Component-based reduced order modeling for heat transfer in thermal fin and data server

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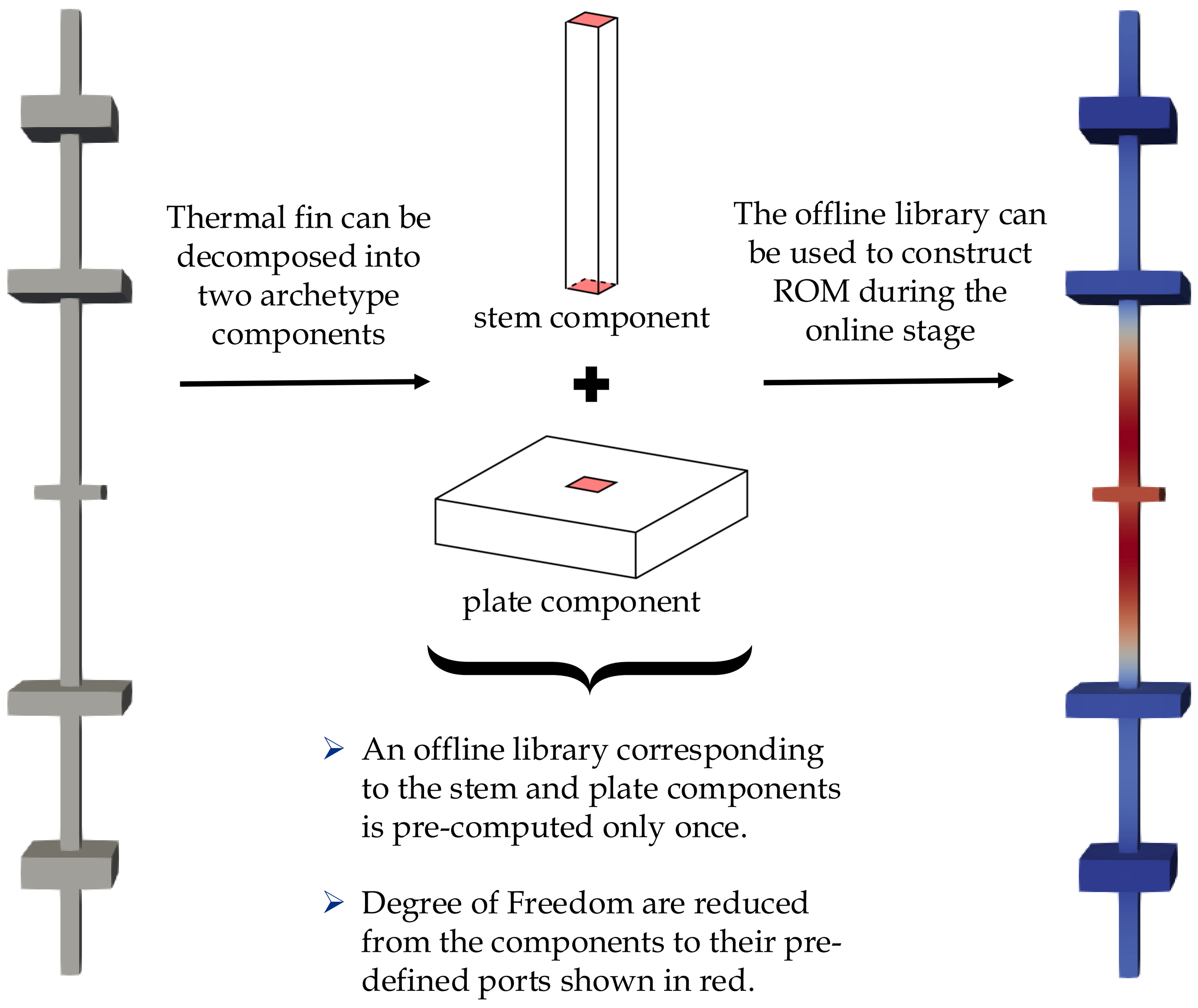
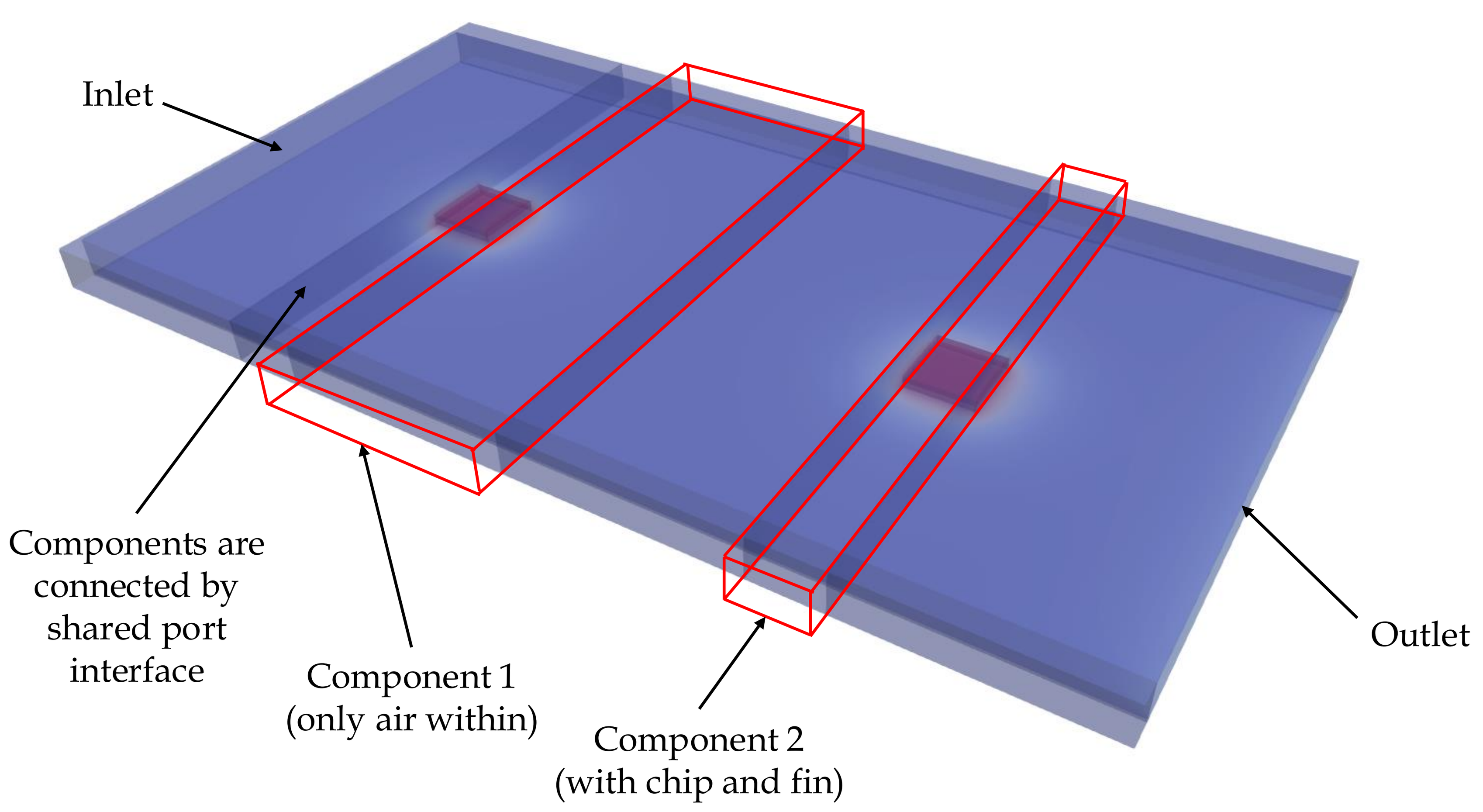
1 Introduction

