Developing a User Interface for Live 3D Mapping of Wildfires

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by
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Report submitted to:

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Executive Summary

In June of 2013, nineteen firefighters died trying to contain a wildfire in Arizona (Coe & Merrill, 2013). An after action report of the tragedy revealed a local resident was streaming live video of the fire as it burned on the mountainside (S. Guerin, personal communication, April 5, 2017). The video displayed a key shift in wind direction that ultimately caused the fire to turn back onto the firefighters on the ground and smother them. If the fire crew had the most up-to-date information, they could have communicated the wind shift to the ground troops and evacuated them to a safe area. Unfortunately, the crew did not discover the video until after the fire had already taken all nineteen lives.

Because emergency situations cannot be predicted, emergency personnel need to be vigilant and prepared to respond appropriately. Executing an emergency response that minimizes danger to civilians and first responders depends upon effective communication and coordination. Optimal communication during emergency management enables involved personnel to be fully aware of the situation. Consequently, crews can work quickly and distribute resources appropriately (Chen, Sharman, Rao, Upadhyaya, 2008). However, current wildfire management communications systems do not always meet the needs of those involved in wildfire response, contributing to miscommunications and delays in responding to emergencies (Scholz, 2012).

Simtable LLC, a company based in Santa Fe, NM, develops technologies that advance three-dimensional modeling, data visualization and human-computer interaction. Simtable is currently developing web-based software called LiveTexture that will allow firefighters to view and annotate three dimensional maps of a wildfire in real time. LiveTexture will aggregate imagery of an area from several sources and generate a three-dimensional model of that area, with relevant information overlaid onto the model. The goal of LiveTexture is not only to allow firefighters to communicate faster but also to enhance the firefighters' understanding of the situation by giving them a visual and intuitive view.

Currently, Simtable has not yet developed a user interface (UI) for LiveTexture. The UI, or web-based screens, represents the physical means through which users will interact with LiveTexture. The adoption and utility of LiveTexture is largely limited by its UI design; For end users, a useful software has a UI that enables users to accomplish their goals by offering the functionalities they need. Thus, Simtable must develop a UI that meets the needs of its users, including emergency personnel involved in wildfire response.

Background

During an active wildfire response, "coordination and communication support are of the utmost importance" (Scholz, 2012, p. 113). Communication between firefighters is necessary for relaying relevant information such as the locations of resources, personnel, and potentially hazardous areas. Currently, most firefighters in the field employ two-way radios to communicate with one another (Scholz, 2012). However, radio communication currently presents a number of obstacles for firefighters, such as difficulty hearing and lack of visual information (US Fire Administration, 1999).

Firefighters often enter situations with little to no information (Litzenberg, personal communication, 2017). This is due to a lack of ability to gather information quickly about the incident (Hand, Wibbenmeyer, Calkin, & Thompson, 2015). The longer it takes for firefighters to prepare a response, the more time the fire has to expand and become unmanageable. Firefighters should thus harness information as quickly as possible so that a response plan can be formulated during the early stages of a wildfire, keeping the initial spread to a minimum.

Social media holds one of the largest existing reservoirs of data (Yin, 2012) and can deliver data nearly instantly (Sachdeva, 2012). The real-time nature of social media as well as the geographic data that is becoming inherent in social media might provide invaluable opportunities for firefighting professionals. During wildfires, firefighters create and employ maps to identify potentially hazardous areas and possible routes to take when sending personnel to the scene of a fire (Simon, 2015). Thus, firefighters could use social media, combined with attached geographic information, to help them determine locations of fires and construct more accurate maps of the surrounding area. Firefighters could also use imagery from social media to more easily visualize a wildfire in near real time and better understand the surrounding environment, enabling them to make more appropriate decisions (Crowley, 2011).

When visualizing a situation, three dimensional models can give emergency personnel who are not on scene a much more comprehensive and detailed view of a situation. Currently, three dimensional “point cloud” models (see Figure A) of an area can be constructed by stitching together multiple two dimensional images of the same area from different angles. Simtable LLC is developing LiveTexture as a way to take in imagery of an area both directly and from social media, then use the imagery to construct and update three dimensional point clouds in real time. Users of LiveTexture will be able to add and share layers of information onto the point cloud, as well as view the point cloud of the area from any angle in real time. The capabilities of LiveTexture will one day allow firefighters to communicate much faster and more effectively. However, LiveTexture does not currently have a UI to allow firefighters to do so.

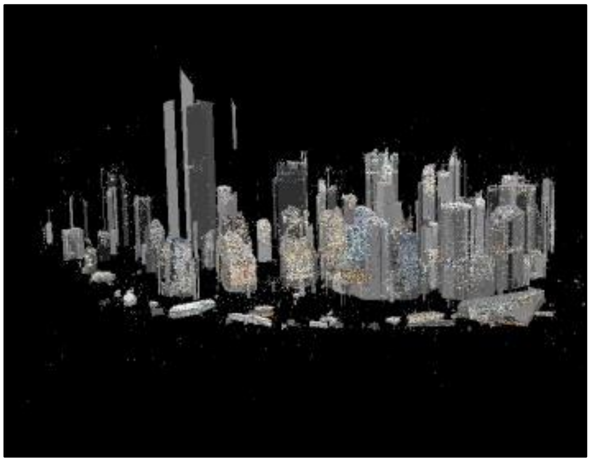

Figure A: 3D Point Cloud of a City

Project Goal and Objectives

The goal of our project was to create and prototype a user interface for LiveTexture intended for the real time aggregation and presentation of wildfire information. To accomplish our goal, we completed the following objectives:

1. Understand the limitations of information flow within the current wildfire management system.
2. Understand the domain, context, and constraints of what LiveTexture should accomplish.
3. Develop mock up user interfaces.
4. Assess the effectiveness of the user interface to determine where improvements can be made.

Methods

We employed a user-centered design process in order to create and prototype interfaces for LiveTexture. User-centered design processes focus first and foremost on understanding the needs and goals of each type of user who will interact with the interface. This design method allows developers to make sure they implement all of the necessary functionalities the users need in order to be successful.

The scope of our project was limited to three specific user groups: members of the general public, firefighters on the ground reporting information about a wildfire, and virtual operation support team (VOST) members who collect and analyze information from social media during a wildfire. To empathize with the needs of our users and learn the functionalities they would require from LiveTexture, we conducted semi-structured interviews with representatives from each user group. We used insights from the interviews to develop user personas, descriptions of the target audience that will utilize the interface. The personas were used to identify the features our interface would need to improve the quality of life for our users. Our user interface design was designed to address the needs and goals of our user-personas. To help us design a user-friendly interface, we also investigated existing successful UIs, such as Periscope and Google Drive, to learn what types of features and designs are intuitive and easy to navigate. Finally, we evaluated the effectiveness of our UI by conducting evaluations during the interface design process. The purpose of the evaluations was to gain feedback on how to design a more usable interface and what functionalities we needed to change or add. With the feedback we gained from the evaluations, we were able to create multiple iterations of the design. The iterative design process we used is outlined in Figure B.

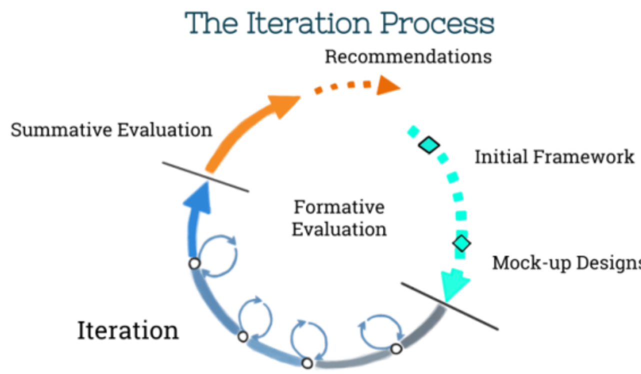

Figure B: The Iterative Design Process

Results

Current Wildfire Management Systems Lack Real-Time Visual Communication

From our interviews with professional firefighting personnel, we learned that firefighters currently operate on a twenty-four hour information cycle, meaning that the fire managers are operating off of data that is at least a day old at all times. Furthermore, firefighters cannot communicate information visually during an emergency response; they only have access to two way radios when in the field. This prevents firefighters from gaining a full situational awareness prior to arriving on scene and even while on scene due to the large, unpredictable nature of wildfires.

User Interfaces Design Should Be Centered On the User

Through researching interface design and development frameworks, we learned that understanding the users was essential in creating a usable design. A universal goal of any UI is to meet the needs of the user. Any addition or change to UI should be aimed at improving the design from the perspective of the user. A vital step in the design process is understanding the users. A deep understanding of the user's goals, behaviors, and needs must be attained before the design process begins. Any design aspect of the UI will be guided by these understandings. The end result of this process is a UI that is more efficient and satisfying for the end user.

User Interfaces Should Be Minimalistic and Standardized

In addition to interviews, we conducted research into several popular applications, specifically those designed for mobile devices. We looked at applications like Periscope and Snapmap for their map layouts, and games like Battlefield 1 or Pokémon GO for how they projected their information and display onto the main view. With this research, we specifically focused on the interfaces of the applications, investigating and drawing inspiration from elements that were particularly noteworthy. What we found is that the UIs of these apps were designed to keep the screen clean and uncluttered with buttons and menus, to have more of a minimalistic style with options initially hidden away when not in use.

Iterative Design Processes Yield More Usable Interfaces

The evaluations we conducted during the iterative design process helped us refine our design and cater it more towards the needs and desires of the end users. The feedback we received from design evaluations helped us to identify functionalities that we were missing in the interface design, as well as major flaws in the design that could contribute to usability problems. Conducting the evaluations helped us to realize that we needed to first and foremost focus on addressing the needs and goals of end user groups, before becoming tangled in the fine details of how the interface should look. After going through the iterative process multiple times, the interface became more effective at addressing the users' needs. We were able to design an interface that gave users a more complete understanding of the capabilities of LiveTexture. A sample of our final UI designs are shown at the end of the Executive Summary in Figures C and D. The first screen displays the overhead map view of where a user is located in the world and what direction their camera is oriented in (indicated by the icon's extended "field of view"). Other users in the area are visible on the map as well. The user can click on another user's icon and be taken to that user's live video feed, as shown in the second screen. In this case, the other user's screen happens to be annotated with lines and markers, which are used to communicate information to viewers of the live feed.

