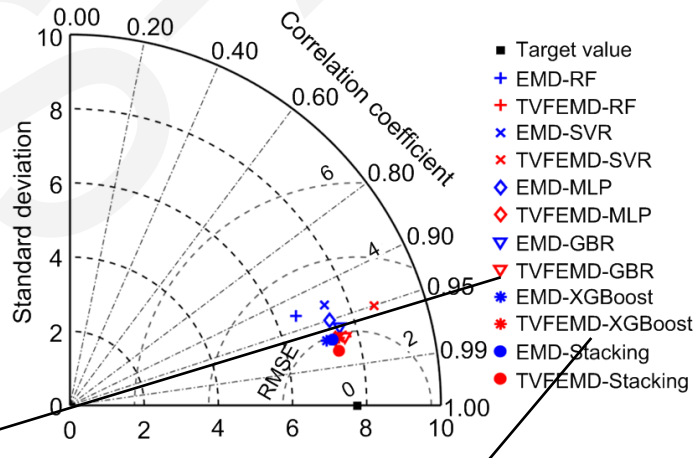
Taylor diagram analysis

➢ **Original model and Time lag-based**



TVFEMD-GBR model
(R^2 = 0.97, MAE = 0.98, RMSE = 1.23)

➢ **EMD-based and TVFEMD-based**



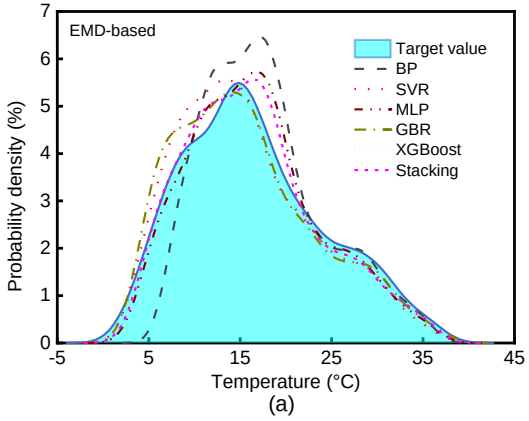
TVFEMD-XGBoost model
(R^2 = 0.97, MAE = 0.96, RMSE = 1.24)

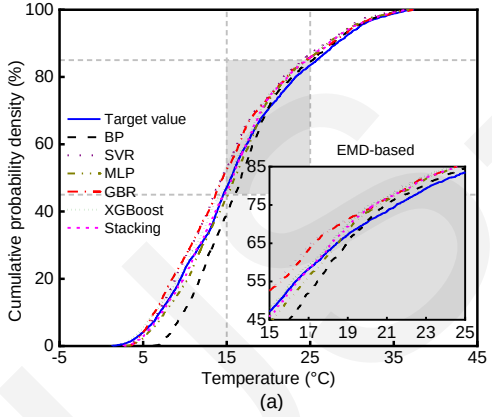
Excellent prediction performance

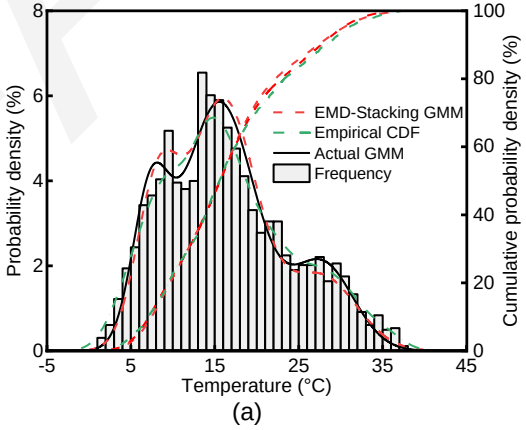
- **The predicted distribution of TVFEMD-stacking is the closest to the fitted distribution of the target values**

Statistical analysis

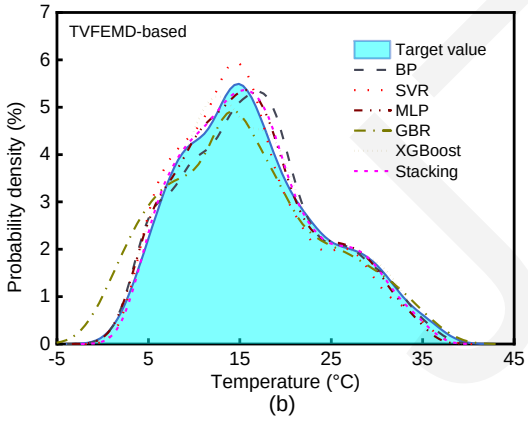
➢ **EMD-based**

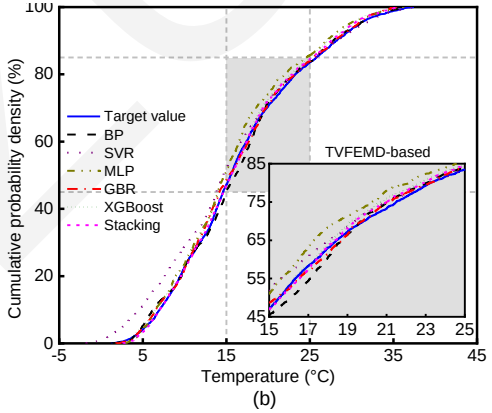


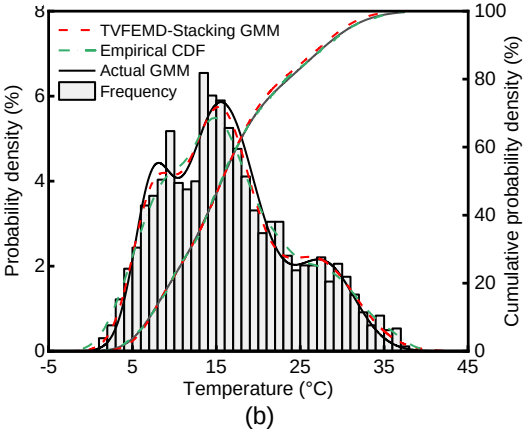




➢ **TVFEMD-based**







Empirical probability density plots

Cumulative probability density plots

Prediction and target value distribution fitting results

Conclusions

- The FE model was validated by on-site monitoring, which accurately calculated the temperature field of SCCDs under solar radiation. A single ML model prediction method can be developed based on FE data. The prediction accuracy was relatively low, with the SVR model performing the worst (R^2 = 0.86, MAE = 2.27, RMSE = 2.86).
- The predictive performance of a total of 20 models, which include four scenarios: considering no time delay, considering time delay, considering time delay and EMD, and considering time delay and TVFEMD. Each, combined with five individual ML models, was evaluated. The results show that considering time delay and input features from empirical mode decomposition can effectively improve the predictive accuracy of individual models.
- The models that combined time lag and feature decomposition had higher prediction accuracy. Among them, the TVFEMD-GBR model and TVFEMD-XGBoost model had relatively higher prediction accuracy, with evaluation indicators of (R^2 = 0.97, MAE = 0.98, RMSE = 1.23) and (R^2 = 0.97, MAE = 0.96, RMSE = 1.24), respectively.
- The stacking ensemble models based on EMD and TVFEMD can both further improve the prediction performance of the single ML model. The predicted distribution of TVFEMD-stacking is the closest to the fitted distribution of the target values, with a difference in RMSE between the probability density function and cumulative distribution function of 0.0014 and 0.0043, respectively.
- The model proposed here is highly accurate and can be used for rapid prediction of the temperature distribution of SCCDs under environmental influences. The content of this study can provide a reference for further analysis of temperature gradients over long service lifecycles, as well as real-time analysis of thermal deformation behavior and thermally induced strains.