Community-oriented Wildfire Planning with Agentic AI: Automated Fire Spread Simulation and Interactive 3D Visualization

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Abstract

With the increasing frequency and severity of Wildland–Urban Interface (WUI) wildfires, there is a growing need for community-oriented planning approaches that integrate foresight, preparedness, and participatory decision-making. This paper presents an intelligent and interactive framework that engages communities, urban planners, and emergency responders in exploring fire-resilient strategies through agentic AI-driven wildfire simulation and interactive 3D visualization. The proposed system enables users to define scenario-based queries via a conversational interface, which are automatically translated into orchestrated 2D and 3D fire spread simulations. A virtual, interactive environment supports intuitive exploration of alternative wildfire scenarios and community-scale mitigation strategies. The framework aims to enhance public awareness and adaptive behavior while providing science-informed decision support for evaluating fire dynamics under varying terrain, infrastructure, and fuel conditions. Built upon a Large Language Model (LLM)-powered agentic architecture, the system automates simulation workflows and lowers technical barriers, enabling users with diverse backgrounds to participate in wildfire planning processes. Simulation outputs are delivered through web-based 3D visualization and immersive holographic interfaces, supporting iterative and interactive analysis of fire spread in urban environments. Through this approach, communities can assess risk, compare mitigation strategies, and improve preparedness for real-world wildfire events.

1. Introduction

Once occasional events, wildfires in the Wildland–Urban Interface (WUI) have transformed into ongoing crises that threaten community safety and environmental stability (Radeloff et al., 2018; Karels, 2022). As human settlements expand into fire-prone regions, the WUI now covers approximately 4.7% of Earth’s land surface, turning localized fire events into large-scale socio-economic hazards (Schug et al., 2023; Van Borkulo et al., 2005). These fires result in the loss of human lives, property, and infrastructure while devastating ecosystems, soils, and air quality. From the burning areas to continental-scale smoke pollution and down to debris flows and water contaminations, these fires exert huge cascading effects on a wider scale (Tang et al., 2025). The escalating frequency and intensity of WUI wildfires then point toward the urgent need for coordinated community-level interventions (Stephens and Ruth, 2005). Yet, barriers continue to stand in the way: among them are insufficient stakeholder participation, a lack of grounding for local capacity, and an inability to implement proactive risk mitigation and climate-resilient planning (Copes-Gerbitz et al., 2022; Satizábal et al., 2022; Basta et al., 2007).

It is generally accepted that the proactivity of wildfire risk policy in the WUI welcomes very little hindrance between awareness and mitigation (Copes-Gerbitz et al., 2022). There are still few widely accepted methods for prevention and mitigation that should be taken in wildfire deterrence procedures, and limited by community opposition for numerous reasons ranging from risks to perceived smoke to aesthetics to property values. From a methodological point of view, the barrier that prevents non-technical community members in high-risk areas from accessing and interpreting advanced wildfire simulations remains largely unbroken (Wallace et al., 2025; Basta et al., 2007). As fewer communication channels and less expertise are required in preparing inputs to GIS, configuring simulation parameters, and interpreting outputs, the wider the chasm grows as these tasks become more complex (Dye et al., 2023).

Tackling this challenge would mean integrating fire science, GIS, sensor measurements with recent advances in generative and agentic AI for the purpose of creating an intelligent and easy-to-use system that would automate data preparation and simulation workflows, minimizing the need for technical specialists (Xu et al., 2025b,c; Hofstra et al., 2008; Xu et al., 2024). Immersive visualizations envision their users interactively exploring alternative fuel-management strategies (Wong et al., 2025; Edgeley et al., 2024). Such interactive experience endow residents and decision makers with an intuitive grasp of the ways proactive fuel treatments affect fire spread, while also fortifying the acceptance of such treatments by the community as a climate-resilient approach to wildfire prevention.

This article proposes an intelligent, community-oriented workflow that integrates advanced wildfire modeling with participatory planning (as illustrated in Figure 1). The framework provides a user-friendly platform for geospatial data integration, automated scenario configuration, and interpretation of fire spread dynamics, enabling users without specialized expertise to actively engage in wildfire risk assessment and planning.