Conclusion

One of the most important steps in designing a useful and successful product is developing a functional and user-friendly UI. LiveTexture's UI will one day enable emergency personnel to successfully perform their jobs to the best of their abilities. Firefighters will have an increased understanding of the environment around a wildfire before they even arrive on scene; Incident commanders will be able to outline in the real world exactly where they want air crews to drop fire retardant. The UI will allow users of LiveTexture to easily interact with the software, communicating and visualizing wildfires in real time. As seen by the tragic wildfire in Arizona that claimed the lives of nineteen firefighters, such a capability could potentially save the lives of firefighters and civilians alike.

Figure C: Overhead Map View with Other Users in the Area

Figure D: Annotated Live Camera

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Abstract

Our project aimed to help our sponsor, Simtable LLC, bring real-time visual communication to fire personnel. Simtable LLC is developing a software called LiveTexture, which will collect imagery of wildfires from several sources and generate a three dimensional (3D) model of the situation. The technology will enable firefighters to view and annotate 3D maps and exchange information in real time. We researched the limitations of current wildfire management communications systems, and interviewed wildfire response personnel to determine the functions their jobs require. The end result of our project included non-functional mock-up user interfaces that visually outlined how users will interact with LiveTexture to more efficiently reach their goals.

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Chapter 1: Introduction and Background

In June of 2013, nineteen firefighters died trying to contain a wildfire in Arizona (Coe & Merrill, 2013). An after action report of the tragedy revealed a local resident was streaming live video of the fire as it burned on the mountainside (S. Guerin, personal communication, April 5, 2017). The video displayed a key shift in wind direction that ultimately caused the fire to turn back onto the firefighters on the ground and smother them. If the fire crew had the most up-to-date information, they could have communicated the wind shift to the ground troops and evacuated them to a safe area. Unfortunately, the crew did not discover the video until after the fire had already taken all nineteen lives.

Because emergency situations cannot be predicted, emergency personnel need to be vigilant and prepared to respond appropriately. Effective communication and coordination are vital to executing an emergency response without endangering civilians or emergency personnel. Proper communication during emergency management also enables involved personnel to be fully aware of the situation. Consequently, crews can work quickly and distribute resources appropriately (Chen, Sharman, Rao, Upadhyaya, 2008). Thus, gathering and communicating relevant information efficiently and understandably provides for a successful emergency response. In our report, we aim to develop ways to improve information flow during emergency responses to wildfires.

1.1: Wildfire Background

Wildfires typically occur in forests during the warm and dry periods of the year. Severe droughts, hot weather, and the buildup of fuel result in a greater probability of wildfires (Agee & Skinner, 2005). Wildfires are not entirely harmful to the environment and can serve to remove the dense plant life that blocks sunlight from reaching the ground, preventing new life from growing (USDA, 2006). Similarly, farmers who own small plots of land will often use “slash and burn agriculture” which involves clearing their land and burning the stalks of the crops after harvest to enhance the soil’s nutrients, allowing farmers to reuse the land for years longer than they otherwise could (Thomaz, 2013). However, despite the benefits of these semi-regular wildfires, the creation of the United States Forest Service (USFS) led to some drastic changes in the United States’ policy towards wildfires.

1.1.1: Wildfires on the Rise

At the start of the 20th century, due to the declining condition of national parks in the United States (US), a full zero-tolerance policy was created against wildfires; any and all wildfires were suppressed and extinguished as soon as possible (Agee & Skinner, 2005). As a result, trees, grass, and bushes became stockpiles of fuel in an unstable process of unrestrained growth (Agee & Skinner, 2005). The culmination of the above factors led to denser forests with overgrown vegetation, all acting as fuel ready to burn (Agee & Skinner, 2005).

Between 1983 and 1999, the average amount of land burned by wildfires was just under three million acres per year (NIFC, 2000). The year 2000 marked the first time in over five decades when more than seven million acres of land in the United States burned in less than a year (NIFC, 2000). In each of the years 2004 and 2005 individually, over eight million acres of land burned from wildfires, and in 2006 this number reached nine million acres per year (NIFC, 2015). The average amount of land burned by wildfires continues to grow slowly, and presents a clear risk to residents of the US as well as a threat to the environment (EPA, 2015).

1.1.2: Wildfires in New Mexico

New Mexico is one of many states in the western US that experiences especially high risk of wildfires. Between April 2, 2016 and April 2, 2017, the state experienced 17 wildfires of varying size, the largest burning just over 42,000 acres of land (InciWeb, 2017). New Mexico's dry, hot climate and long stretches of mountains create an environment where the forests are primed for wildfires (Fire Behavior, 2005). Property damage caused by wildfires in New Mexico has reached its high at a billion dollars for a single uncontrolled fire (Rothman, 2005).

1.2: Managing Wildfires

1.2.1: Fire Behavior and Situational Awareness

Understanding fire behavior is the key foundation for a firefighter's situational awareness. The three major factors that affect the spread of a fire are fuel, weather, and topography. An area's steepness and terrain will alter wind currents; this affects the rate and direction of fire spread (Altman, 2012). Firefighters pay close attention to these factors when assessing a situation to predict the wildfire's progression, travel, and dangers. By understanding how a fire will act, a firefighter can fight it properly, reducing the chance of injury or death.

1.2.2: Communication in Wildfire Response

During an active wildfire response, "coordination and communication support are of the utmost importance" (Scholz, 2012, p. 113). Communication between firefighters is necessary for relaying relevant information such as the locations of resources, personnel, and potentially hazardous areas. Currently, most firefighters in the field employ two-way radios to communicate amongst each other (Scholz, 2012). As portable radios allow for near real-time communication, firefighters have used them for a long time. However, radio communication still presents a number of problems (US Fire Administration, 1999).

Although researchers have improved the technological capabilities of two-way radios, "important information is not always adequately communicated" while using radios during a wildfire response (US Fire Administration, 1999, p. 1). For example, one conversation between firefighters on a two-way radio can be suddenly interrupted by dispatch, disrupting the flow of information (Varone, 2012). Many fire crews themselves have reported that such a lack of effective information flow has even contributed to incidents involving firefighter fatalities. Furthermore, little research has been conducted in an effort to improve communication among firefighters on the ground (US Fire Administration, 1999).

1.2.3: Gathering Information

Firefighters often enter situations with little to no information (Litzenberg, personal communication, 2017). This is due to a lack of ability to gather information quickly about the incident (Hand, Wibbenmeyer, Calkin, & Thompson, 2015). The longer it takes for firefighters to prepare a response, the more time the fire has to expand and become unmanageable. Firefighters should thus harness information as quickly as possible so that a response plan can be formulated during the early stages of a wildfire, keeping the initial spread to a minimum.

Fighting forest fires entails deciding whether to extinguish the fire, contain the fire, or let it burn itself out (Hand et al., 2015). Completely putting out fires is expensive and endangers the lives of firefighters. Fire chiefs must weigh the risks of firefighter and civilian death, cost of property damage, and cost of putting the fire out or containing it (Hand et al., 2015). As in any other risk-reward decision-making scenario, the more information that is available to decision makers, the more successful their decisions will be.

1.3: Social Media in Emergency Situations

The online network of social media holds one of the largest existing reservoirs of data. Social media consists of websites and web-based mobile device applications that enable people to interact with others by creating and sharing content such as text, pictures, and videos (Yin et al., 2012). One example of a social media platform is Twitter, which allows users to publish short text-based messages, or "tweets", in 140 characters or less (Yin et al., 2012).

Many people use social media to communicate quickly with others and to seek up-to-date information (Whiting, 2013). During natural disasters, relief organizations use social media to create inter-agency maps, which note which areas and location are in need of immediate help (Gao, 2011). A 2009 survey of the public conducted by the American Red Cross showed that during an area-wide emergency, 75% of people reported that they will use social media to report incidents (Simon, 2015, p. 616). Thus, a large amount of information is available on social media during emergencies, yet it is not currently adequately utilized by response teams (Gao, 2011).

1.3.1: Benefits and Shortcomings of Social Media in Emergencies

Many people use social media to communicate quickly with others and to seek up-to-date information (Whiting, 2013). A 2009 survey of the public conducted by the American Red Cross showed that during an area-wide emergency, 75% of people reported that they will use social media to report incidents (Simon, 2015, p. 616). Thus, a large amount of information is available on social media during emergencies, yet it is not currently adequately utilized by response teams (Gao, 2011).

Social media updates about wildfires could provide crucial information for firefighters. Furthermore, "social media is becoming increasingly geographic" as users can broadcast their location online (Simon, 2015, p. 614). The geographic data that is becoming inherent in social media might provide invaluable opportunities for firefighting professionals. During wildfires, firefighters create and employ maps to identify potentially hazardous areas and possible routes to take when sending personnel to the scene of a fire (Simon, 2015). Thus, firefighters could use social media, combined with attached geographic information, to help them determine locations of fires and construct more accurate maps of the surrounding area.

With pictures and videos from social media, firefighters can visualize how a wildfire unfolds in near real time and gain improved "situational awareness" (Crowley, 2011). Situational awareness offers firefighters insight into the actual environment around the fire, which allows them to "derive meaning and aids in decision making" (Crowley, 2011, p. 2). Through the use of social media, firefighters can obtain multiple camera angles of the fire, allowing them to better understand how to approach the situation (Castrillon et al., 2011).

Even so, individual images from social media only allow firefighters to view a wildfire from one angle at a time. Currently, they are not able to obtain a complete, 360 degree view of the wildfire and all of the operations and environments surrounding the fire. Such limited views inhibit the extent of the firefighters' situational awareness (Guerin, 2017). Additionally, social media users do not always broadcast their locations when they create a post (Simon, 2015). As a result, first responders cannot determine where a particular image was taken from or what direction the user was facing.

Social media, however, can deliver data nearly instantly, allowing firefighters to learn about a wildfire sooner and deploy resources earlier. Rather than waiting for outside organizations to process data and then display it long after an event occurred, "information flow through social tools is a much more effective and economical method to gather data in real time" (Sachdeva, 2016, p. 3). For example, Twitter users posted about an earthquake in Morgan Hill, California within 30 seconds after it began, whereas the US Geological Survey's National Earthquake Information Center took several minutes to register the natural disaster (Sachdeva, 2016). Even so, first responders only want to see *relevant* information from social media. In many instances, social media users may post fake images or report false information. Thus, social media content requires extensive filtering and organization, which often takes a significant amount of time (Sachdeva, 2016).

