Pyro-Sense

The forest's living, intelligent immune system

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Background

The escalating climate crisis has intensified wildfires into a critical planetary challenge. While technologies like drones [6] and robotics [2] exist, they operate as fragmented tools, creating a significant **Human-Computer Interaction (HCI) challenge** where knowledge is siloed [1] and responders face high cognitive load [5]. This project addresses the OzCHI 2025 brief by arguing for a paradigm shift from designing discrete tools to designing for **more-than-human collaboration**. To explore this, we present **PyroSense**, a speculative design concept for a living robotic "layer" that forms a symbiotic partnership between rangers, AI, and the forest itself, acting as a provocation for a more resilient planetary future.

Objectives

- **Sense wildfires before they ignite** with a persistent, ground-level intelligent network.
- **Actively defend the forest** with an autonomous, morphing robotic shield.
- **Empower human rangers** with the strategic command of an entire ecosystem.

Problem

Current wildfire management suffers from a fundamental disconnect between data, tools, and experts.

- **Fragmented Knowledge & Systems:** Data is siloed across stakeholders, hindering collaboration and effective knowledge sharing [1].
- **High Cognitive Load on Responders:** Experts are overwhelmed by complex data from non-intuitive interfaces, slowing critical decision-making [5].
- **Lack of Persistent Ground-Truth Data:** Temporary, top-down surveillance misses the persistent, high-resolution ground data needed for accurate prediction [4, 7].

Existing Solutions

Current technologies provide a foundation but have clear limitations, presenting an opportunity for a new approach. **Static Sensor Networks (WSNs):** Offer in-situ monitoring but are fixed and cannot adapt to dynamic fire fronts. **Aerial Surveillance (Drones/Cameras):** Provide valuable real-time views [6, 7] but are transient and lack the ground-level data needed for predictive modeling [4]. **Field Robotics:** Are typically deployed as remote-controlled tools for specific tasks [2], rather than as integrated, autonomous partners.

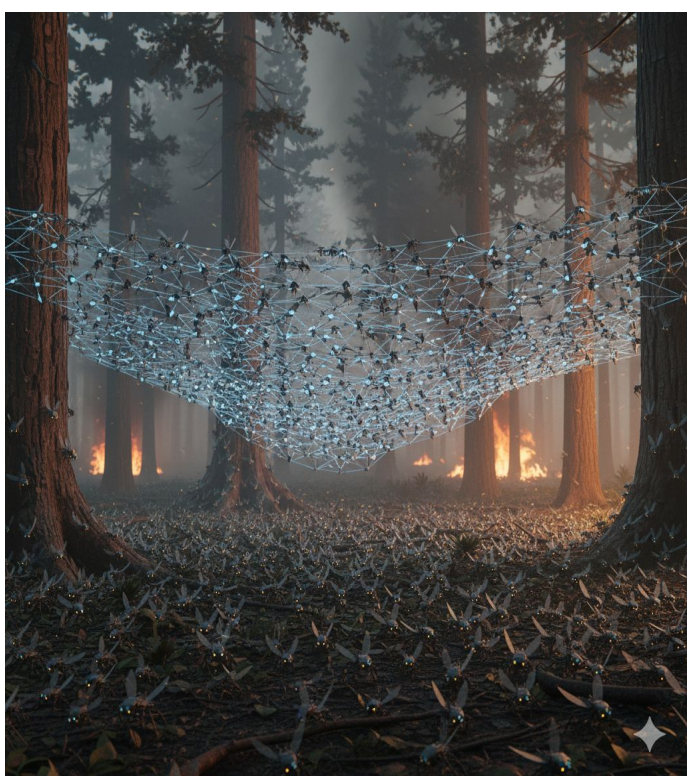

Fig. 1. The Adaptive Swarm in Action (Mesh & Shield Forms)

Design Process

Phase 1
The "Smart Carpet", a static, roll-out sensor membrane for passive monitoring. Limitation: Inability to adapt to dynamic threats; treated the ecosystem as a passive surface.

Phase 2
The "Living Swarm", mobile swarm of morphing robots with a distributed AI brain, enabling physical adaptation and action. Insight: Technology must be an active participant, not just a passive observer.

Phase 3
Added the "Symbiotic AR", an Augmented Reality interface for high-level strategic command, shifting the human's role. Insight: Empower the user as a steward, not a stressed-out operator.

Phase 4
The "Accountable System", Integrated ethical and ecological principles into the core design for responsible innovation. Insight: Long-term success requires accountability in materials, AI, and knowledge integration.

Our Proposal

As a speculative artefact, PyroSense challenges the boundary between natural and artificial systems, provoking a conversation about a future of symbiotic stewardship.

Key Features

- **Adaptive Swarm:** Robots crawl, climb, and fuse into formations.
- **Smart Targeting:** AI concentrates coverage on highest-risk zones.
- **Morphing Capability:** Shifts between sensing nets and dense heat shields.
- **Human Interface:** AR overlays deliver live fire maps and shield data.
- **Modular Design:** Units are reusable and integrate with existing wildfire systems.

Fig. 2. The Dynamic "Living Swarm". This figure illustrates the mobile, decentralized sensing of the PyroSense system. The agile robotic units are shown actively crawling and climbing the terrain, showcasing their multi-surface mobility. This active deployment enables the collection of high-resolution ground data (thermal, humidity), a crucial function for the AI to inform precise and timely fire prediction.

