GOOD SYSTEMS
A UT Grand Challenge

Fire and Smoke Digital Twin - A computational framework for modeling fire incident outcomes

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Introduction

The detection and tracking of fires is commonly achieved through the use of satellite data, with models relying on abnormal heat signatures and bright spots on the Earth's surface [1]. While this approach is effective for detecting large wildfires, it is not suitable for tracking urban fires which are more frequent and have a greater impact on people [2].

To address this, we propose a new fire tracking and forecasting platform, called "FireCOM". This platform utilizes real-time data on fires and building footprints, combined with weather information, to accurately predict the smoke fallout one, two, and three hours after a fire incident. The FireCOM model has the potential to improve public health by warning people about lowered air quality conditions in their areas, as well as assisting fire departments and decision-makers in mitigating the effects of fire and smoke. The primary function of this tool will be as an early warning system, providing citizens with crucial information about potential hazardous fires and smoke.

Figure 1: A VSmoke smoke simulation in-browser, with residences affected also highlighted according to smoke impact.

Research Goal

The aim of our research is to implement our Fire and Smoke Digital Twin within a digital twin environment (DT), which is a novel concept of integrated, multiphysics, multiscale, and probabilistic simulations that closely mimic the real world [3]. By utilizing live data, our digital twin will be capable of automatically updating itself, making accurate predictions, and modeling potential responses to current events. This will enable us to develop a robust tool for effective fire and smoke management, with real-time insights into potential outcomes and responses.

Methods

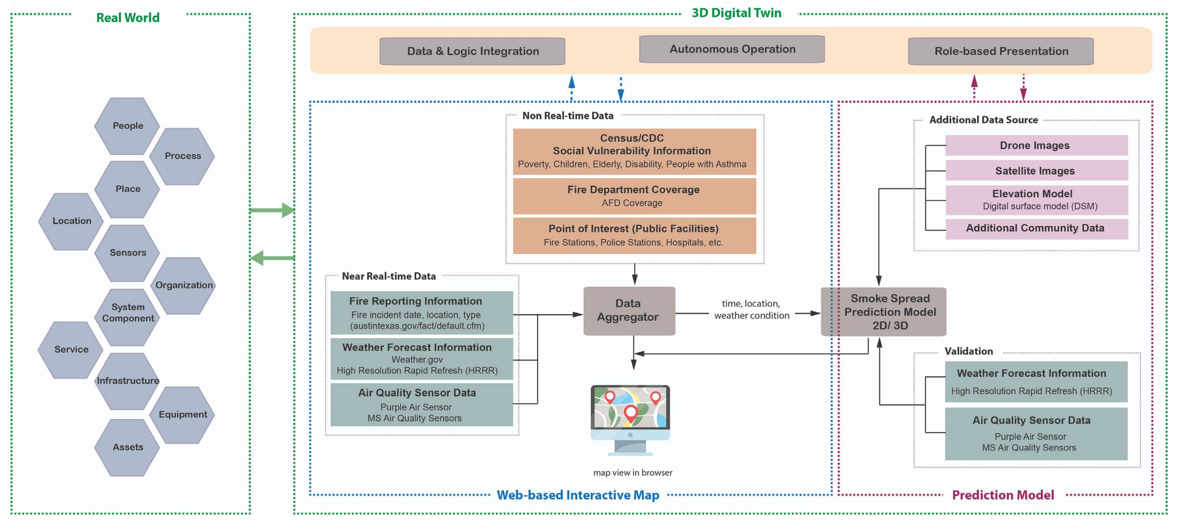

Figure 2: A diagram of the urban smoke prediction workflow.

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Figures

To simulate urban fires, we generated fluid simulations for each urban smoke in real-time using two algorithms: MantaFlow and VSmoke. VSmoke produced 2D smoke simulations [4], whereas MantaFlow generated 3D smoke forecasts [5], which would be more accurate in a complex city. We also compared our publicly collected fire data to approximate "urban fire risk" areas of the City of Austin based on the average amount of fires and compare against Austin's own wildfire risk analysis.