1.3.2: Geofeeds

There are a few different ways in which social media feeds can be filtered or aggregated. One of particular interest is geofeed aggregation. A geofeed is a set of user posted data, found on various sites, that is filtered based on its relevance to a particular location. This data includes text, pictures, videos, hyperlinks and others. Content providers include "SM platforms … and/or other providers that can distribute content that may be relevant to a geographically definable location" (Geofeedia, 2016).

The company at the forefront of geofeed use is Geofeedia. The company's main product is a system that allows users to define a specific location, aggregate all social media posts from that area, and then filter the results by keywords, in real time (Geofeedia 2016). Currently, the majority of Geofeedia's users are law-enforcement agencies like the police and the Federal Bureau of Investigation (Geofeedia 2016).

1.3.3: Geofeed Applications

Several geofeeds have been used in real world applications. In 2008, a company based in Africa, Ushahidi, Inc., developed an application for users to submit reports about emergencies through text messages, Twitter, email, and the Ushahidi website. Locations of reports are mapped in 2D in near real time for all people using the application to view (Roche, 2013).

Figure 1: Ushahidi Application in Haiti: 2D Map of Earthquake Reports. Licensed under http://onepeggenius.com/wp-content/uploads/2010/01/haiti-ushahidi-map.png

During the 2010 Haiti earthquake, US Marines offering assistance in the area used information collected by Ushahidi to locate deployment zones for field teams. "Stakeholders strongly believe lives were saved as a result of UHP [Ushahidi Haiti Project]" (Morrow, 2011, p. 6). An additional technology known as TweetTracker offered a similar service in Haiti in 2010. It gave "valuable insights and situational awareness" to relief organizations by searching for relevant tweets based on the tweets' locations and keywords used (Kumar, Barbier, Abbasi, & Liu, 2011, p. 661) (Figure 1 above).

A geographic information company, Esri, helped California's Office of Emergency Services (Cal OES) by implementing an interactive system that displays up-to-date wildfire locations, boundaries, hazardous areas, and weather conditions on a map. The system collects and organizes the locations and boundaries of the hazardous areas, the weather, and other information gathered from various relief agencies, coordinating the data into one place (Esri, 2017). Using this technology, Cal OES can help first responders assess damage, update field workers, and view social media posts containing relevant keywords (Esri, 2017).

1.3.4: Limitations and Privacy Issues of Social Media Use

Collecting and organizing online data from a large number of people is called "crowdsourcing" (Arolas & Guevara, 2012). Crowdsourcing can provide valuable data on wildfires, however there are a few challenges involved in acquiring that data. For example, the amount of social media data that needs to be processed is difficult to manage (Simon, 2015). Furthermore, not every social media user attaches a location to his or her posts. Social media does not always provide reputable information either; fraudulent users can send in fake reports, undermining relief efforts. One of the biggest concerns with social media crowdsourcing is the lack of security features and privacy protection available for users (Gao, 2011).

With the advent of location services, people want to share their locations with friends without jeopardizing their personal privacy (Sun, Xie, Liao, Yu, & Chang, 2016). While location services allow users to feel more connected to their fellow users, "the more [users] disclose, the more they risk what they themselves consider breaches of their privacy" (Trepte & Debatin, 2011, pg. 3).

One example of a privacy issue that made public headlines involves the previously mentioned company Geofeedia. In October of 2016, Twitter, Facebook and Instagram stopped supplying the content of its users to Geofeedia due to the revelation that police were abusing the data by monitoring protestors and rioters. As of the end of 2016, Geofeedia was attempting to show that the benefits of the program, mainly public safety, outweigh the sacrifice of privacy of social media users, so that Geofeedia may regain access to Facebook, Twitter and Instagram's content (Marotti, 2016). The company has not publicly announced whether or not they have succeeded as of early 2017. Through the use of geofeeds, pictures and videos of the same event can be aggregated and used to generate a three dimensional image of a situation.

1.4: Current Technology

Three dimensional (3D) mapping is a leading technology used to visualize and track various objects in reality as 3D images. One company at the forefront of 3D mapping is Geoweb3d, which makes high quality 3D visualizations of cities and other landscapes. The company has introduced a system that can project 3D objects created from pictures and videos into their 3D maps through a technology known as point clouds. They are also able to input live camera feeds into the visualizations and orient them properly to the existing 3D layout (Geoweb, Gallery, 2012).

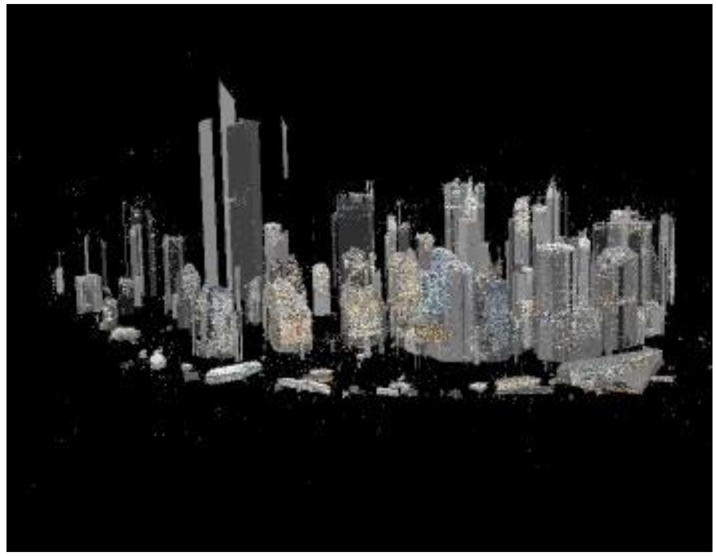


Figure 2: Lower Manhattan: 3D Point Cloud and Buildings. Grant Schindler. Licensed under non-commercial reuse at http://www.cc.gatech.edu/~phlosoft/

Point clouds are 3D images made up of thousands or millions of individual points with known coordinates relative to one another. These points create an object when viewed from a distance. Point clouds are created from several images through software that finds points of similarity in each image and maps them to one another in 3D.

Another technology at the forefront of innovation is an app called "SmokeD". SmokeD has been used in California to detect smoke columns in remote areas by collecting and simultaneously analyzing public imagery (SmokeD, 2017). The system is able to gather imagery from a number of public cameras mounted on fire towers, then utilize special algorithms to analyze the images and identify the presence of a smoke column from a wildfire within minutes of the fire starting. SmokeD also allows public users to submit their own images of a fire. With enough viewpoints of the same smoke column, SmokeD can determine the exact location of a wildfire and send out appropriate alerts (IT for Nature, 2017). This technology, on a basic level, is very similar to what our sponsor, Simtable, LLC, is trying to accomplish.

1.4.1: Simtable LLC

Simtable LLC, a company based in Santa Fe, NM, develops technologies that advance 3D modeling, data visualization and human-computer interaction. Simtable's mission is to create advanced visualization and simulation programs to better inform firefighters and first responders of environmental hazards such as wildfires.

1.4.2: AnyHazard

Simtable created the web browser application AnyHazard with the goal of creating a more streamlined system of communication and collaboration between different groups involved in wildfire management. The current use of AnyHazard is modelling specific incidences for emergency preparedness. These include modelling terrorist attacks, plane crashes, and chemical leaks. AnyHazard features a 2D map that can be overlaid with several different layers of geographic information, such as topography or a satellite view. The map can also be highlighted and marked with various points of interest, such as evacuation zones, fire crews, and the current status of the disaster. Icons marked on the map are shared to other users' devices in real-time. AnyHazard also has the ability to simulate an entire wildfire scenario, including the spread of the fire, effectiveness of different countermeasures, and civilian evacuations. Anyhazard is currently used by over fifty emergency response organizations, such as fire departments and forest services, nationally in training their operatives for various emergency situations. Currently, Simtable is attempting to make their technologies usable *during* emergency responses rather than just in training. One of their new software developments, LiveTexture, is aimed at accomplishing this.

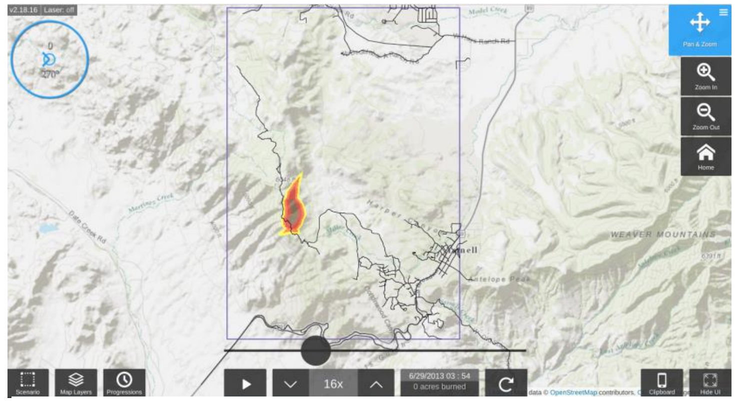


Figure 3: AnyHazard: Fire simulation of the Yarnell Fire (June 28, 2013). Showing fire progression layer.

1.4.3: LiveTexture

LiveTexture is browser-based software which can use various sources of 2D imagery from an area of interest to create 3D representations of the area. It aims to use real-time imagery collected from volunteers and bystanders on social media and from firefighters on the ground (Starbird & Leysia, 2011). The LiveTexture webapp can collect live camera feeds from phones as well as information on the phone's location and orientation. As more views and angles are captured on an incident such as a wildfire, the more information will be available. The end goal of LiveTexture is to gather 2D emergency information in real time and present it to relevant stakeholders in an intuitive 3D format.


Figure 4: LiveTexture website with three active users in Santa Fe, NM. Centerline and camera angle shown for each user. www.livetexture.com/

Simtable aims to move LiveTexture beyond the research and development phase and into the hands of users. Before this is possible, a user interface must be developed. Simtable has created very basic user interfaces for LiveTexture, as seen in Figure 4. However, these interfaces are designed to be used by LiveTexture developers, not end users. Thus, Simtable wanted to create an interface that can distribute for its customers to use when the LiveTexture technology is fully developed.