2. Community-based System for Fire Risk and Mitigation

Wildfire management has shifted from its traditional command-and-control model to collaborative fire planning, where communities, fire authorities, land managers, and local decision-makers share responsibility for preparedness and mitigation (Essen et al., 2023; Fernandes, 2023; Zlatanova et al., 2007). This

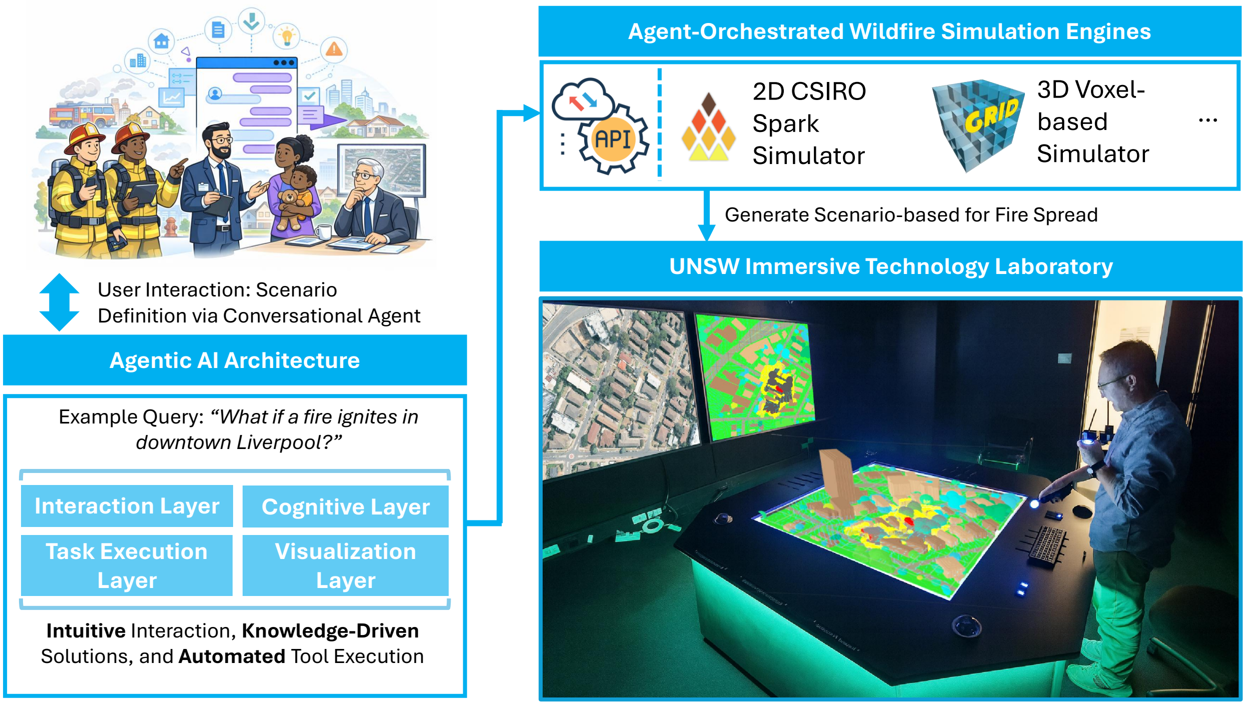


Figure 1. Agentic AI framework for interactive wildfire scenario generation, multi-model simulation, and immersive mixed-reality visualization.

transition takes into account that wildfire risk in the WUI is conditioned by biophysical factors such as fuel and environmental conditions, as well as social dimensions including household behavior, land use, and local risk perception (Lambrou et al., 2023; Toman et al., 2013). Originating in the 1990s from community fire-safe councils, the approach has since evolved into institutionalised frameworks such as CWPPs, Fire-Adapted Communities, and Australian community-based bushfire planning led by CFA and NSW RFS brigades (Jakes et al., 2011; MacDougall et al., 2014).

