PROJECT SUMMARY

WUI-NITY: a platform for the simulation of wildland-urban interface fire evacuation

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Background: Fires in wildland-urban interfaces (WUI) are associated with severe negative consequences, such as large community evacuation, property losses social disruption, short- and long-term damage to infrastructure, injuries, and evacuee and responder fatalities.[1][2][3] Wildland fires represent an important safety issue in many regions of the world. The future expansion and increased complexity of wildland-urban interfaces (WUI) pose severe challenges to community safety from an evacuation perspective.[4] Therefore, WUI incidents are likely to become more severe and affect more people.

The social and physical geography associated with WUI communities present a special challenge that needs to be addressed to ensure life safety. Developmental densities, the layout and capacity of the road network, and the surrounding geographical terrain all might contribute to the capability of community members to reach a place of safety in response to a WUI incident.[5] Understanding the development of the fire alone is not a sufficient predictor of the impact of the incident on nearby populated areas.[6] Therefore, WUI incidents require a multi-domain approach to assess their impact and the effectiveness of any mitigation efforts implemented. A simulation framework that can establish evacuation performance ahead of time (before responses are implemented), would complement current planning and educational approaches and broaden the scope of the evidence available in a cost-effective way. Such a framework might be used to predict how an evacuation develops based on current and possible future fire conditions, given different affected populations and evacuation decisions and the access / availability of different resources (e.g., road access, public transport, traffic congestion,

[1] Manzello, S.L., Yamada, T., Jeffers, A., Ohmiya, Y., Himoto, K., Carlos Fernandez-Pello, A., 2013. Summary of workshop for fire structure interaction and urban and wildland-urban interface (WUI) Fires–operation Tomodachi–fire research. Fire Saf. J. 59, 122–131. https://doi.org/10.1016/j.firesaf.2013.03.021
[2] Maranghides, A., Mell, W., 2011. A Case Study of a Community Affected by the Witch and Guejito Wildland Fires. Fire Technol. 47, 379–420. https://doi.org/10.1007/s10694-010-0164-y
[3] Mell, W.E., Manzello, S.L., Maranghides, A., Butry, D., Rehm, R.G., 2010. The wildland–urban interface fire problem – current approaches and research needs. Int. J. Wildland Fire 19, 238. https://doi.org/10.1071/WF07131
[4] Hammer, R.B., Stewart, S.I., Radeloff, V.C., 2009. Demographic Trends, the Wildland–Urban Interface, and Wildfire Management. Soc. Nat. Resour. 22, 777–782. https://doi.org/10.1080/08941920802714042
[5] Cova, T.J., Dennison, P.E., Kim, T.H., Moritz, M.A., 2005. Setting Wildfire Evacuation Trigger Points Using Fire Spread Modeling and GIS. Trans. GIS 9, 603–617. https://doi.org/10.1111/j.1467-9671.2005.00237.x
[6] Cutter, S.L., Boruff, B.J., Shirley, W.L., 2003. Social vulnerability to environmental hazards. Soc. Sci. Q. 84, 242–261.

etc.). To achieve this, the simulation framework would need to represent the core components driving the incident; e.g., a predictive model of residential response, fire development and traffic flow.

A specification for such an integrated platform architecture has been developed by the authors of this proposal during a recent Foundation research project. An implemented framework would be able to simulate the evolving incident conditions based on the time-based developments of the core components and how they interact to produce an outcome of interest. This framework allows the simulation of multiple domains that enables time-based vulnerability mapping of affected populations reflecting their capacity (or otherwise) to cope with the conditions faced. Existing static vulnerability maps generally rely on historical data or conditions (e.g. weather, vegetation, socio-economic factors, etc.). Existing risk maps typically focus on single domains (e.g. fire). Dynamic vulnerability mapping provides instead a vehicle for displaying this simulated response in relation to the dynamic evolution of the fire and then representing the derived vulnerability given the results generated. This represents a significant enhancement of current static mapping approaches that more effectively exploits the predictive functionality of the proposed multi-domain framework providing broader and deeper insights into the emergent conditions and their implications.