1.4.4: Implications and Impact

Our goal was to create a prototype user-interface that takes several of Simtable's current technologies, particularly LiveTexture and AnyHazard, and brings them together into a single streamlined interface. The user interface we designed combines the functionalities of these programs and allows users to effectively use both technologies at once. The program for which we were designing an interface will be used to share real time views of any location in the world in three dimensions. Applications of this technology include firefighting and emergency management. Fire chiefs and first responders will have the ability to label points of interest, track specific crew members (see Figure 5), and share information with whoever they want.

Figure 5: Mockup of a live annotated camera view where names and employee contact numbers are shown in the view (phone numbers blurred)

In the end, the interface will allow firefighters and first responders to communicate visually in real time during an emergency response. The technology will allow for a streamlined communication system among emergency response groups. It will improve emergency preparedness and increase situational awareness during emergency responses, which could ultimately save the lives of first responders and civilians alike.

Chapter 2: Methodology

The goal of our project was to create and prototype a user interface design intended for the real time aggregation and presentation of wildfire information. We achieved this goal by accomplishing four main objectives. Our objectives are as follows:

1. Understand the limitations of information flow within the current wildfire management system.
2. Understand the domain, context, and constraints of what LiveTexture should accomplish.
3. Develop mock up user interfaces.
4. Assess the effectiveness of the user interface to determine where improvements can be made.

In this section we describe the specific methods we employed to complete each individual objective and explain why we chose those methods. Each of the objectives allowed us to understand how we could best execute the actual design of the user interface.

2.1: Objective 1: Understand the limitations of information flow within the current wildfire management system

The first step in designing any new product is understanding where the current system is lacking. In order to improve upon what is already in use, we needed to know what limitations existed in the current emergency response communication system. We foresaw that two separate groups will be using LiveTexture in the future as a means of communication: fully trained emergency personnel (e.g. a firefighter or field observer) and the general public. Emergency personnel will most likely use LiveTexture to communicate with other team members, while the public will mostly use LiveTexture to receive real-time emergency updates. Thus we needed to investigate the flow of information both within emergency response organizations as well as from emergency response teams to the public.

In order to gain the best understanding of what the current emergency management communication system lacks, we conducted semi-structured interviews with various emergency response members, particularly those who deal with wildfires. From the interviews, we wanted to learn how information is communicated through the current system, when relevant information becomes available to those involved with the emergency, and other logistical problems that exist on an organizational level. We also asked them about ideas they had that could improve communication amongst team members in the field. We designed questions specific to each particular job within the emergency response system to fully understand the needs and roles of different emergency personnel.

The first professional user group we interviewed was field observers (see Appendix A). A field observer is a member of a wildfire response team whose task is to remain close to the fire and relay information back to the main headquarters. Thus, the field observer group was an essential group that we interviewed because we asked them about what information they gather on the fire and how the information is communicated. The next professional user we interviewed was a public information officer (PIO) (see Appendix B). A PIO relays information from the incident commander (IC) or other high level fire managers to the public during a wildfire. A PIO is a critical member of a wildfire response team as they represent the primary link in the flow of information from the fire personnel to the public. Therefore, it was vital that we interviewed a PIO, because they were the only people who could inform us on the current system of transmitting data from wildfire personnel to the public. Thirdly, we interviewed higher level fire chiefs (see Appendix C). Fire chiefs are responsible for making some of the most important decisions regarding how to respond to a wildfire using the information gathered during a crisis. We asked the fire chiefs about how much information is currently available and what information they would want to have early in a fire response.

From the interviews, we identified several problems with the current system. From the responses, we grouped problems into different categories by identifying patterns or commonalities. We then created a brief list of the overarching problems, and identified ways in which we could create a successful user interface.

2.2: Objective 2: Understand the domain, context, and constraints of what LiveTexture should accomplish

To determine the project's domain, or research space, we conducted semi-structured interviews with each Simtable employee. The goal of these initial interviews was to gain an understanding of the employees' perspectives on the capabilities and implications of LiveTexture. We also asked them their views on what features will be necessary to include. By developing an understanding of the product we were working with, we were better able to develop an interface that brings Simtable's perspectives in line with the goals of the user groups.

To begin researching the areas in which LiveTexture could be applied, we conducted interviews with subject matter experts (SMEs). These experts were knowledgeable of the scope and potential uses of LiveTexture within their lines of work. The SMEs we interviewed were experts in various fields: Eric Aeslin was a Communications Technician working for the US Forest Service, and Mar Reddy-Hjelmfelt was a member of a Virtual Operations Support Team (VOST), which supports emergency responders by gathering and processing relevant information available online. The initial interviews with SMEs were open and exploratory in nature because we did not want to bias answers by asking leading questions (Cooper, 2007). These semi-structured interviews focused on learning the interviewees' personal views of where LiveTexture could be applied as well as their opinions on necessary features.

In order to analyze the findings we acquired from our interviews, we constructed provisional user personas. User personas are models that outline a user's behavior, motivation, and goals. The personas were used to describe the behavior and goals of different types of users. The goal behind the creation of the personas was understand the specific needs of the specific individuals we are designing the User Interface around

To create user personas, we first divided the potential users into distinct categories and outlined the various attributes of these different categories. The three categories were professional firefighters, information officers, and the general public. We created three user personas to each represent a different category. For each user persona we outlined the environment in which they operate, their needs and requirements, common difficulties, and design imperatives, with all the data coming from what we learned in our interviews with SMEs. Design imperatives were the specific implementable functions that would make them efficient and successful users. During the construction of the user personas, we identified what a user does, thinks, and feels, to understand their point of view. To identify how and when a user persona would utilize the LiveTexture program, we constructed workflow scenarios. We created enough scenarios to outline all the tasks a user accomplishes in their environment. We identified where each persona would fit into a scenario based on their role and location. The scenarios were reviewed to create key path scenarios for each user persona. Key path scenarios narrow a scenario to focus on a user's most significant interactions. These key paths were continually revised and detailed as more findings were obtained.

The utilization of user personas during the development of the user interface allowed us to create a UI that is more likely to capture the needed functions of each user. Context scenarios allowed us to communicate the developed design solutions within the team and to our sponsor.

2.3: Objective 3: Develop mock up user interfaces

In order to design an effective user interface, we needed to know what interfaces currently work well in the digital world, and why. With the information from the user personas developed in Objective 2, we knew which functions that the user interface must have; however we needed to know how to display the functions in the interface. "Clarity is the most important element of user interface design….If people can't figure out how your application works they'll get confused and frustrated" (Fadeyev, 2009). The success of a UI is often more dependent on how information and functions are displayed rather than the actual abilities of the UI (Fadeyev, 2009).

We split the research on current UIs into two sections. The first section consisted of us conducting semi-structured interviews with two groups of people: "on the ground" firefighters and members of the public, particularly of the early twenties age group. In the second section, we conducted research into UI development and examined several well-known UIs (phone apps, computer games and websites) on what makes them successful.

In the interviews with firefighters (Appendix D), we focused on gaining information about what UIs they have used in their lives, whether that be in video games, social media, or other applications, and how some of the functions of those UIs could be applied to their work in the field. We tried to interview relatively new firefighters in the force because we reasoned that they would be a better source of new ideas in dealing with fires, whereas veteran firefighters might be both more satisfied with the current system and less willing to learn new technologies. We also focused on what information the firefighters currently have available to them prior to arriving at a scene, and what information they would like to have as they arrive at a scene to understand where the current system was lacking. Ideally, with their experience in the field dealing with fires and their exposure to various UIs, these men and women would be able to give us the best insight into how the UI should be designed. From their responses, we took the most common recommendations and developed them into important aspects that should be implemented into the UI.

In the interviews with the public, we focused on gaining general information about UIs. We asked questions such as: what are some of the apps they use on their phones, what are some UIs that they have particularly disliked, and what are some UIs that they think even their grandparents could learn in a short period of time (see Appendix E). The interviews were conducted in groups to allow for interviewees to build on each other's ideas and discuss why certain ideas are better than others. We conducted interviews with two other WPI teams because they consist of college students with experience in user interface interaction. We chose to speak to members of the younger age group (early twenties) because they have more familiarity with digital communications, media, and technologies. This increase in usage stems from more experience with UIs used on the internet, in phone apps and in game interfaces (Bower, 2013). As such, they would give us the best insight into what makes a successful UI. From these interviews, we gathered the most common recommendations and developed them into important aspects to implement into the UI.

The final portion of this objective was to develop mockup UIs, or two dimensional screenshots that show what the LiveTexture screens will look like visually but have no actual functionality. The findings from Objective 2 determine what aspects and functions should be included in the interface, and the research in Objective 3 determines how the user interface should look and operate. We began the development process by creating mockups of the different interface interactions outlined in the user workflows. For each interaction we determined the primary, required features and created simple sketches to communicate them. We discussed the optimal way for an interaction to occur (swipe, press, or held press) in the UI and created a visual mockup of each step on an illustrator program. These were then integrated back into the workflow to demonstrate the interface in a slideshow manner.

The mockups displayed how the functions needed by each user persona were fulfilled in a clear and simple UI design. With these mockup UIs, we were able to conduct the iteration process described in Objective 4.

2.4: Objective 4: Assess the effectiveness of the user interface to determine where improvements can be made.

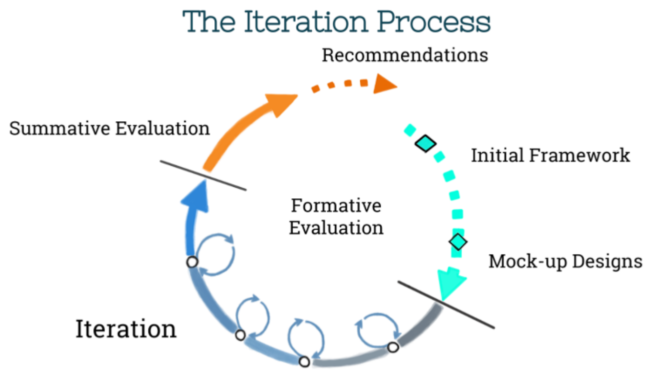


Figure 6: Product evaluation cycle: iterative designs. Retrieved from: https://www.evaluationtoolbox.net.au/index.php?option=com_content&view=article&id=16&Itemid=20

An invaluable step in any UI design process is validating how effectively the interface allows users to accomplish their goals. According to Nielsen (2012), a renowned expert in the field, an effective UI is deemed "usable." A usable interface is easy to learn, allows users to accomplish tasks quickly, is simple enough for users to remember how to accomplish tasks, is pleasant to use, and performs all of the functionalities the users need it to. To enhance the effectiveness, or usability, of the UI, we applied a process of gradual improvement through new iterations. According to Sail (2003 p. 3), "iterative design is the current best-practice process for developing user interfaces". In most instances, the more iterations of the UI, the better the UI becomes (Sail, 2003).