2.1 Shared Responsibility and Stakeholder Roles

The concept of shared responsibility in wildfire management recognizes the idea that risk cannot be mitigated by a single organization or emergency agency (Karels, 2022; Palsa et al., 2022). While the fire services may provide technical expertise, warning systems, and operational response, effective response depends heavily on coordinating actions with a myriad of other actors including homeowners, land managers, utility companies, insurers, and local governments. Homeowners affect ignition and structure survival by maintaining defensible space, applying fire-resistant materials, and following insurance and safety standards (Auer, 2024). Land-use planners determine long-term exposure by means of zoning, development approvals, and infrastructure design, while forest and park agencies act on vegetation and ecosystem health scales (Shive et al., 2025; Murray et al., 2023; Neuvel and Zlatanova, 2006). The Indigenous communities contribute important cultural knowledge including traditional burning practices that restore ecological balance and inform sustainable fire regimes.

As real-world examples, the wildfires in Los Angeles of 2025 illustrated the role of local stakeholders and homeowners in the shared responsibility framework. Many residents took direct measures to protect their homes. Some kept their houses and grass wet by using garden hoses and improvised sprinkler systems. Others created their own water supply by connecting portable pumps to swimming pools (Chang and Rendon, 2025). In Australia, such acts of self-protection are supervised by a team of local residents organised in Community Fire Units (CFUs), which are supported by legitimate fire fighting units (e.g. Fire and Rescue in New South Wales). Such cases clearly demonstrate that community preparedness and on-the-ground decision-making can only be achieved through both institutional response and local engagement (Fuchs et al., 2026).

2.2 Barriers to Public Engagement in Wildfire Planning

Despite extensive literature on public engagement and collaboration in wildfire management, significant barriers remain. A large proportion of residents are unaware of the wildfire risks to their properties or the effectiveness of mitigation measures such as prescribed burning and structural retrofitting (Fuangaromya and Brown, 2023). Participation in wildfire management is often time-consuming, requires specialized knowledge, and depends heavily on trust—yet such trust is unevenly distributed among renters, elderly populations, and low-income groups (Paveglio and Edgeley, 2023).

Emergency response agencies frequently face challenges in communicating complex fire science in ways that are accessible and meaningful to local communities. At the same time, residents may perceive external planners as imposing solutions or lacking sensitivity to local values and lived experiences. These differing perspectives can delay project approval and hinder coordination among stakeholders, ultimately affecting cross-boundary fuel management efforts (Smithwick et al., 2024).

Governance fragmentation further complicates wildfire planning. Landowners, local councils, utilities, insurers, and fire authorities often hold overlapping yet poorly aligned responsibilities related to action, funding, and liability. In the absence of clear roles and accountability, risk-reduction efforts tend to remain at the planning stage rather than being effectively implemented (Miller et al., 2022; Hamilton et al., 2023). Reducing wildfire risk in the WUI is therefore not solely a technical challenge but a socio-technical one. It requires effective knowledge transfer, accessible communication for non-technical stakeholders, and trust-building through transparent public messaging, local engagement, and community-based outreach (Wallace et al., 2025; Coston and Wade, 2024).

3. Agentic AI System for Community-oriented Hazard Management

Recent advances in agentic AI systems have created new opportunities for intelligent platforms that automate specialized tasks while maintaining friendly, human-like interfaces. By combining reasoning, memory, and adaptive interaction, these systems can transform complex analytical processes into accessible conversational experiences (Xu et al., 2025b,a). Building on this progress, we propose an integrated workflow that leverages agentic AI to connect multiple domain-specific wildfire simulation models with cross-platform interactive visualization tools. We propose a system in which a chatbot interface enables users to configure simulation parameters, explore scenarios, and visualize results in a unified environment, transforming advanced modeling and visualization into more accessible, human-centric workflows that can support decision-makers and community-oriented wildfire planning (Niloofar et al., 2023; Muste et al., 2017; Xu et al., 2023).

3.1 Design Specification

Developing an agentic AI system for community-involved fire management requires a design that bridges technical complexity with human-centered cognition and accessibility. To guide this development, we embrace a few key system design specifications:

1. First, the system must support human-centered interaction by enabling users to communicate in natural, plain language without requiring domain-specific knowledge. The system should be capable of interpreting user intent and translating it into structured, executable scientific workflows.

2. Second, the system must support interoperability among heterogeneous data and model sources to allow seamless integration of data and creation of user-defined fire simulations.