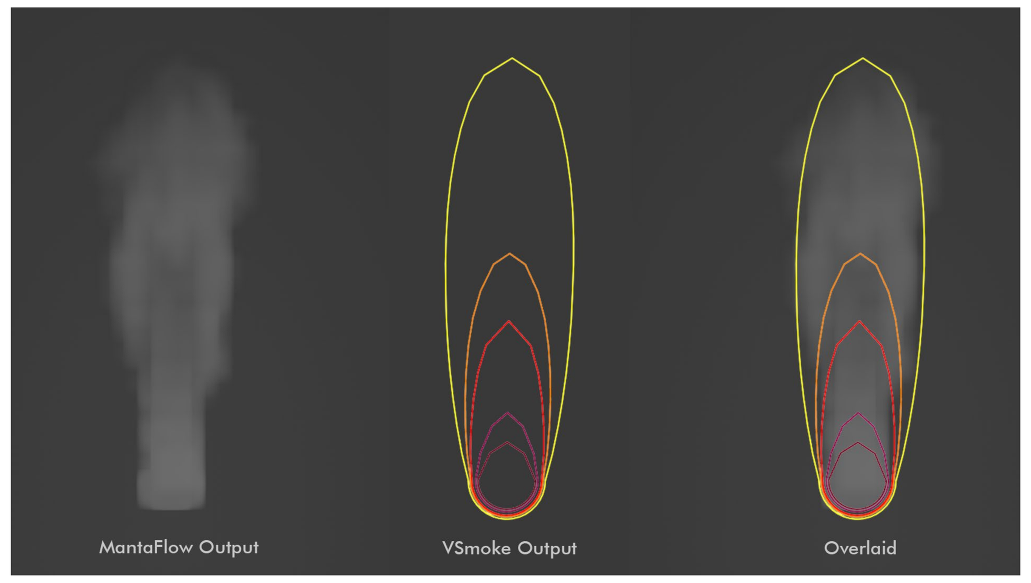

Figure 3: A comparison of the VSmoke and MantaFlow predicted smoke outputs.

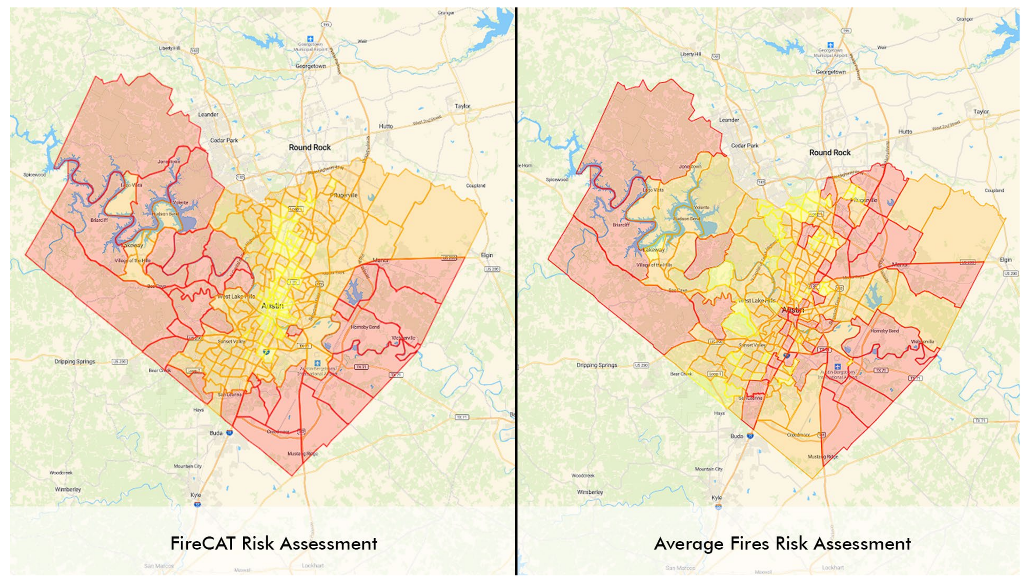

Figure 4: A comparison of FireCAT Wildfire Risk Assessment (left) and our Fire Averages per tract (right).

Results

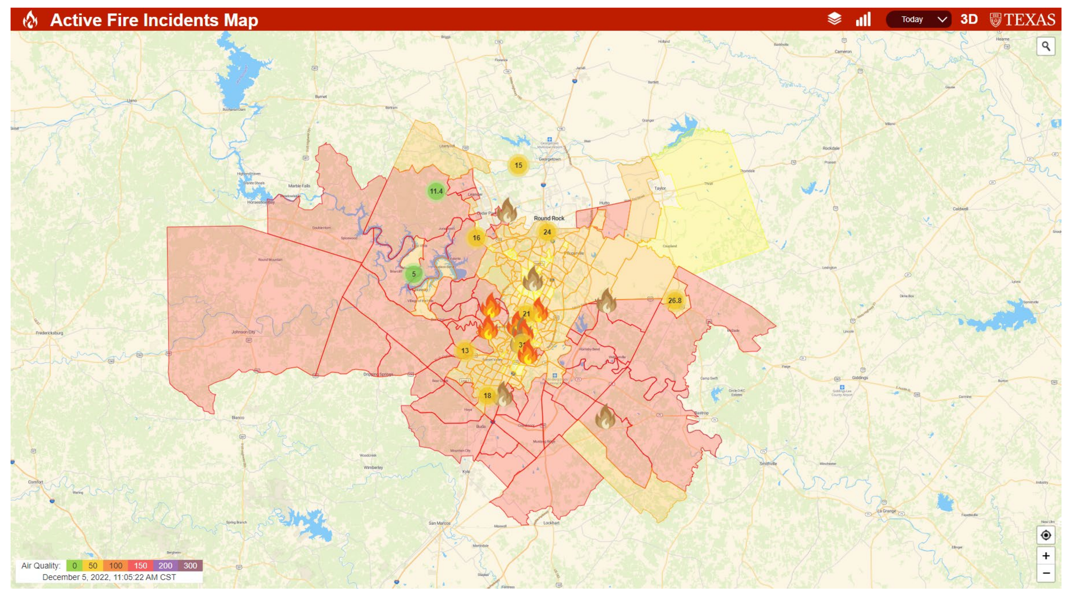

Figure 5: Our 2D real-time fire and smoke map in-browser.

