Collaborative Autonomy and Safety for Teamed Human – Unmanned Aircraft Systems in Fast Evolving Wildfire Environment: Year 1 Summary

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Problem and Objectives

Accurate prediction of wildfire spread for active burning wildfires is critical for effective and safe wildfire management. The objective of this project is to develop innovative research that can transform wildfire management by enabling operational wildfire spread prediction and situation awareness for firefighters using a team of unmanned aircraft systems (UASs). Specific tasks of the proposed research include: 1) Develop novel cooperative fire sensing and wind estimation using a team of UASs and advanced data assimilation to enable data-driven wildfire simulation for operational wildfire spread predictions; 2) Develop innovative UAS coordination and path planning algorithms governing UASs' autonomy, including information-driven global task allocation and human safety-aware local path planning; 3) Develop innovative approaches to support teamed human-UASs collaboration, including a novel human-directed autonomy approach that allows humans to direct UASs' autonomy based on their domain knowledge and expert opinions; and 4) Comprehensive evaluation of the proposed research, including evaluation by flying a team of UASs over real prescribed fires on lands managed by Kansas Biological Survey (KBS).

Fig. 1 (a). Ground view of KHawk Zephyr 3 UAS (within red circle)

Fig. 1 (b). Onboard aerial view of the fire burning site

Technical Solution and Innovation

KHawk UAS Platform

Fig. 2. KHawk Zephyr3 UAS and KHawk Zephyr 55 – Thermal UAS.

UAS Prescribed Fire Monitoring Experiment

Fig.3. GPS trajectory of KHawk UAS flight 1.

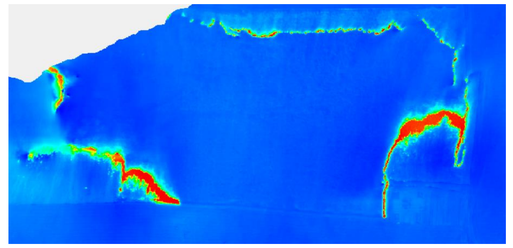
Fig.5. GPS trajectory of KHawk UAS flight 2.

Fig.4. Ortho aerial map of the fire field during the burning, (left) RGB; (right) NIR+Red.

A prescribed burn was held on April 8th 2019 over a grassland at Baldwin City in Kansas, which is managed by Kansas Biological Survey (KBS). The land is about 400 meter long and 660 meter wide (30.5 acres).

Prescribed Fire Sensing and Simulation

The second prescribed burn was held on October 8th 2019 over a grassland (42 acres) at Welda, Kansas, managed by KBS. KHawk Zephyr 55 - Thermal UAS was flied over the fire line for simultaneous sensing of fire and wind for both burns. Using data collected from the UAS, fire spread simulations were carried out and preliminary results were obtained.



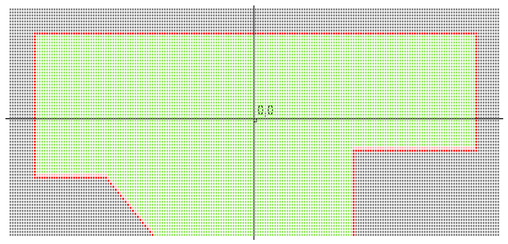


Fig. 6. (top): Fire shape constructed from UAS' thermal camera images. Blue represents areas that are unburned or burned out; Red represents the burning fire front. The fire was ignited by two teams starting from the north side of the fire. In this figure, a portion of the south side has not been ignited yet. **(bottom)**: initial condition of the fire spread simulation roughly matching the fire shape on the top. Gray represents burned area; Green represents unburned area; Red represents burning fire front. The ignition teams' movements are modeled in the simulation too.

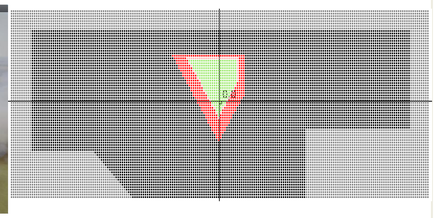


Fig. 7: (left): picture of the prescribed fire towards the end of the burning (the picture was taken from east of the fire area). (**right**) simulated fire shape corresponding to the real fire shown on the left. Preliminary work show that simulation results roughly match the real fire over time. More comprehensive analysis is under way and will be presented in future work.

Broad Impact

The catastrophic California wildfires signify the urgent need of advanced technologies and tools for operational wildfire spread prediction and situation awareness for firefighters and people in and near wildfire areas. The results of this research will benefit wild fire management and other civilian and defense emergency response applications where humans and UASs increasingly work together.

Conclusion

KHawk Zephry 3 and KHawk Zephyr 55 UASs were successfully flied over two prescribed fires to collect fire and wind data. Preliminary fire spread simulation results were obtained using data collected from UASs.

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