3. Third, the system must allow for search and seamless integration of various simulations such as wildfire and wind as well as input of near-real-time sensor data and observations.

4. Fourth, the design should emphasize easy-to-use multimodal interfaces, including chatbot dialogues, browser-based dashboard, and mixed-reality visualizations, to enable two-way communication between the system and diverse groups of users.

In this paper, we focus on a general agentic AI-powered workflow for community engagement rather than detailed technical implementation.

3.2 Conceptual System Design

The proposed system establishes a layered agentic AI architecture that integrates user interaction, cognitive reasoning, tool-integrated execution, and multimodal visualization to support automated wildfire simulation and analysis workflows (Xu et al., 2025b). As illustrated in Figure 2, at the high level, users define wildfire scenarios through natural-language and geospatial inputs, which are captured in the interaction layer and interpreted by coordinated AI agents in the cognitive layer. These agents translate user intent into executable, knowledge-augmented simulation workflows, which are then orchestrated through function calling and an API-based tool interface to invoke external simulation engines and data-processing services in the execution layer. The resulting outputs are rendered through web-based and holographic visualization platforms, forming an end-to-end pipeline.

The workflow is enabled by four main layers, each responsible for a distinct role in the agentic system:

1. **Interaction Layer**: This layer provides multimodal interfaces for user engagement, including a chatbot interface and a map-based interface. The chatbot enables natural-language interaction for scenario configuration and query, allowing users to describe and run different wildfire scenarios. The map interface complements this by supporting spatial input and interactive exploration, enabling users to define ignition points, areas of interest, and spatial constraints directly within a geospatial context.

2. **Cognitive Layer (Agentic Core)**: This layer serves as the reasoning engine of the system and consists of multiple coordinated agents. The LLM agent interprets user prompts and extracts structured intent from natural-language inputs. The planning agent then translates this intent into executable specifications and generates knowledge-augmented scientific workflows that define simulation steps, tool usage, and data dependencies. Validation agents subsequently verify the feasibility, completeness, and consistency of both workflows and outputs, enabling error detection and iterative refinement. Together, these agents implement a sense–plan–validate paradigm for autonomous workflow orchestration.

3. **Execution Layer**: This layer provides tool-integrated services for simulation and data processing. Through an MCP-based tool interface, the system invokes external modules including geocoding services, wildfire simulation engines (in this paper we use 2D SPARK models and 3D voxel-based simulators), data preparation pipelines, and simulation output processing components. Simulation results and associated metadata are stored in a geospatial database, enabling efficient retrieval and reuse. This modular design allows for extensibility with additional models and analytical tools.

4. **Visualization Layer**: This layer delivers simulation outputs through complementary visualization platforms, including a web-based viewer and a holographic visualization interface. The web-based environment enables interactive exploration of simulation results, including temporal playback and spatial inspection, while the holographic platform supports immersive, interactive analysis. Together, these visualization modalities provide effective means for observing and interpreting complex wildfire dynamics.