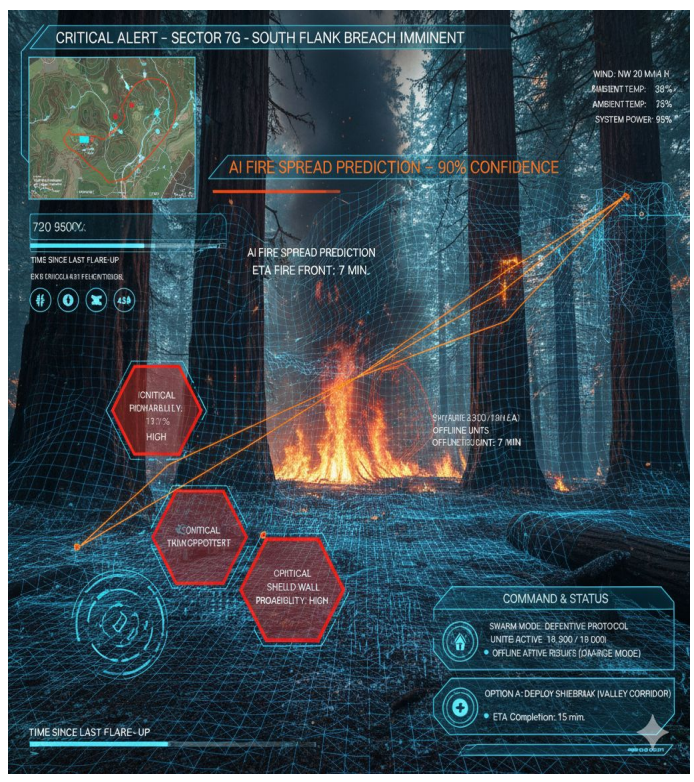

Fig. 3. This image displays the ranger's Augmented Reality (AR) overlay, which facilitates strategic command. It fuses the real forest view with AI fire spread predictions and real-time swarm status (unit count, mode). This clear, synthesized data minimizes cognitive load and empowers the human steward to quickly approve or modify high-level collective actions, ensuring a symbiotic partnership in crisis management.

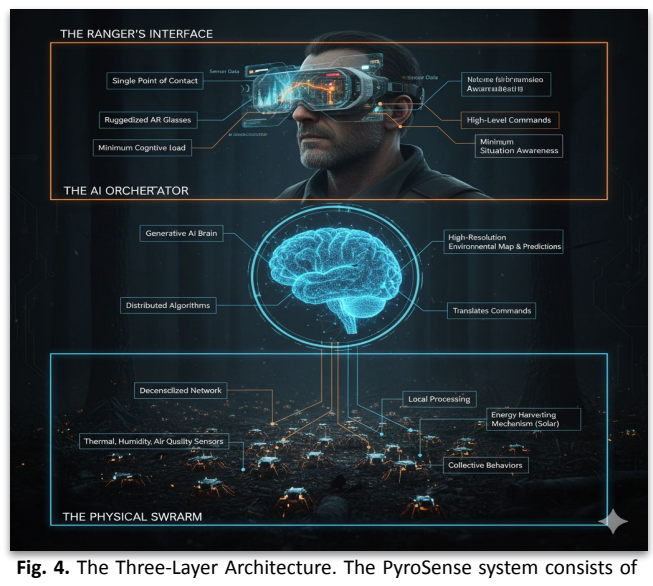

Fig. 4. The Three-Layer Architecture. The PyroSense system consists of three layers: the Physical Swarm (sensor robots) sends data to the AI Orchestrator (the brain), which translates this into high-level commands delivered via the Ranger's AR Interface (human control point).

Summary

Wildfires are no longer isolated events but a growing planetary crisis. Current tools detect and predict yet stay detached from the landscape. **PyroSense** imagines an AI-driven swarm that acts like a living surface, blending with the forest to sense, shield, and adapt. It reframes technology as an ecological partner rather than an add-on.

- Symbiotic systems reduce silos and decision overload.
- Embedding technology in ecosystems builds adaptive resilience.
- Speculative design pushes HCI to see tools as living systems.

Future Work

Next steps: explore ethics, sustainable materials, community roles, and field tests of adaptive swarms.

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References

[1] Migineishvili, N., et al. (2025). Wildfire and Forest Management: Opportunities for HCI Research. *ACM Transactions on Computer-Human Interaction.* pp. 1-33.

[2] Surmann, H., et al. (2024). Lessons from Robot-Assisted Disaster Response Deployments by the German Rescue Robotics Center Task Force. *Journal of Field Robotics,* 4192), pp. 782-797.

[3] Subramanian, K., et al. (2024). Supporting Human–Robot Interaction in Manufacturing with Augmented Reality and Effective Human-Computer Interaction: A Review and Framework. *Machines,* 12(10), pp.706.

[4] Taneja, R., et al. (2021). Effect of Fuel Spatial Resolution on Predictive Wildfire Models.*International Journal of Wildland Fire,* 30(10), pp. 776-789.

[5] Mehta, R. K., et al. (2022). Human-Centered Intelligent Training for Emergency Responders. *AI Magazine,* 43(1), pp. 83-92.

[6] Duangsuwan, S., & Klubsuwan, K. (2023). Accuracy Assessment of Drone Real-Time Open Burning Imagery Detection. *Forests,* 14(9). pp. 1852

[7] Günay, O., et al. (2009). Video based wildfire detection at night. *Fire Safety Journal*, 44(6), pp. 860-868.