- Large-scale and complex engineering structures require simulations to understand and quantify physical phenomena.
- The Finite Element Analysis (FEA) model is widely used for that, albeit computationally and memory intensive.
- These structures are often decomposable into components of identical features, which make Component-based Reduced Order Modeling (CBROM)[1,2] an ideal approach.
- In this research, we aim to simulate the heat transfer in thermal fin[2] and data server using CBROM approach.

2 Materials and Methods

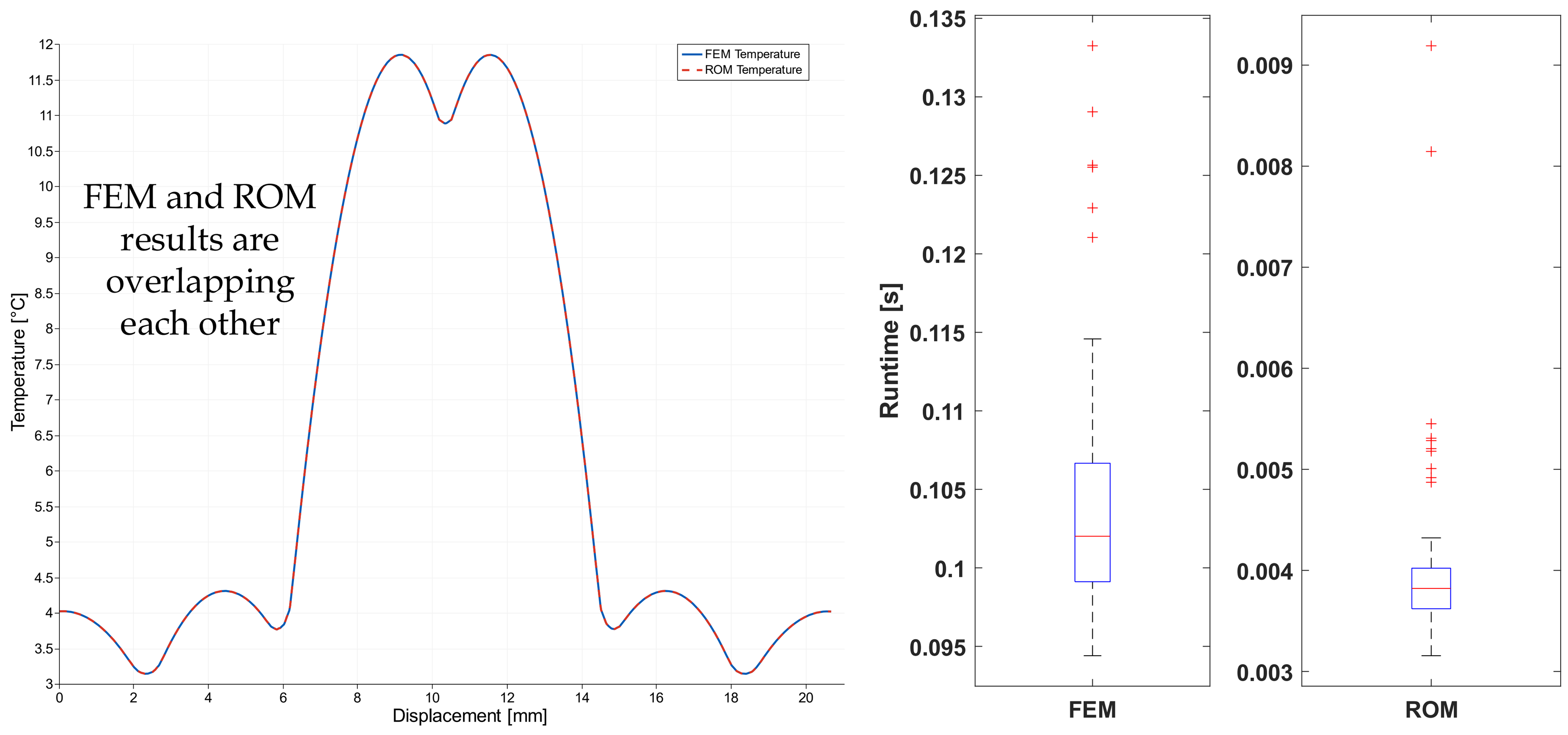


- Data server is 600mm wide, 1070mm deep, and 44.45mm (1U) tall, and made up of five materials: stainless steel (top and sides), plastic (bottom), air, silicon (chips) and aluminum (fins).
- Assume a single data server rack to be in a cool data center room of 22°C, with heat pump to extract hot air away from the outlet. Heat source is generated only from the silicon chips.
- Inlet has fixed end boundary condition of 22°C and outlet has heat flux boundary condition of 35°C. The rest of the surface boundaries have heat flux boundary condition of 22°C.

