Drone-based Advanced Situational Awareness for Airborne Firefighting

Project Closeout

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Design Impact Statement

1.0 Introduction

The purpose of this document is to highlight some of the impacts that the project design decisions may cause. Specifically, this document will focus on how image compression algorithms will impact the following areas: Public Health, Safety, and Welfare Impacts; Cultural and Social Impacts; Environmental Factors; and Economic Factors. The document will provide insight into potential impacts and provide methods as to how to mitigate them to lessen the overall impact in the stated areas.

2.0 Public Health, Safety, and Welfare Impacts

Focusing specifically on image compression of the thermal imagery, the amount of compression could lead to a loss of important details. In a chaotic environment such as a wildfire, these details could be crucial to the safety and effectiveness of the aerial firefighters. Furthermore, the decisions that the firefighters make based on the imagery could lead them to dropping flame-retardant payloads in the wrong areas, allowing the wildfire to cause more damage to the environment and surrounding communities. This could directly lead to a vast array of negative health effects, such as increased cases of respiratory and cardiovascular hospitalizations[1]. In contrast to the negative effects, the imagery provided by the system will cause firefighters to be able to more effectively fight the fires, allowing them to prevent the negative health conditions caused by wildfire exposure.

3.0 Cultural and Social Impacts

There are impacts relating to the social field through the use of internet bandwidth. Access to communication is imperative to both fighting and staying safe from the fire for both firefighters and members of the affected community. The amount of bandwidth that this project uses up could impact other communication systems within the area, especially since this project will be generally used in areas of low connectivity. Rural areas already only see speeds of 15Mbps [2], so something like uncompressed video streaming could easily clog up the channel. By picking an effective video codec, we can avoid congestion of the RF channel and effectively stream video to the aerial firefighters. Using too much bandwidth could make it impossible for others to communicate with their friends and family and could lead to more chaos in the community.

4.0 Environmental Factors

The decisions that the firefighters make based on the imagery could lead them to dropping flame-retardant payloads in the wrong areas, allowing the wildfire to cause more damage to the environment and surrounding communities. This could be disastrous for the area. For example, in 2020 alone, wildfires burnt up nearly 1 million acres of land and over 2200 homes[3]. As stated in the earlier sections, the imagery provided, if provided with sufficient detail, will allow firefighters to more effectively fight fires. By being more effective at dropping payloads, the devastation caused by wildfire can be limited, preventing loss of property and destruction of the environment.

5.0 Economic Factors

As detailed in all the previous sections, wildfires are incredibly devastating. The increased health conditions will affect communities at the individual levels, putting economic strain on individuals via new or worsening health conditions. From 2008 to 2012, the cost for long-term health exposure related to US wildfires reached upwards of 450 billion dollars[4]. The state of the imagery can have both positive and negative effects of this field of impact. If the given imagery provides useful information to the firefighters, they will be more effective at keeping the flames at bay. However, if the firefighters base their decisions solely off of our project's information and the given information is incorrect, then the opposite could occur. The quality of the information given via the system is imperative to its helpfulness towards the wildland firefighters. An additional economic factor comes in the cost of the system itself. Already, the United States spends an approximated 1.6 billion dollars on wildfire suppression[4]. Our system runs currently at around $15000 for the drone, camera, and processor, not including the cloud software or database costs. Implementing these drone systems at wildfires would have to incorporate these costs.For the image compression algorithm itself, there is no economic impact since the algorithm can be implemented directly on the Nvidia Xavier that is used by the system and is not a proprietary algorithm.

Conclusion

When deciding how much to compress the imagery, we must consider what level of detail is necessary to provide beneficial information to the user while still considering the other factors touched on throughout the document. One way we can make this decision could be by generating video streams at varying levels of compression and having a panel of users determine what the maximum amount of compression is before they start to noticeably lose information. By optimizing the amount of bandwidth used with the quality and detail of the imagery, we can provide firefighters with a system that will increase their effectiveness at fighting fires, decreasing the negative impacts detailed in this document.

[1] “Wildfires,” *Centers for Disease Control and Prevention*, 18-Jun-2020. [Online]. Available: https://www.cdc.gov/climateandhealth/effects/wildfires.htm#:~:text=Smoke%20exposure%20increases%20respiratory%20and,medical%20visits%20for%20lung%20illnesses. [Accessed: 14-Apr-2021].

[2] F. Rizatto, “Mobile Experience in Rural USA - An Operator Comparison,” *Opensignal*, 27-Oct-2019. [Online]. Available: https://www.opensignal.com/2019/09/24/mobile-experience-in-rural-usa-an-operator-comparison#:~:text=In%20the%20Distant%20and%20Remote,Mbps%20for%20users%20on%20Verizon.&text=Across%20all%20of%20the%20rural,their%20peers%20on%20other%20networks. [Accessed: 19-Jan-2021].