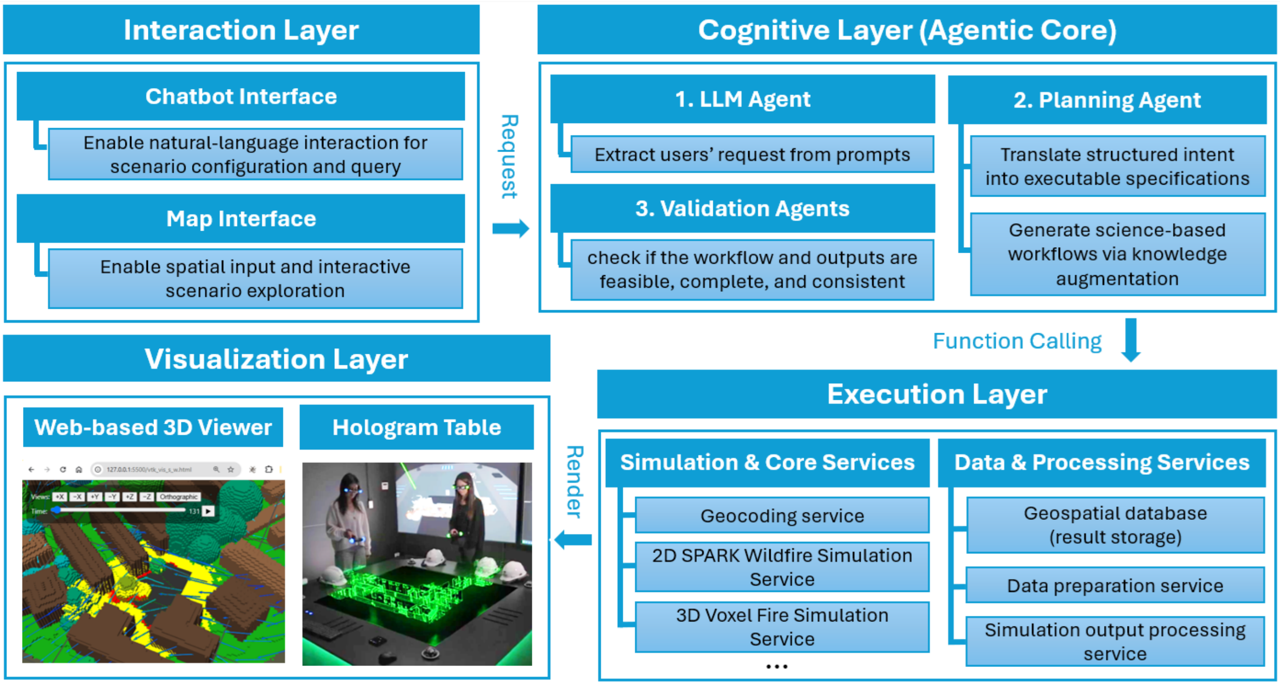


Figure 2. System design and major components of the proposed agentic AI simulation system: from chatbot to interactive display.

Overall, the system establishes an integrated and extensible architecture that bridges natural-language interaction, automated workflow generation, and interactive visualization. By combining agentic AI with multi-model simulation and multi-platform visualization, it supports exploratory and community-oriented wildfire planning, enabling users to configure and analyze scenarios without specialized technical expertise.

4. Implementation and Discussion

This section presents the implementation of the proposed system and demonstrates its capabilities through two user scenarios. Specifically, we showcase the end-to-end workflow of the agentic AI framework for both 2D wildfire simulation using the SPARK model and 3D fire simulation using a voxel-based model.

4.1 Current State of Implementation

The current implementation realizes the proposed four-layer architecture through a modular software stack with a focus on open-source solutions. In the interaction layer, users access the system via a browser-based interface and chatbot frontend, with communication handled by FastAPI. In the cognitive layer, a locally deployed large language model (LLaMA 3.1 via Ollama) interprets user intent and generates workflows, while the backend logic converts requests into structured specifications and function calls. In the execution layer, the system integrates external services, including geocoding using `geopy` (Nominatim), a REST-based SPARK client for 2D wildfire simulation, and a local RPC service for the 3D voxel-based model. FastAPI serves as the backend for routing, security, and asynchronous execution. Finally, in the visualization layer, simulation outputs are presented through interactive interfaces, supporting both web-based 3D and holographic visualization.