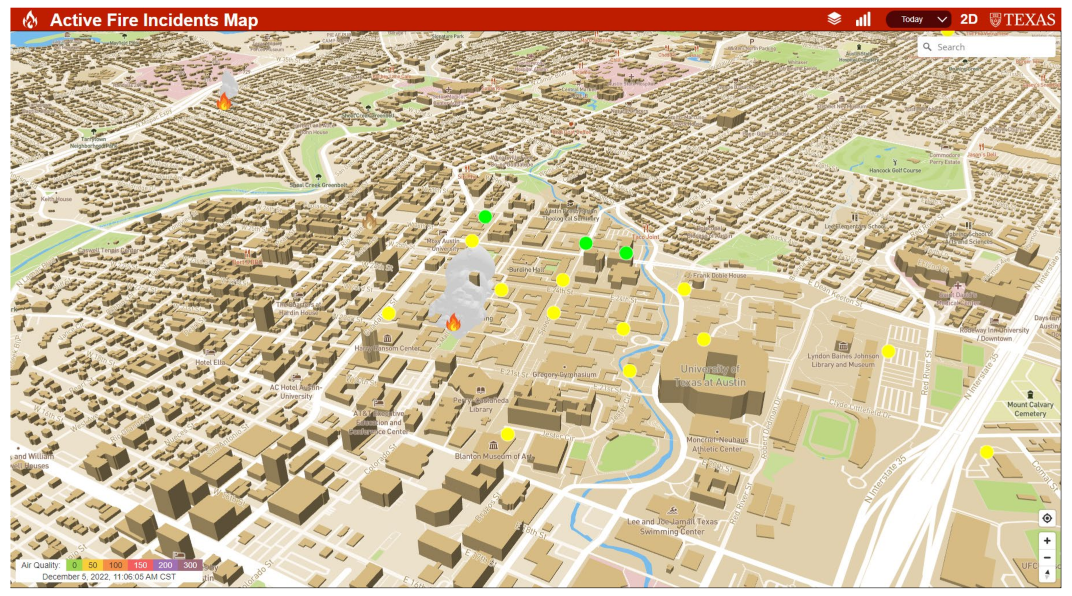

Figure 6: Our 3D real-time fire and smoke map in-browser.

Our study showcases three main areas of novelty: data integration, 2D to 3D shifting, and use of public data. We achieved data integration by incorporating information from various sources, such as building footprints, air sensors, weather updates, and census data. In shifting to a 3D perspective of the city, including topography and building geometry, we were able to obtain a realistic understanding of how each fire will develop, providing citizens and firefighters with informed decisions when dealing with fires in their communities. Our work was based entirely on public data, and the open-source code that we released makes this model easily generalizable and replicable to any city.

Conclusion

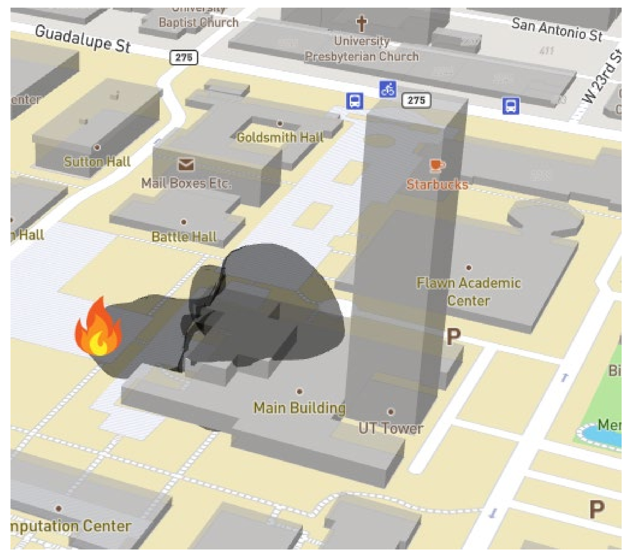

Figure 7: An example supervised smoke fluid simulation in-browser, showing a potential fire and fallout at UT Tower.

Our model represents a significant advancement in on-demand smoke simulations for urban fires, which were previously considered too complex to attempt. With our model, it is now possible to accurately predict both approximate smoke outcomes and hyper-realistic smoke fluid simulations for any fire. As an early warning system, our model has the potential to inform individuals about lowered air quality and smoke in areas of high risk, aiding in the mitigation of negative health impacts such as PM2.5 exposure. We believe that our model will prove to be an invaluable tool for fire and smoke management, providing decision-makers with crucial information to make informed and timely decisions.

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