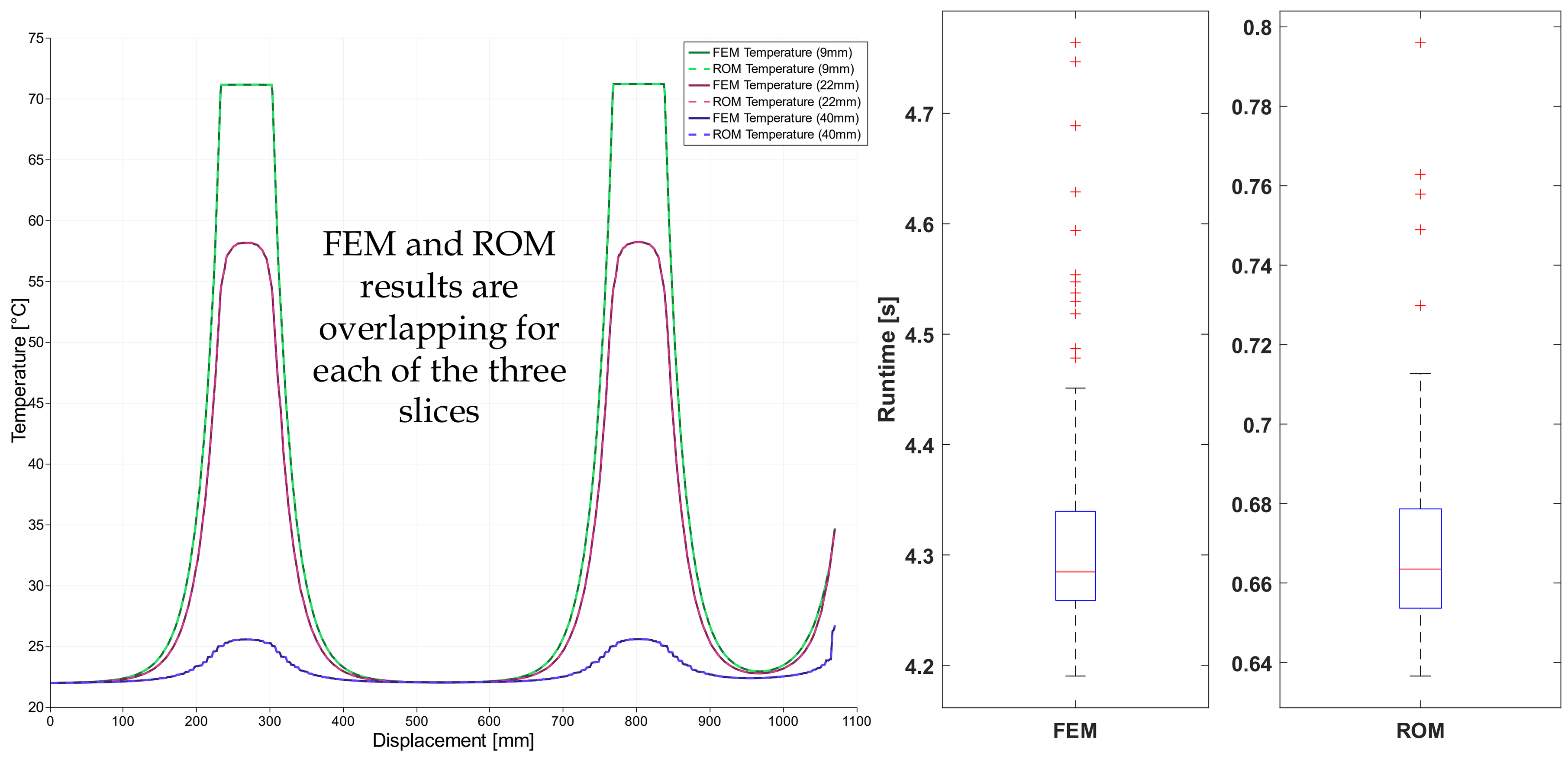


3 Results

- Both FEM and ROM codes are iterated 100 times to calculate the computational runtimes.
- For thermal fin, the temperature for FEM and ROM are measured along the center in the positive z-axis



- RMSE: 4.1684e-14; Average runtime: 0.10424s (FEM), 0.00396s (ROM)
- For data server, the temperature for FEM and ROM are measured along three horizontal x-axis slices at these heights: 9mm (between silicon chips and aluminum fins), 22mm (halfway of data server), and 40mm (near the top in data server).



- RMSE: 6.4244e-12; Average runtime: 4.40965s (FEM), 0.67861s (ROM)

4 Conclusions and Future Work

- Computational runtime for CBROM is 26 and 6.5 times faster than that of the high-fidelity FEA model for thermal fin and data server respectively, while still maintaining high accuracy.
- Analysis of heat transfer may be applied to many other modular systems (e.g., propulsive engines) and can speed up engineering design processes.
- **Future work** can include incorporating convection terms for CBROM to simulate air flow within a data server. Additionally, multiple data servers can be stacked to form a data rack, and further stacked to create a data center using the CBROM approach.

References

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[2] Huynh, D.B.P., Knezevic, D.J. and Patera, A.T., 2013. A static condensation reduced basis element method: approximation and a posteriori error estimation. ESAIM: Mathematical Modelling and Numerical Analysis, 47(1), pp.213-251.

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