The concept of dynamic vulnerability mapping requires (1) the representation of multiple subject domains and (2) using simulations to make predictions. The proposed integrated tool has both of the capabilities. The simulated results may then be in a number of forms:

- traditional 2D overlays showing how the fire, traffic and pedestrian responses evolve in real-time
- interpretations of this simulated evolution to map the identified dynamic vulnerability of the pedestrian population given the conditions faced. This may involve some analysis to determine how the vulnerability levels for certain locations/populations are derived.

This would represent a significant change for practitioners and responders who would then be able to see evolving future conditions and their implications - enhancing their situational awareness.

Research Goal: The WUI-NITY project aims at developing an integrated software platform for the simulation of wildland-urban interface (WUI) evacuation scenarios that can be used both before an incident for planning and during an incident to inform decisions. The primary application of this platform is the ability to generate dynamic vulnerability maps from coupled fire, pedestrian and traffic sub-models.

Project Tasks:

1. Project management and dissemination: This refers to the management of the activities of WUI-NITY project and the dissemination of the results.

2. System Architecture and data-sets for the proof of concept: Update original system architecture design and develop model selection component based on performance criteria. This allows for future modular implementation of different modelling tools with different levels of granularity. Identification of the required data-sets (e.g. weather, geodata/elevation and vegetation, road network and population) for implementation in the proof of concept.

3. Modelling integration. This consists in the selection and implementation of the three modelling components into a virtual reality game engine. This includes 1) an existing empirical fire model (e.g. FARSITE[7]), 2) a crowd model for the simulation of people response and people movement towards private vehicles based on a simplified approach (e.g. A* star algorithm or similar[8] and 3) a traffic model for the simulation of the displacement of private vehicles (cars, buses, etc.) along the road network using a macroscopic method (e.g. a coarse network modelling approach)[9]. Outputs will be obtained from each model and a routine for data transfer/exchange is built. This routine can be based on the existing concept of trigger points.[10]

4. Output analysis and GUI development. A Graphic User Interface (GUI) will be developed in order to allow the importing of all relevant data-sets and input calibration phase. The GUI will be built in such a way to allow a 2D visualization of the scenarios and output vulnerability mapping but also allow a future dedicated 3D mode for the visualization of the WUI-NITY tool scenarios at a household level. This means that the GUI will allow the creation of standalone modelling scenarios that can be used for future training purposes, using procedural generation of objects.

5. Vulnerability mapping. The coupled modelling output will be used to develop static (based on pre-defined set conditions) and dynamic (based on evolving fire conditions) vulnerability mapping. The vulnerability maps will be developed as layer visualized in the GUI which takes into account of a score system which is derived from all simulation layers.

6. Demo case study. A case study will be run with the newly developed WUI-NITY tool to exemplify its use and apply the new concept of dynamic vulnerability mapping with a WUI fire evacuation scenario.

Implementation: This research program will be conducted under the auspices of the Research Foundation in accordance with Foundation Policies and will be guided by a Project Technical Panel who will provide input to the project, recommend contractor selection, review periodic reports of progress and research results, and review the final project report. Funding for this project is provided through NIST.

Schedule: The final report is scheduled to be issued in October 2019.

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[7] Finney, M.A., others, 1998. FARSITE, Fire Area Simulator–model development and evaluation. US Department of Agriculture, Forest Service, Rocky Mountain Research Station Ogden, UT.
[8] Bladström, K., 2017. Route choice modelling in fire evacuation simulators. LUTVDG/TVBB.
[9] Barceló, J., 2010. Fundamentals of traffic simulation. Springer.
[10] Cova, T.J., Dennison, P.E., Kim, T.H., Moritz, M.A., 2005. Setting Wildfire Evacuation Trigger Points Using Fire Spread Modeling and GIS. Trans. GIS 9, 603–617. https://doi.org/10.1111/j.1467-9671.2005.00237.x

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