We began the iterative process with formative evaluations (see Appendix F), which occur during the design process (see Figure 6). The purpose of the evaluations was to identify problems with the design early on so that we could make improvements and develop a more usable UI that met the needs of the users. During formative evaluations, UI specialists evaluate a UI by comparing it to a given set of recommendations about how a UI should look and function (see Appendix G). The recommendations, chosen by the UI developers, provide the evaluators with an idea of what qualities the developers ideally want to implement in the UI (Jeffries, Miller, Wharton, & Uyeda, 1991). In this case, the UI specialists who evaluated the design were Simtable employees. Their experience in the field enabled them to diagnose problems that they knew would make the UI less usable. We asked the evaluators to initially interact with the UI on their own and identify features they wanted to evaluate. We then asked them to apply the UI recommendations we provided to the features they selected. Finally, we asked the evaluators to record any problems they encountered and propose potential solutions (Wong, 2017).

Next, we analyzed the problems identified during formative evaluations and determined areas of the UI where we needed to make changes. With the help of the Simtable team, we rated the severity of each problem on a scale from 1 (trivial) to 9 (critical) (Jeffries et al., 1991). Doing so allowed us to prioritize which problems we needed to focus on for the next iteration. We then made the necessary changes for the next version of the UI and repeated the process of evaluation and iteration, which concluded the design process.

We conducted additional evaluations after the design process to analyze the usability of the final product. While the mockups we created were not final designs for the interface that could be tested and utilized by end users, we still wanted to determine how usable our designs were by the end of our project and help our sponsor understand what needed to be done in the future to improve upon the designs. We determined where potential problems still existed and which screens needed the most changes. The tests provided us with measurable patterns and information on how to improve future UI designs, which allowed us to make further recommendations about the design to our sponsor.

Chapter 3: Results and Discussion

Our findings showed us how and where the LiveTexture user interface could enhance the current methods of reporting and responding to an emergency. We assessed the current system and found areas in which user interface could improve communication and information gathering, analyzed the various functions required by each user within the interface, defined an optimal layout from research into current user interfaces, and iterated our user interface design based on feedback from various sources.

3.1: Objective 1: Understand the limitations of information flow within the current wildfire management system.

Throughout the interviews with various emergency personnel, there was one major theme: emergency responders do their jobs with a minimal amount of information. Firefighters commonly arrive at the scene of an incident with as little information as “there is black smoke coming out of a building downtown,” and need to figure out what is going on and how to handle the situation quickly, without alarming the public.

One specific idea brought forward by one of the interviewees, a local fire chief, was that the fire department cannot immediately expect the worst and move to evacuate the public off a simple 911 call; they themselves need to confirm the situation, and then choose a course of action. If the chief assumed the worst and evacuated the public every time someone reported a supposedly life threatening event, the public would lose faith in the fire department and lose respect for their authority in the case of a true emergency. Thus, fire managers need information as soon as it is available in order to make accurate decisions. For fire managers, appropriate decision making minimizes the threat to the public and ensures only the necessary amount of action is taken and resources are used.

In the majority of the instances in which firefighters are brought into an incident, they are approaching completely foreign territory (Litzenberg, personal communication). While the person living in a particular house may know the layout and where some potential dangers are, the firefighters entering the house do not. These men and women must get the situation under control while also trying to find their way around aggressive dogs, confused civilians and unknown hazards within their area of operation. In the current system, the first person on scene relays as much information as possible back to headquarters so that the fire chiefs can get a better understanding of the situation and make decisions on what types of emergency response personnel to send. However, according to Litzenberg, there is no way to send information to firefighters en route that would improve their situational awareness. When a new truck of men and women arrive to the scene of the incident they must be quickly briefed on the situation then immediately begin working. This forces a compromise between how much information the firefighters are given at the scene and the length of the delay before they can begin working: the more thorough the briefing, the longer the delay.

Another compounding issue is that firefighters rarely have real time data on the current incident. In our interview with a field observer, we learned about the 12 hour information cycle that operates during a wildfire response: in the morning the field observers go to a specific area of the active wildfire and record the edge of the fire on their individual maps. Upon returning for the day, the field observers copy what they wrote on their maps onto the large table map in the incident command headquarters. After they are done, Geographic Information System (GIS) experts come in and digitize all the marks made by the field observers, and generate a new map of the leading edge of the fire. Finally, this digital map is printed and distributed to all wildfire response members for the next day of work. Through this, we can see that the "most current" map available is at least twelve hours behind real time. This limits the ability of fire manager to make quick, accurate decisions when it comes to dealing with wildfires.

In combination, these insights brought us to the first finding: **There is a severe lack of information in the current wildfire response system**. First responders arriving at the scene of an incident need more information to do their job quickly and successfully.

Real time data is necessary when dealing with events that can change drastically with a simple shift of the wind, and the current system cannot provide this data. Thus, one of the most important aspects of the user interface is that it incorporate real time data gathering. Specifically, the interface should permit and encourage civilians already at the scene of the incident to submit real time information. This, in effect, would end the 12 hour information cycle and provide updates by the minute or second.

Furthermore, the interface should be able to provide situational awareness to firefighters prior to them arriving on scene. While the fire crew is en route to the incident, they should be able to gain a significant visual understanding of the situation and the area of operation, and the interface should make that possible. The interface design should permit the first responder on scene to mark off points of importance or danger so that upon arrival firefighters know where to go and what to avoid without having to be briefed.

There were several other deficiencies with the current system that we identified through the interviews. Nearly all of these issues stem from a central problem: the use of verbal communication only. A wildfire can be reported in several different ways, but in each case dispatch typically gets a relatively small amount of information through a verbal conversation. For example, when a civilian notices plumes of smoke behind his or her house, he or she calls 911 and give his or her general location (a street name or nearby landmark) and the direction in which they are looking. In this instance, responders can hardly narrow down the exact location of the wildfire, and the limitations of the current system are already apparent. There is so much more information available to the civilian that he or she cannot convey to the emergency responder, simply because he or she cannot easily communicate verbally what he or she can see.

In our interview with a field observer, we learned of the difficulties associated with locating wildfires when only using a two way radio. Currently, if two field observers (in separate locations) see smoke off in the distance, they both radio in to dispatch, and then describe where they are and where they are looking with their handheld maps and compasses. Dispatch then must understand their exact coordinates, dealing with intrinsic flaws such as accents, slang and varying coordinate systems, and map the field observers' locations with pins on a paper map, and attempt to find the point of intersection of the field observers' lines of sight with string. This process is both tedious and highly inaccurate.

Furthermore, the field observer described the difficulty in communicating location with airplane pilots. Commonly, field observers direct pilots to the proper locations for fire retardant drops to slow the rate of expansion of the wildfire. With only verbal communication available, this is often a challenging process because the field observer needs to articulate exactly where he or she wants to drop the retardant using coordinates and cardinal directions. Similarly, the pilot needs to perfectly understand what the field observer is saying and execute the drop with no visual aid.

While these are all good examples of information flow into and among emergency personnel, there is also the problem of relaying information from the emergency personnel out to the public. In our interview with the virtual support operations team (VOST) member, we gained insight into how information is distributed to the public. Currently, the public can access emergency information through a few different mediums (generally news websites, Twitter, or television), but often, they end up finding a map with a fire perimeter and an evacuation zone. It is then up to the civilian to find her position on the map and decide if she is in danger or if she is safe to stay where she is. Not all members of the general public are competent map readers nor geographically proficient and the above process relies on their ability to read and fully understand the map. Thus, a simpler view is needed so users can understand their situation and evacuate if needed.

These problems with the current communications led us to the second finding: **The current wildfire response system is limited by the use of solely verbal communications**. Wildfire response teams should be able to communicate quickly and effectively through visual communications.

The user interface should take a visually based format to allow all users to share and submit pictures and videos so that emergency responders can accurately assess the situation. In the case of the civilian reporting a fire, they should be able to share all that they can see without sacrificing their privacy. Similarly, the interface should allow users to clearly see markings of emergency locations such as fire lines and expansion, and should notify them if they are in a dangerous area.

The design should have the ability for users to mark up images with information they consider important, particularly in the case of a field observer. When attempting to show the airplane pilots where to drop the retardant, the field observer should be able to draw a line in his or her view and have it show up on the ground in the pilot's view of the area. This augmented view could also be applied to the above case in which the first responder to a scene could mark up the area with important locations and safe spots in his view, and personnel in route would be able to see the augmented marks added by first person on scene and gain a greater situational awareness.

While the interviews we conducted were extremely helpful in understanding the current system of wildfire communication, we recognize that we only interviewed one field observer, one fire chief and one public information person. Thus, their individual experiences and demographics most likely biased some of their responses to the interview questions. Ideally, we would have interviewed multiple field observers, fire managers and public information personnel from several different areas and of varying backgrounds in order to gain a full scope of opinions on the current wildfire response system, but we did not have enough time to do so. Thus, we took their responses and used them to develop the user interface.

3.2: Objective 2: Understand the domain, context, and constraints of what LiveTexture should accomplish.

The research of this objective focused on understanding all prerequisite knowledge required to understand the scope of the project. The research began by understanding the different aspects of LiveTexture, and from there we developed insight into its potential uses. Our interviews with Simtable employees focused on the potential and possible implications of the program. Our interviews with experts in different fields identified specific applications of the LiveTexture program. The deliverable of this objective was a framework for the design of the UI.

From our interviews with Simtable employees, we elucidated the scope of the LiveTexture system, as well as its constraints. Stephen Guerin described Simtable as having five different "verticals", or specific industries, trades, and professions that they are targeting and marketing their services to. LiveTexture can be specialized to meet the needs of those involved in wildfire suppression, emergency management, oil and gas safety, military operation, and vector born disease containment. Due to the limited time at the project site, our sponsor delimited the scope of the project to wildfire and emergency management. Rather than develop the workflow and mockups for all aspects of LiveTexture, the project focused on three specific use cases. The three user stories, or specific examples of how LiveTexture can be used, were a professional field observer marking a wildfire, a virtual operation support team member georectifying an image obtained from social media, and a civilian user obtaining information on an incident through LiveTexture. The research during this objective was aimed at gaining a better understanding the complexities involved in these three user stories.