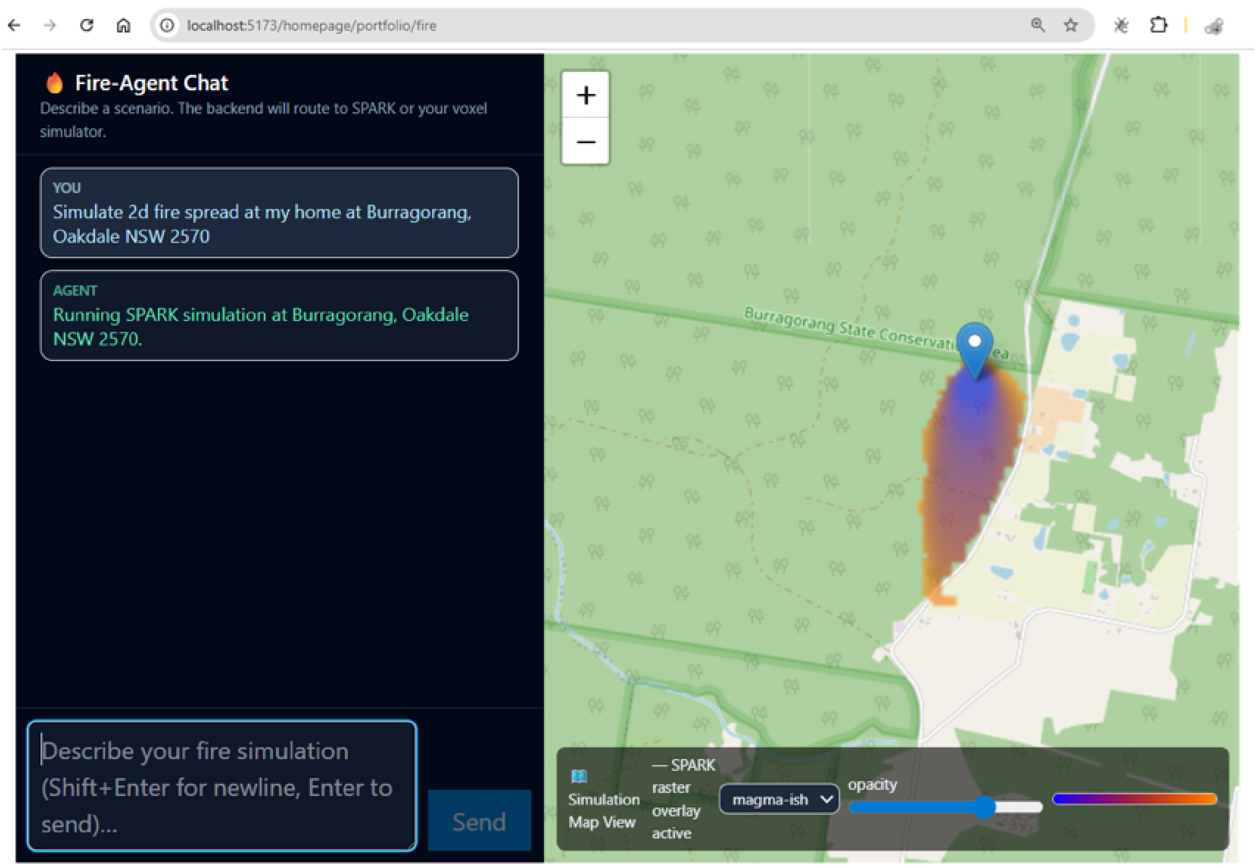
Within this architecture, the framework is designed to support multi-model orchestration by integrating both 2D and 3D wildfire simulations. It incorporates the SPARK wildfire simulation framework developed by CSIRO for 2D fire-spread modeling (Miller et al., 2015), alongside a 3D voxel-based model for simulating volumetric fire dynamics (Xu et al., 2025d). At present, the SPARK integration is fully operational, with simulation parameters automatically generated and executed through the agentic pipeline, while the 3D voxel-based integration remains under active development. Outputs from both models are rendered through the visualization layer, demonstrating the extensibility of the framework.

4.2 Use Case Demonstration

The demonstration is structured around two representative scenarios: (i) a community-oriented use case based on natural language interaction, and (ii) an expert-focused use case involving interactive exploration through web-based and holographic visualization interfaces (Figure 1).

To evaluate the proposed system, a group of firefighters from Fire and Rescue NSW were invited to interact with the platform using both the Holographic Table and Wall display at the UNSW MERE’s Immersive Technology Laboratory. The session assessed the usability and interactivity of the visualization environment, as well as its relevance to real-world wildfire response scenarios. Feedback was collected from both technical and non-technical participants to evaluate its effectiveness in supporting understanding and decision-making.

4.2.1 Community-Oriented Use Case A web-based interface equipped with an LLM-powered conversational agent enables users to define wildfire scenarios through natural language queries, such as “How would a wildfire spread if it ignited near Cape Baily Track, Kurnell, NSW 2231?” or “Simulate 2D fire spread for my property in Burragorang, Oakdale, NSW 2570.” The underlying agentic AI system interprets user intent, extracts key parameters required for simulation (e.g., location, environmental conditions, and date and time), and automatically configures and executes fire spread models via available wildfire



YOU
Simulate 2d fire spread at my home at Burragorang, Oakdale NSW 2570

AGENT
Running SPARK simulation at Burragorang, Oakdale NSW 2570.

