Fire Technology manuscript No.
(will be inserted by the editor)

Multiscale Fire Modeling Using Inverse Convolutional Neural Networks

Jonathan L. Hodges · Brian Y. Lattimer

Received: date / Accepted: date

Abstract This paper presents a novel predictive analytics approach to

Keywords Compartment Fire · Machine Learning · Computational Fluid Dynamics · CFD · Convolutional Neural Network

1 Introduction

Understanding the transport of combustion products in a compartment fire is vital in fire hazard analysis. Although advancements in computing technology have made computational fluid dynamics (CFD) of structural fires possible, the computational cost can be prohibitive. Parametric studies and predictions of large structures often rely on more coarse predictions such as those from zone fire models. Researchers have presented multiscale modeling approaches to fuse 3-D CFD with 1-D zone models; however, each approach inherits the computational cost of CFD [1–6]. A new compartment fire model which is capable of providing rapid predictions of 3-D spatial-temporal profile of intensive properties within a compartment is needed.

The use of numerical tools to predict the flow of air and combustion products in compartment fires has been an integral part of fire protection engineering since the 1970s [7]. Zone fire models provide rapid predictions of mean values of intensive properties in a compartment and mean transport between compartments. CFD models provide

Although advancements in computing technology have made computational fluid dynamics (CFD) predictions of structural fires feasible, modeling large domains using CFD is beyond the capability of current technology.

The fundamental principle which makes convolutional neural networks (CNNs) versatile is the capability to learn how to represent complex shapes as combinations

J. L. Hodges
Jensen Hughes
2020 Kraft Drive, Suite 3020
Blacksburg, VA 24060 USA
Tel.: +1 540-808-2800 x10611
E-mail: jhodges@jensenhughes.com

of high level feature maps. Krizhevsky showed many of the features learned by the CNN in the ImageNet competition described the inter-relationship of the 3 color channels [8]. As an analogy to image classification, data such as elevation, moisture content, and wind speed can be treated as channels in an image. Given enough data, a CNN will be able to learn relationships between these physical parameters which can then be used to predict a future fire perimeter.

The objective of this study is to apply a CNN framework to predict the spatial-temporal distribution of a wildland fire front in homogenous vegetation without relying on any other models at runtime. Data for use in training and testing the network was generated using Rothermel's phenomological model. The sensitivity of the network to each input parameter is examined, and the trained parameters of the network are used to infer relationships about input parameters. The work presented herein represents a proof-of-concept on a simple configuration with future work to expand the method to use experimental data with heterogenous spatial conditions.

2 Methods

The method presented herein

3 Results

The robustness of the

4 Discussion

The overall shape of

5 Conclusion

A novel predictive analytics approach to

Acknowledgements This research was developed under Contract No. 200-2014-59669, awarded by the National Institute for Occupational Safety and Health (NIOSH). The findings and conclusions in this report are those of the authors and do not reflect the official policies of the Department of Health and Human Services; nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.

References

1. L. Wang, Q. Chen, Applications of a coupled multizone-cfd model to calculate airflow and contaminant dispersion in built environments for emergency management, HVAC&R Research **14**(6), 925 (2008)
2. F. Nobile, Coupling strategies for the numerical simulation of blood flow in deformable arteries by 3d and 1d models, Mathematical and Computer Modelling **49**(11-12), 2152 (2009)

3. J. Choi, Multiscale numerical analysis of airflow in ct-based subject specific breathing human lungs. Ph.D. thesis, University of Iowa (2011)
4. F. Colella, G. Rein, R. Borchiellini, J.L. Torero, A novel multiscale methodology for simulating tunnel ventilation flows during fires, Fire technology **47**(1), 221 (2011)
5. A.P. Kuprat, S. Kabilan, J.P. Carson, R.A. Corley, D.R. Einstein, A bidirectional coupling procedure applied to multiscale respiratory modeling, Journal of computational physics **244**, 148 (2013)
6. A. Haghighat, K. Luxbacher, B.Y. Lattimer, Development of a methodology for interface boundary selection in the multiscale road tunnel fire simulations, Fire Technology pp. 1–38 (2018)
7. J. Quintiere, in *Fire Standards and Safety* (ASTM International, 1976)
8. A. Krizhevsky, I. Sutskever, G.E. Hinton, in *Advances in neural information processing systems* (2012), pp. 1097–1105