From the interviews, we learned of the different assessments each Simtable employee made. We learned that Simtable's overarching goal of developing LiveTexture is to enable users to perform at their highest effectiveness. Their technologies enable users to communicate more efficiently, and allow information to be shared in innovative ways. With developing the LiveTexture system, Simtable is attempting to make advanced 3D visualizations more accessible and user-friendly. By utilizing the mobile platforms, handheld smartphones, Simtable can overcome the previous restrictions to 3D visualization, the need for expensive computers (Kaufmann 1999).

Having an understanding of the scope of the project, we aimed to understand the specific applications of LiveTexture within the use cases. During our interviews with subject matter experts (SMEs), we discussed their views of how LiveTexture could be applied to the field they currently worked in. During our interview with Eric Aeslin of the USFS, we discussed specific applications and features he would like to see. We also discussed the solutions LiveTexture could provide to problems created by outdated technology. By utilizing a base map, and reloading only newly received data, the 12 hour information could be greatly decreased. The vital features for a field observer were being able to preload data for offline use, ability to view other lookouts in real time in order to align two camera views, and determining the GPS coordinates of a visible smoke cloud. This interview was essential in developing the workflows for the field observer user persona. Another SME that we interviewed was the VOST member. A VOST member's goal is to curate social media feeds in order to create informational briefs those on the scene of a wildfire or other emergency. An essential feature for a VOST member would be to georectify a relevant image from twitter, providing more information that would contribute to the situational awareness of the incident.

These interviews gave us answers to the questions, “Who are my users?”, “What are my users trying to accomplish?”, “How will users interact with my product?”, and “What kind of experiences do my users find appealing and rewarding?”. Understanding these, we were able to create user personas for a field reporter, VOST member, and a member of the general public (Appendix H). Because we only had sufficient time to interview a single SME from each field, we could not gather extensive qualitative data with which to full establish our user personas. As such, we created provisional personas and recommended that Simtable continue user research in order to sufficiently define user behaviors, motivations, and goals. However, we developed our personas enough to generate necessary functionalities for each persona.

To develop the context of LiveTexture, we needed to understand the different range of interactions users will have with LiveTexture. We created timelines of an example emergency situation. Individual user personas were applied to identify when the different users would require or share information. For example, a hiker spotting a fire would submit a picture of the smoke plume, but then have to obtain a safe evacuation route. We identified the specific instances where a user would come in contact or interact with the LiveTexture program. In each instance, the user utilizes the program to attain some goal. These scenarios took the form of wireframes, or basic outlines of our design’s functionality. The significant paths we identified were sharing a live camera feed, drawing and sharing an annotated map, and being able to orient and accurately locate image onto a 3D map view. By outlining the different tasks the user groups will use LiveTexture for; we were able to determine the screens that will be necessary to develop mockups for. In the next objective, we will detail our research into usability design and layout.

3.3: Objective 3: Develop mock up user-interfaces

We were unable to interview individual firefighters due to a lack of time, so we conducted a group interview with about seven firefighters of the City of Santa Fe (some joined late or left early so the average number was about seven at a time). However, we were still able to gain insight into what they would want in a UI design. There were two main design elements that were recommended from the group of firefighters we interviewed: they insisted on a quick and simple guidance system and liked the idea of being able to pull up information directly in the interface.

In their current information system, dispatch sends the location of the caller to the laptop in the fire trucks and the laptop is supposed to route the truck to the location of the incident. However, the laptops in the trucks work so slowly that the route will finally load as the truck arrives on scene. Thus, as was explained to us by one of the firefighters, the better option is to use Google Maps on their personal phones and route themselves based on the location given by dispatch. This caused them to put a heavy emphasis on a user interface that quickly routes the user to wherever he or she needs to go in a simple fashion, much in the way Google Maps does. When prompted with the idea of augmented reality, the firefighters agreed that either having an augmented line along the road for where to go or large arrows up above the road at locations where turns need to be made would be helpful in navigation.

The other theme that the firefighters spoke about was the lack of information that first responders have when arriving on scene. Thus when we asked about user interface ideas, the firefighters brought up the importance of being able to display a large amount of information in an intuitive way, but only when the information was needed. The example provided by the firefighters was when you click on an icon and a box of relevant information appears next to the icon giving the user more information about that particular item. This method of interaction keeps the UI clear of unnecessary information until the user needs the information. When prompted about augmented reality and augmented icons, the firefighters said the icons could give helpful information such as a patient's medical situation or the status of a job. We took these two ideas, simple navigation and icons with more information ready to display, and implemented them into the design of the user interface.

In our interviews with other WPI students, we gained valuable insight into what makes a simple and effective user interface. The interviews resulted in both general ideas that should be kept in mind when designing the UI and specific icons or points of information that should be displayed in the UI. We interviewed two groups of WPI students.

One of the overarching ideas mentioned in both of the interview groups was a "less is more" style of interface, where icons and buttons are kept to the edges and the main view takes up the majority of the screen. Some of the examples that were brought up to explain this idea were first-person video games. In these types of games, the player sees exactly what the character in the game sees and he or she interacts with the game environment. In nearly all of these games, the screen is filled entirely with what the character sees, and any supplemental information is either displayed along the edges of the screen or on alternate screens and menus. We analyze this style further in the team research below. Thus, in the designs, we focused on having a minimal number of icons and buttons, and keeping the buttons and icons that were necessary to the edges of the screen

Another one of the more general themes brought up in one of the student group interviews was the concept of having a few separate screens rather than pop-ups covering the one main screen. In the phone app Snapchat, there are several screens and each one has a specific purpose, and the user swipes left, right, up or down to alternate between the screens. In the out second student group, there was a majority preference on this Snapchat feel rather than the standard desktop style. While there was a concern that Snapchat has grown to have a few too many screens to swipe between, the second interview group was highly in favor of having two to four separate screens with their own functions. Thus, in the designs we focused on having screens devoted to specific functions rather than having one screen that would have menus overlaid.

One specific idea that was brought up in our first WPI student interview was the idea of having countdown timer that showed when a fire or other emergency would arrive. One interviewee mentioned that being able to know when a particular event, whether a wildfire or hurricane, is predicted to arrive at their location is more important than knowing how far away is. When one interviewee mentioned this, several other interviewees agreed, saying that it is much more useful to know when rather than how far because knowing when forgoes the need of the user to calculate how much time they have based on distance.

In addition to this point on ETA, multiple interviewees from the first student group stated that they would prefer clearly marked danger and safe zones in the interface. When prompted to explain further, these interviewees described having clearly defined markers that showed where a potential threat was and how to get to the nearest point of safety. We proposed the possible use of augmented reality to do so and the interviewees agreed that having augmented icons that can be clicked on for more information would be an ideal way to display information, much in the same as the firefighters. Along with these danger and safe markers, we prompted both groups to come up with their ideal way to be given an evacuation route in augmented reality. The interviewees in the first group responded nearly unanimously with the idea of a live augmented

marker as to where the user is supposed to go, and when the user got to that point, the marker would move to the next turn, similar to those used in adventure games. In the second group, the interviewees agreed on the idea of big arrows augmented above the road at every corner or turn, similar to racing games (Figure 7).

One thing we kept in mind during our work was that the data was not objective. Not every member of the public will agree on "good" or "bad" features, so there is a possibility that certain future users will not view designs in the same way as our interviewees. Furthermore, we realize that by conducting group interviews, certain interviewees' opinions may not have been heard because they were inclined to simply agree with other interviewees. However, we used any input that we were given in the developing of the UI.

Figure 7: Need for Speed Underground racing game with direction arrow showing where to turn. Retrieved from: http://videogamecritic.com/images/xbox/need_for_speed_underground_2.jpg

In addition to interviews with various groups, we researched successful applications and examined their user interfaces within the team. We looked at general, successful applications and applications specifically pertaining to augmented reality and mapping as LiveTexture will include interfaces dealing with both. We researched both video games and social media applications, noting elements that were important to the interface's success.

One game mentioned in our interviews was *Battlefield 1* (see Figure 8). *Battlefield 1* uses an augmented view where the character's view takes up the majority of the screen and resources and other player information takes up much less space. The various elements that appear on screen, such as the top-down "mini-map", score, and ammunition information (circled in red in Figure 8), are in consistent locations along the bottom or top edges of the screen. We can use these ideas in the UI design, keeping any information that needs to be displayed on screen to the edges, and having the main view take up the majority of the screen.

Figure 8: *Battlefield 1* example. Mini-map, ammo and score information circled in red. Retrieved from: https://i.ytimg.com/vi/gpK98WIr1Ik/maxresdefault.jpg

Also, *Battlefield 1* features augmented markers that hover above teammates, constantly showing their locations and status in the game. This style of augmented markers could be very helpful in viewing other users in an augmented view in the user interface. Similarly, the game uses augmented markers to show point of interest (places to get ammunition, locations to capture or objects to destroy) for the player to find and interact. These markers are intuitive, informative and, most importantly, take up very little of the user's view. Thus, we can use the layouts and styles displayed in *Battlefield 1* to design the optimal UI for LiveTexture.

The most well-known phone app to use augmented reality (AR) is Pokémon GO; therefore it makes sense for us to review its user interface. In the AR view, all buttons and options are kept to the side and are transparent, allowing for the maximum amount of the AR view to be seen (Figure 8). This avoids clutter, creating a clean, minimalistic interface. Just like with Pokémon GO, we wanted to develop an AR view that was intuitive and clear in functionality. We used transparent or minimalistic icons and buttons where applicable to keep users immersed in the view, and let the buttons blend in when not in use.

Figure 9: Pokemon GO example showing the minimalist user interface and augmented view. Retrieved from: https://static4.gamespot.com/uploads/original/1179/11799911/3209899-go.jpg

Snapchat has over 166 average daily active users making it one of the most used phone apps (Constine, 2017). Its success is likely due to its simple, effective user interface and the in depth social integration. The app's main function is to allow users to send pictures or brief videos to one another, however the app has evolved to do much more. Its user interface features a main screen, then several other screens, each with its own purpose, and each can be accessed by swiping in a particular direction. This is a function described in our interviews that is intuitive and easy to do, thus making it a useful aspect to include in the UI.