Figure 3. LLM-powered chatbot interface: providing a street address triggers retrieval simulation parameters via SPARK API and running a fire-spread model.

simulation APIs. The cognitive layer determines the appropriate simulation model based on the user’s intent and requirements, such as whether to perform large-scale 2D fire spread modelling or to explore fire dynamics within stratified fuel layers using a 3D simulation.

The example presented in Figure 3 illustrates the chatbot interface, which supports intuitive input of location-based queries and “what-if” scenario exploration, while automatically executing 2D fire spread simulations using the CSIRO SPARK model. By lowering technical barriers, the system enables community members, planners, and emergency responders to interactively explore wildfire dynamics and assess potential impacts in a user-friendly manner.

4.2.2 Expert Use Case and Qualitative Evaluation For expert users, understanding vertical fire dynamics across complex urban infrastructure is essential. To address this need, we designed an expert-oriented use case centered on 3D voxel-based fire simulation and qualitative evaluation. The simulation outputs were assessed by firefighters and domain researchers using an immersive holographic visualization platform. A 3D urban model with a spatial extent of $336 \times 368 \times 153$ m was used, with a voxel resolution of 0.8 m. More than 12 simulation scenarios were generated (as shown in Figure 4) to systematically evaluate fire behavior under varying environmental conditions.

These scenarios demonstrate how variations in wind speed, wind direction, and fuel type—under a fixed ignition point—affect wildfire dynamics. For instance, one set of experiments simulated a surface fire in open community grounds under four wind conditions: no wind and southwesterly winds at 5, 10, and 15 m/s. Another scenario examined a high-rise building fire originating on the tenth floor under the same wind conditions. A third scenario focused on a residential apartment fire under six wind conditions, including southwesterly and easterly winds at 5, 10, and 15 m/s. Collectively, these scenarios provide a diverse set of test cases for evaluating the system’s capability to simulate complex fire dynamics and support interactive, expert-driven analysis through immersive visualization.

5. Conclusion

This paper presented a community-oriented wildfire planning framework that integrates agentic AI, automated fire spread simulation, and interactive 3D visualization to support participatory and informed decision-making in WUI contexts. By leveraging a LLM-powered agentic architecture, the proposed system enables users to define scenario-based queries through natural language, which are automatically translated into orchestrated 2D and 3D wildfire simulations. The integration of web-based and immersive holographic visualization further facilitates intuitive exploration of fire dynamics across both community and expert use cases.

The demonstrated use cases highlight the system’s capability to lower technical barriers and enable diverse stakeholders, including community members, planners and emergency responders to engage in wildfire risk assessment and mitigation planning. The qualitative evaluation conducted with firefighters and domain experts suggests that the interactive visualization environment is effective in supporting understanding of complex