[3] “2020 North American Wildfire Season,” *disasterphilanthropy.org*, 07-Dec-2020. [Online]. Available: https://disasterphilanthropy.org/disaster/2020-california-wildfires/#:~:text=nearly%20140%2C000%20acres.-,Impact%20%E2%80%93%20Oregon,2%2C200%20of%20which%20were%20homes.&text=The%20fire%20destroyed%202%2C357%20homes,them%20mobile%20homes%20and%20trailers. [Accessed: 14-Apr-2021].

[4] J. Roman, A. Verzoni, and S. Sutherland, “The Wildfire Crisi,” *NFPA Journal*. [Online]. Available:https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/November-December-2020/Features/Wildfire#:~:text=Federal%20wildfire%20suppression%20costs%20in,the%20National%20Interagency%20Fire%20Center.

Project Timeline

- Course Project Development
- Project Research and Planning
- Software and Testing
- Presentation

Artifact	Due Date	Task Description	Meeting Date for Artifact	Responsible Parties
Teamwork Reflection Paper	11/19/2020	Reflect on the team's overall performance and individual progress	11/18/2020	Full team
Block Diagram	11/26/2020	Block diagram containing 3 blocks per team member and contains a flow of information	11/25/2020	Full team
Engineering Requirements	11/26/2020	Final draft of engineering requirements with eight defined requirements	11/25/2020	Full team
Block Validation	12/03/2020	Completing blocks with summaries for each block and clear drawings, flow charts and design.	12/02/2020	Full team
RIR Draft	12/03/2020	Research Implications Report Draft containing challenges that may be faced, stakeholder analysis, implementation and discussion etc.	12/02/2020	Full team
Finalize Scope and Requirements	12/03/2020	Thoroughly finalize scope and requirements	12/02/2020	Full team

		within the project with accurate descriptions		
Block 1 Checkpoint	Week 11	Each team member must have completed all specifications and interfaces within block for system requirements	01/04/2021	Full team
Block 2 Checkpoint	Week 12	Each team member must have completed all specifications and interfaces within block for system requirements	01/11/2021	Full team
Block 3 Checkpoint	Week 13	Each team member must have completed all specifications and interfaces within block for system requirements	01/18/2021	Full team
Final Block Checkpoint	Week 14	Each team member must have completed all specifications and interfaces within block for system requirements	01/25/2021	Full team
Independent software completion	Week 17	Completion of individual software requirements based on blocks	02/08/2021	CS team
Software testing	Week 19	Testing all software for bugs and other issues that may arise	02/22/2021	CS team
Drone and Software integration	Week 20	Combine hardware and software without errors	02/22/2021	Full team
Finalize integration	Week 20	Successfully	03/08/2021	Full team

		integrate both software and hardware		
Develop poster draft	Week 21	Create first version of poster	03/10/2021	Full team
Finalize poster	Week 22	Finalize information on poster and design	03/15/2021	Full team
Print Poster	Week 25	Print poster for the Capstone expo	04/05/2021	Full team

Scope and Engineering Requirements Summary

Name	CR	ER	Verification Method	Test Process	Test Pass Condition	Evidence Link
Georeferencing Accuracy	The second aspect is to process the imagery from the drone to select the interesting hotspots (perhaps with human interaction) and dewarp and georeference the imagery	The system will produce georeferenced points for the model that are within 10 meters of accuracy when compared to their real world location while 1 KM away.	Test	1. The location of the drone and a test location will be recorded with a third party positioning device. The drone needs to be at least 1KM away from the test location. 2. The drone will record the perceived test location and current drone position. 3. The calculated values will be compared to those measured by the third party device.	If the recorded result is within 10m of the real world result, the test passes	https://media.oregonstate.edu/media/t/1_0d2icaj6
System Latency	"A drone that can fly to specific locations, take images, and relay information back to a central server"	The system output will update within 1 minute of the drone subsystem changing location or orientation.	Test	1. A timer will begin when the system begins capturing at a test survey position 2. Once the system outputs are updated with the new data, the timer will be stopped.	If the timer indicates that the time elapsed is less than 1 minute, the test will have passed.	https://media.oregonstate.edu/media/t/1_s59mwq8x
Visual Representation of Temperature Gradient	The remote viewer is assumed to be a flying pilot, wearing a Head-Worn Display, who would be able to "look at" the fire (through the drone's eyes) via live georeferenced	The system will output a visual representation of the temperature gradient of the fire such that 9 out of 10 users via the remote viewer subsystem can discern the difference	Test	1. Show a remote viewing subsystem user the augmented reality representation of a range of temperatures in the fire model with at least 75 Kelvin differences in the data.	If 90% of users report an 8 or higher on the google form for being able to successfully delineate temperature regions of at least 75 Kelvin, the test will pass	https://media.oregonstate.edu/media/t/1_0ne62cpp