On the main screen, the buttons are small and placed in the corners as to not take away from the main camera view. One downside in the Snapchat interface is that the buttons are not the most intuitive. While an experienced user will know exactly where everything is and how to get there, a user who does not use the app often will not be reminded of where things are by the icons used in the main screen: they are too nondescript and general. Thus, while we can use a similar layout to Snapchat, the UI we design should have accurate, descriptive and intuitive icons that will direct a brand new user exactly where they need to go.

After spending time researching and analyzing these applications and their interfaces, we came to the conclusion that **user interfaces should be simple, minimalistic, and consistent**. Particularly in the case of smartphone use, using the minimal amount of screen space for icons and buttons, keeping the design simple, intuitive and consistent provides for the most effective user interface.

3.4: Objective 4: Assess the effectiveness of the user interface to determine where improvements can be made.

Evaluation 1:

During the first formative evaluation, we presented the screens shown in Figure 10 in a PowerPoint presentation to our sponsor, Stephen Guerin, who served as the evaluator. The first screen, which would load when someone first enters LiveTexture in a web browser, showed a 2D map view with an icon of where the user is located and their view direction, indicated by the centerline extending from the triangle icon. Screen 2 showed the menu options that would appear if a user theoretically clicked the "hamburger button" (the three horizontal lines) in the lower right corner of the screen. If a user clicked the camera icon in the lower left, the third screen would appear with the camera view. The camera view offers the option to record videos and see where you are in the world in a 2-D map in the upper left corner of the screen. If the user clicked on the small 2-D map in the camera view, they would return to the full-screen map view. Finally, the fourth screen displayed two user icons in the same area of a 2-D map. The blue icon would represent one user, while the green icon would represent another user. If "blue" theoretically clicked on "green," the black menu of options seen on the map would appear, allowing blue to contact green, share information with green, or see green's live and past videos.

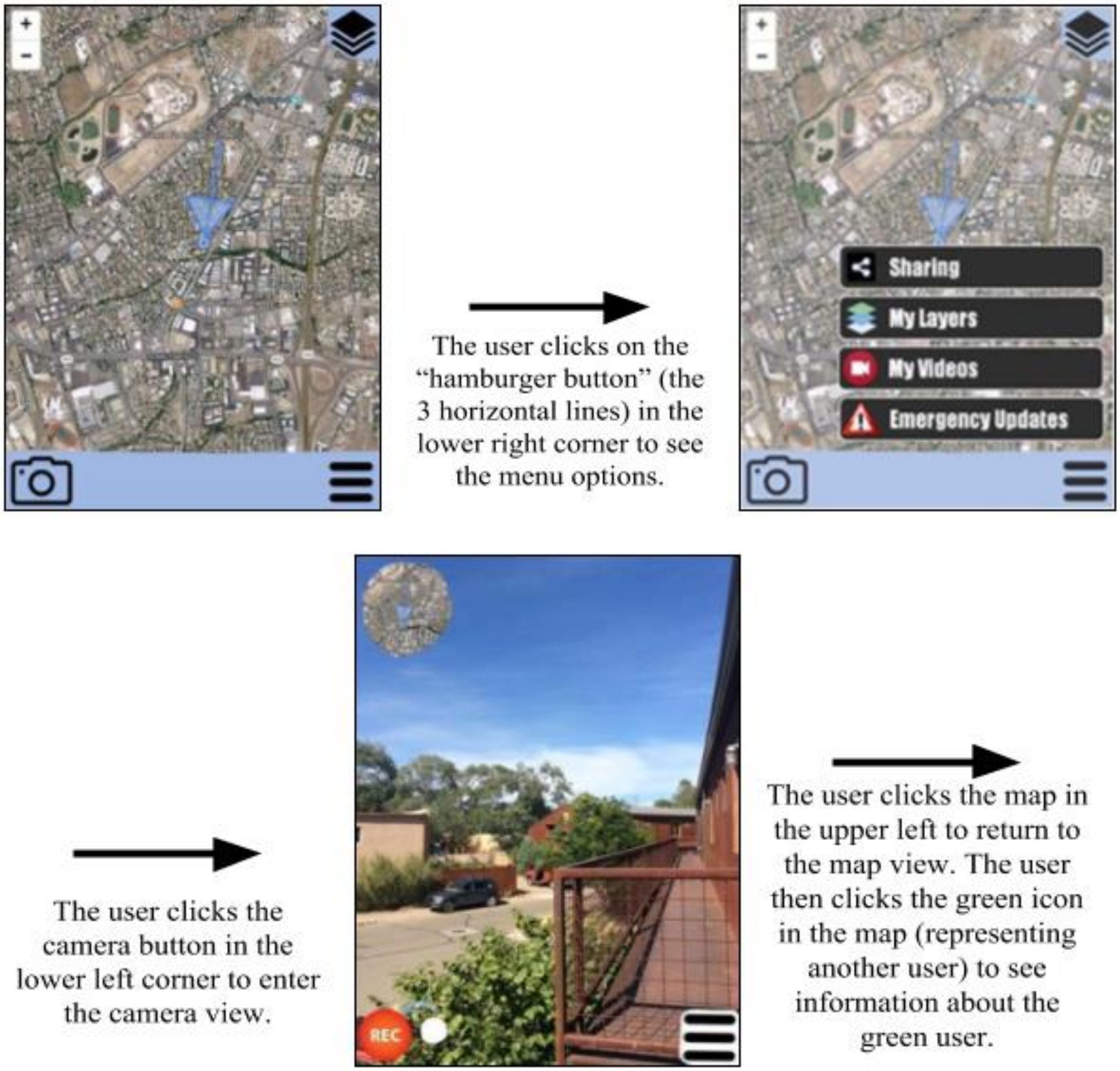


Figure 10: Evaluation 1 General Screen Presentation

Mr. Guerin noted that he liked the options available in the menu, as well as the small 2-D map in the top left corner of the camera view. He also liked the small white button next to the record button in the camera view, which would allow the user to capture screenshots whilst recording a video. During the evaluation, Mr. Guerin also encountered various problems with the UI design, which are outlined in Table 1 of Appendix I. The severity rating for each problem was determined by us with the help of Mr. Guerin. The ratings were on a scale from 1 (trivial) to 9 (critical), based on how important the problem was to fix in order to make a more usable UI.

Based on the feedback we received about buttons, we realized our sponsor wanted to swipe between screens rather than use buttons as much as possible. However, from an interview we conducted earlier with a group from the general public, 67% of the group preferred minimizing the number of swipes between screens. Therefore, we decided to compromise by designing the UI to have swiping only once in each direction, but still offer physical buttons that took the user to the same screens as swiping.

In general, we realized from the initial feedback that we needed to create a more minimalistic design. However, we learned from earlier interviews with end users that designing an interface that addresses the actual needs and goals of the users themselves is most important. Thus, we needed to prioritize implementing the functions each user required into the UI over making the UI look aesthetically pleasing. We still wanted to design a UI that was easy to understand and navigate, but we first focused on laying out the necessary functions. For example, we needed to give users the option to share specific map layers with other people. If a firefighter had map layers including the locations of crew members, areas for air attack to drop fire retardant, and fire perimeters, they should have the ability to only share the fire perimeters layer with the general public.

The screens we presented in the first evaluation did not encompass all of the final designs because we were still conducting the design process. After the first evaluation, our sponsor gave us additional feedback on screens and functions to add to the design, which is outlined in Table 2 in Appendix I.

The feedback we received in Table 2 helped us determine which functionalities we needed to add to the UI design. We had not previously considered having a spectator mode where someone can watch another user's view from a third person "off-the-shoulder" perspective. Third-person views made sense to implement so that users could see someone else's camera view while simultaneously viewing their surrounding area in order to obtain a better understanding of the situation. The majority of the feedback we received from Mr. Guerin was centered on different ways one user can view another user's camera view. For example, feedback also included being able to see another user's view in first person, with the camera's field of view, or "frustum," lines projected outwards. Users could also be able to click on another user's camera view and drag the video back in time to view the past. Thus, we concluded that **future iterations needed to include the ability to see other users' camera frustums on the map, from a third person perspective, and from a first person perspective.**

Though the feedback we gained from the first evaluation was very informative and helped us improve the design, we recognized that we only had one evaluator test the design. In some cases, having one evaluator may allow the evaluator to not be biased in their feedback by the opinions of other evaluators, but we could have gained additional input if we had more evaluators critiquing the design.

Evaluation 2:

We used the feedback from the first formative evaluation to create a second iteration of the UI design, which included multiple new screens with additional functionalities. We then conducted a second formative evaluation with three different evaluators, who were all Simtable employees. We presented the screens shown in Figures 11-14 to the evaluators in the form of multiple PowerPoint presentations.

Presentation 1: Annotating a Camera View

For the first presentation, we walked through a hypothetical scenario of a field observer annotating their view of a wildfire in the camera view. The first screen represents where the field observer would start recording a live feed. After the field observer has recorded the video, they would then press and hold anywhere on the video to bring up a radial toolbar to begin the process of annotating the view. The toolbar could be moved around anywhere in the image while the field observer is annotating. The toolbar also includes the ability to add points, polylines, and polygons to an image. The fourth screen shows the end result of a field observer annotating a line and a polygon to the video.