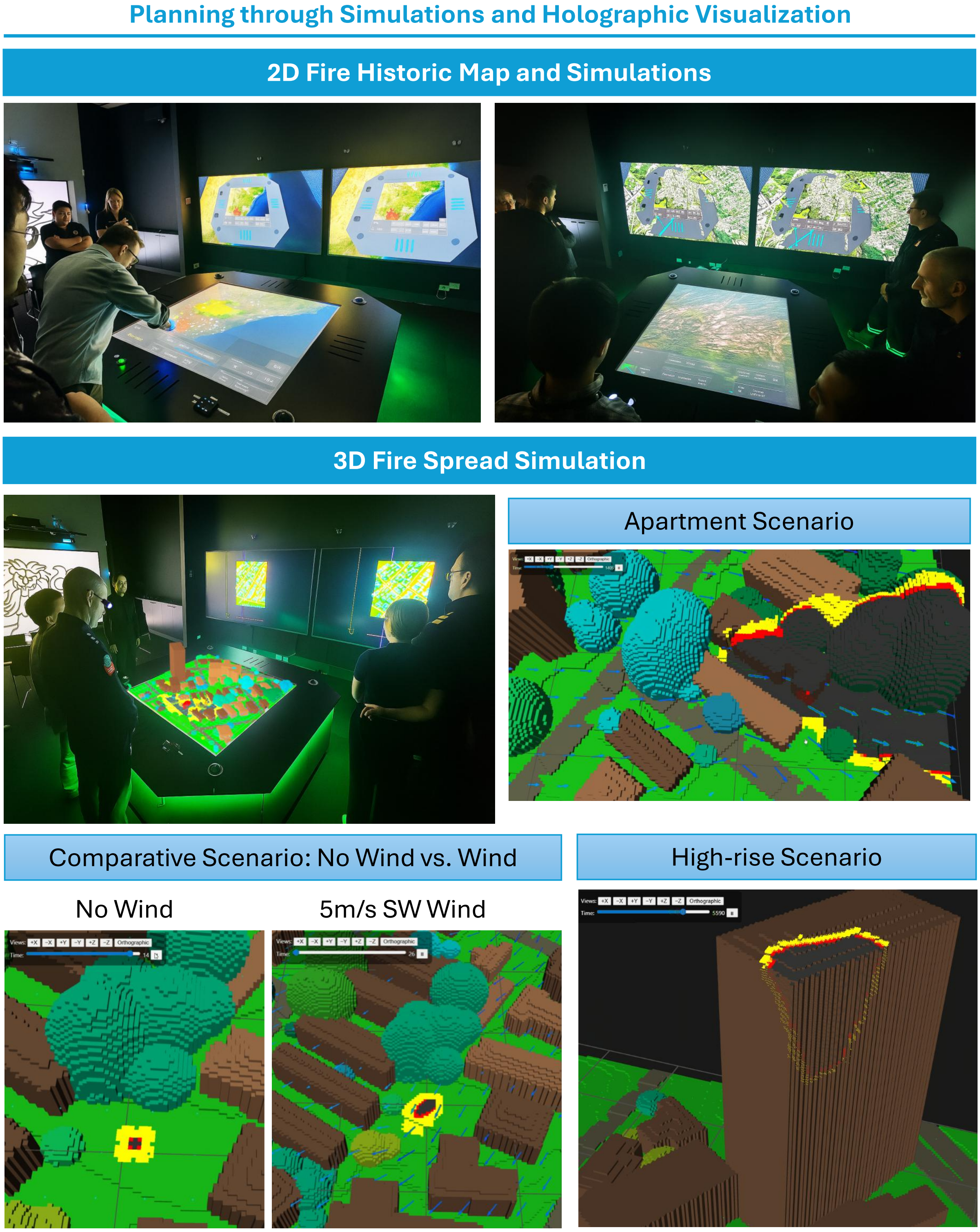


Figure 4. Demonstration of fire simulation on Hologram Table at UNSW MERE. The voxel colors represent fire spread states (red: burning, yellow: heating) as well as corresponding fuel types, while the wind directions are illustrated by blue arrows.

fire behavior and exploring alternative scenarios under varying environmental conditions.

Despite these promising results, several limitations remain. The current implementation primarily focuses on scenario exploration and qualitative evaluation, with limited quantitative validation of simulation accuracy and user decision outcomes. In addition, the integration of the 3D voxel-based simulation remains under active development, and further work is needed to improve scalability and real-time performance for large-scale urban environments. Future work will also include more comprehensive utility and usability evaluations to systematically assess the system’s effectiveness, user experience, and impact on decision-making across different stakeholder groups.

Future work will focus on incorporating additional simulation models (e.g., coupled fire–atmosphere dynamics), integrating real-time data streams (e.g., sensor networks and weather data), and conducting systematic user studies to evaluate decision-making effectiveness and usability across different stakeholder groups. Further exploration of human-in-the-loop interaction and explainable agentic workflows will also be essential to enhance trust, transparency, and adoption in real-world wildfire planning contexts. Overall, this work demonstrates the potential of agentic AI as an enabling paradigm for bridging advanced wildfire modeling with community-oriented planning, offering a scalable and interactive approach to support proactive risk mitigation and resilience building in fire-prone environments.

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