	conformal imagery of the fire.	between temperatures that have a difference of at least 75 Kelvin.		2. Ask the user to delineate the regions based on temperature 2a. Ask the user to determine the hottest part of the shown data 2b. Ask the user to determine the coldest part of the shown data 3. Record their success or failure 4. Have the user record their ability to delineate temperature regions on a google form 5. Repeat for 9 more users		
Visual Representation of Data Age	“...a helicopter pilot desires to know in advance of approaching the location and magnitude of fire hotspots, before being asked to target them with pinpoint precision while engulfed in a cloud of smoke.”	The system will output a visual representation of the age of the fire data such that 9 out of 10 users via the remote viewer subsystem can discern the difference between visual representations of data that have a difference of at least one minute in each 10M bins.	Test	1. Show a remote viewing subsystem user the augmented reality representation of the fire model 2. Ask the user to delineate the regions based on age 2a. Ask the user the data age of the center data point 2b. Ask the user the data age of the point adjacent to it 3. Record their success or failure 4. Have the user record their ability to delineate temperature regions on a google form 5. Repeat for 9 more users		
Visual Representation	Image processing of thermal	While using the system 9 out of	Test	1. Show a remote viewing	If 9/10 users are able to	https://media.oregonstate.edu/media/t/1_hi36lb

of Position	gradients	10 users will state they could identify the location of the fire hot spots within 10M.		subsystem user the augmented reality representation of the fire model with at least 10 meter differences of location in the data. 2. Ask the user to delineate the regions based on position 2a. Ask them to list out the location of three data points 3. Record their success or failure 4. Have the user record their ability to delineate temperature regions on a google form 5. Repeat for 9 more users	successfully delineate the data based on position and report above an 8 on the google form on their confidence to recognize location, the test will pass	3e
Fire Model Resolution	"...a helicopter pilot desires to know in advance of approaching the location and magnitude of fire hotspots, before being asked to target them with pinpoint precision while engulfed in a cloud of smoke."	The system will output a model of the fire that is binned such that the model discerns the temperature of points at most 15 meter apart.	Test	1. Examine model built from recorded data 2. Ensure that model resolution is as dense or denser than one data point per 15 square meters	Model resolution is at least one data point per 15 square meters	https://media.oregonstate.edu/media/t/1_nui73px3
Fire Model Building	"Forest fire might be too dangerous to approach; and yet a helicopter pilot desires to know in advance of approaching the location and magnitude of fire hotspots"	The system will collate and maintain a model including all of the fire data collected for at least 20 minutes of flight time .	Test	1. Build model using 20 minutes of unique data, 1200 data points total 2. Verify that the model contains all 1200 data points	The model contains all 1200 unique data points	https://media.oregonstate.edu/media/t/1_sxs9d03m
Model Output	"The second aspect is to process the	The system will output a representation	Demonstration	1. Navigate using a web browser to the	If the system produces a viewable, top	https://media.oregonstate.edu/media/t/1_jlwquube

	imagery from the drone to select the interesting hotspots (perhaps with human interaction) and dewarp and georeference the imagery before transmission to the remote viewer."	of the fire model viewable as a top-down map view.		output web page 2. View the top down output of the model	down representation of the model of the fire then the test passes.	

Risk Register

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance indicator	Responsible Party	Action Plan
R1	Vendor Delay	Timeline	~10%	M	Changes in shipping dates	Full team	Retain
R2	Damaging drone during testing	Technical	~5%	H	Poor flying conditions, improper protocol with flying(risky flying, dangerous moves, etc.	Drone pilot	Reduce
R3	Poorly attached parts, lose modules during flight	Technical	~5%	H	Mountings, attachments, tightness of screws, fasteners	ECE team/ build team	Reduce
R4	Change of material/data cost	Cost	~20%	L-M	Change of cellular costs, method of data transfer, price change	CS team	Retain
R5	Loss of member due to COVID19	Environment	~1%	H	Changes in health	Full team	Reduce (social distance)

Future Recommendations

Recommendation	Reason	Solution Starting Point
Change project requirements so that the drone can be flown.	The FAA standards for drone flying is 400 feet above the ground.	Find a way for the whole project group to access the drone and change the requirement from 1km to 400 feet.
Change Unity data structure of the holoLens fire model.	The data structure used was a list and this was inefficient.	Changing the data structure from a list to a hash table or a heap would make it more efficient.
Implement an initial GPS position of the headset in the hololens	Tracking the initial GPS position of the headset is not possible using just the hololens.	Using additional hardware that can track the initial GPS position of the headset is recommended.
Optimize image processing	Due to the immense amount of data that is collected there needs to be an optimized way of processing images.	Utilize packages and optimization strategies.
Ask for hardware early	We waited until near the end to fully collect hardware and it made implementation more difficult than it needed to be	Communicate with stakeholders
Remove the hand tracking overlay from the Hololens app	The hand tracking blocked some of the information and was often distracting	Dig into the Unity docs for the Mixed Reality Toolkit
Split the project into relevant subprojects	The project as a whole could very easily be split into 3 separate subprojects based on the subsystems. The georeferencing algorithms and the connection to AWS via the Xavier could have been their own project alone.	Separate out into subgroups with focus on the AR, cloud model, and drone implementation
Look into other AR capable devices	While the Hololens2 is powerful and offers decent documentation, for this project it is not ideal. The Hololens is designed for indoor use and utilizes environment mapping within close range. For mapping to	Research other AR capable devices or determine better methods to map out a large environment easily i.e. Unity terrains

	far off terrain, the system falls apart and needs much more complex software to account for this	