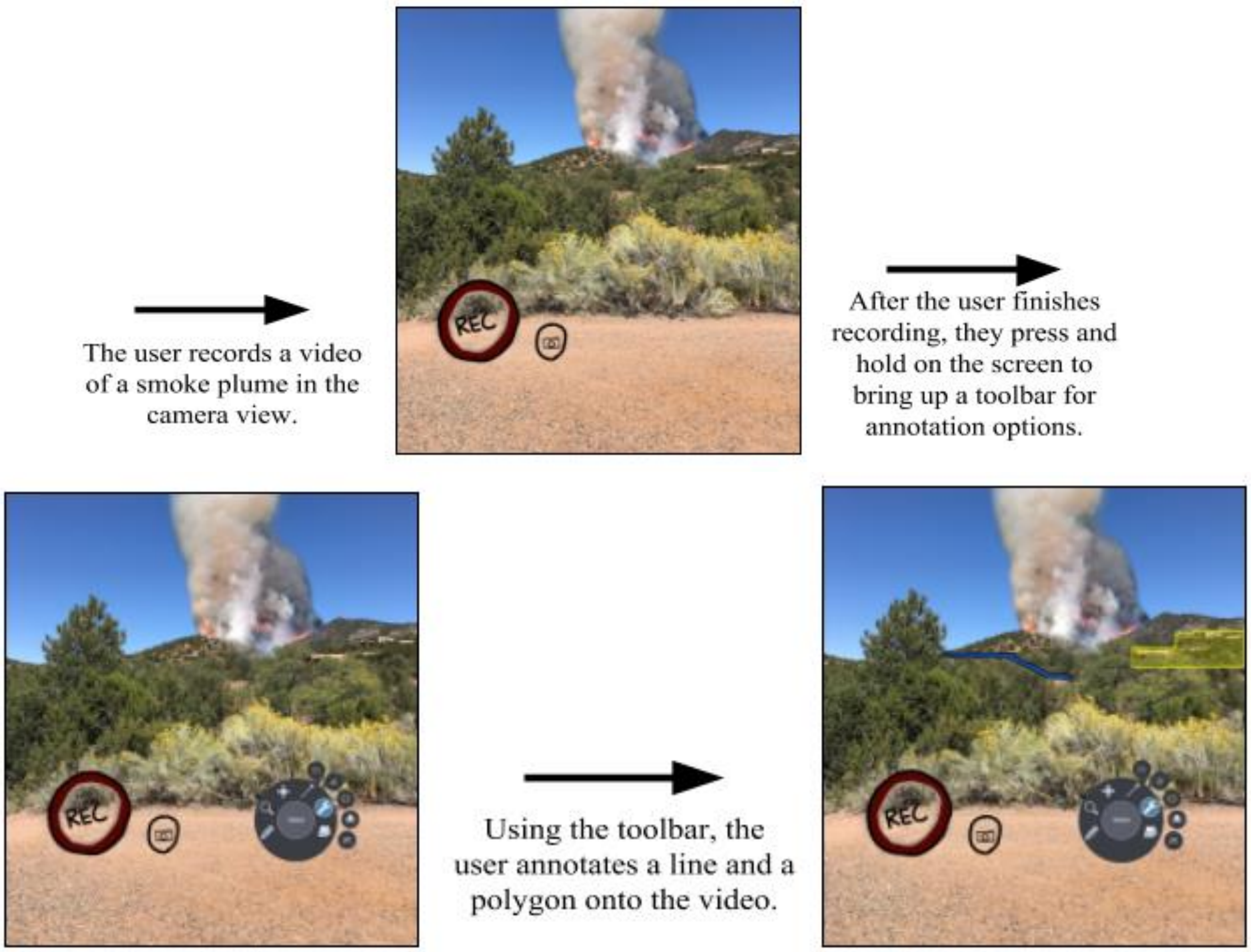


Figure 11: Evaluation 2 Camera View Annotation Presentation

Presentation 2: Sharing Screens

For the second screen presentation, we walked through a hypothetical scenario for a field observer on a wildfire. In the first screen, the field observer has finished annotating the area around a wildfire in their camera view, and clicks the button in the top right to begin the process of sharing the annotations with specific people. In the following screen, the field observer views their personal layers, with green representing active layers and gray representing inactive layers. In the third screen, the field observer then selects the specific layers they want to share, clicks on the share button in the bottom left, and moves to the fourth screen to select which social media platforms and groups they want to share their data to.

The user finishes annotating an image and clicks the share button in the top right to view the layers they have added and other layers they have access to.

The user presses and holds on a layer to bring up selection boxes. The user checks off the layers they want to share (Wildfire Near Mt. Atalaya & Family Properties) and clicks the share button in the bottom left.

The user selects the social media platforms and groups they want to share the layers in the image with.

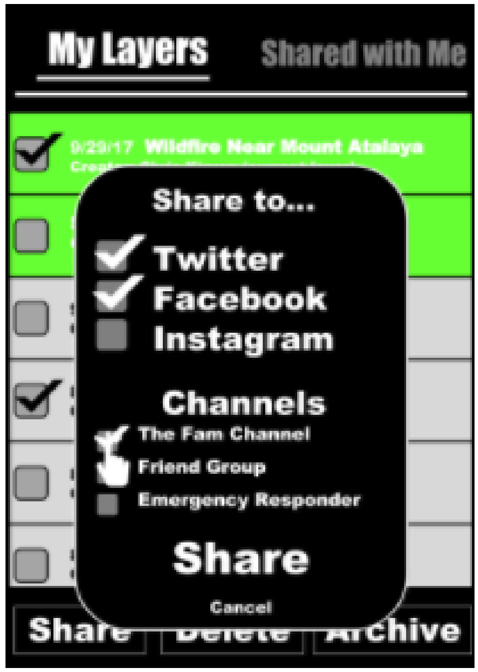


Figure 12: Evaluation 2 Sharing Screens Presentation

Presentation 3: Enter Another User's View

For the third screen presentation, we walked through a scenario involving a member of the public who is not home at the time, but knows there is a fire near their home and wants to check how far away the fire is from their home. When the person looks at the first screen, they see the camera frustum of another user on the map taking a live video in the general direction of their home. The person clicks on the camera frustum and transitions to the second screen, which displays a small menu next to the frustum allowing the person to either contact the user who is broadcasting the live feed or enter the user's camera view. The person opts to enter the live feed and moves to the third screen, which shows a wildfire on the mountainside outlined by a cylindrical icon. When the person clicks on the fire icon, they move to the fourth screen where a message appears next to the icon with information about the wildfire, such as the name of the fire and percent containment. Finally, in the fifth screen, the person drags their finger between the edge of the fire and their nearby home to see a line that tells them the distance between the two points.

The user sees another user's camera frustum on the map.

The user clicks on the frustum and sees options to contact the user or enter their live feed.

The user clicks on the "View" button to enter the other user's live feed, where the smoke plume from a fire is outlined.

The user clicks on the cylinder outlining the plume to see more info about the fire.

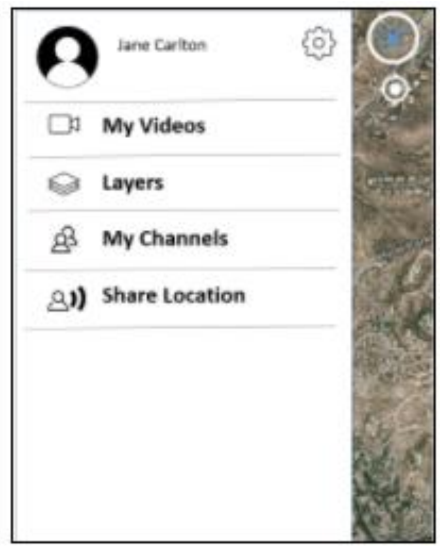
The user drags a line with their finger to get the distance between the fire and the nearby house.

Figure 13: Evaluation 2 User Frustum and Live Feed Presentation

Presentation 4: General Public Evacuation

The final screen presentation involved a member of the general public who wanted to know where they were in relation to a wildfire and determine whether or not they needed to evacuate. The first screen shows the person's 2D map view, where they can click on the "hamburger" button in the top left to access the menu options shown in the second screen. The person clicks on the "Layers" tab in the menu to move to the third screen, where they activate the fire perimeter and evacuation zone layers, which are now green. Once the layers are active, the user returns to the 2D map to see the layers appear in the fourth screen. The user notes that their black location icon is in the middle of an evacuation zone. The software is able to determine this and automatically displays an evacuation notification at the top of the screen. The person then clicks on the notification and is taken to the fifth screen, where they receive turn by turn directions in an augmented reality view of how to evacuate from the area they are in.

The user clicks the "hamburger" button in the top left to access menu options.



The user clicks the "Layers" option, then clicks on "Fire Perimeters" and "Evacuation Zones" to activate those layers

The selected layers appear on the user's map; The user sees they are in an evacuation zone.

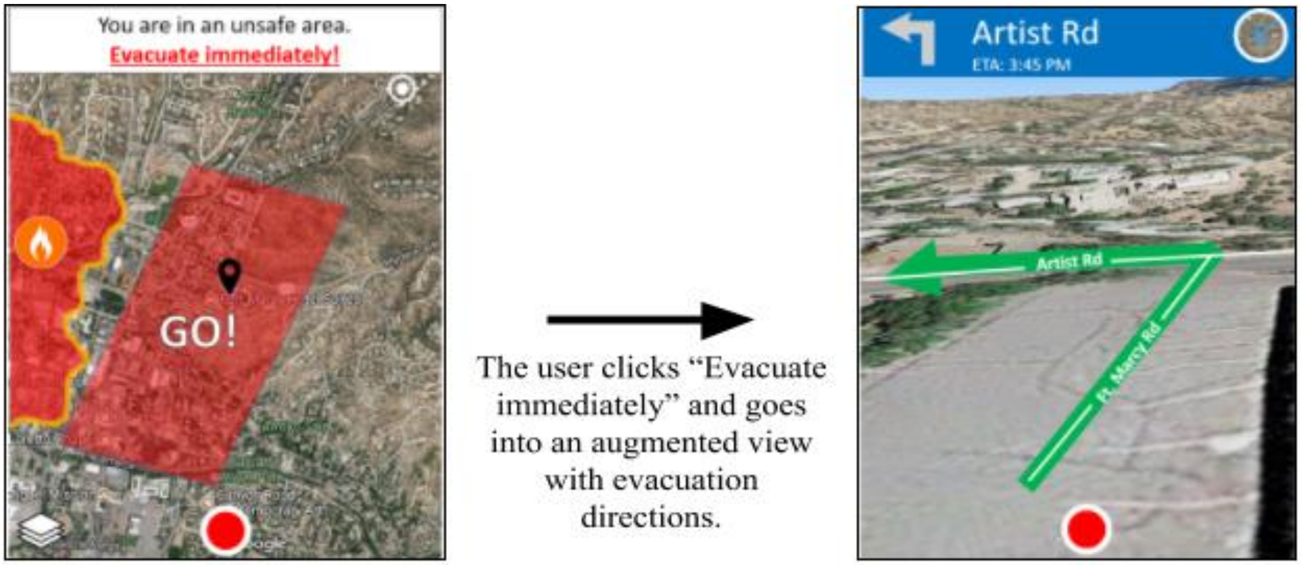


Figure 14: Evaluation 2 Public Evacuation Presentation

After analyzing the feedback we received, we found that the evaluators were very pleased with the types of functionalities we had added to the design. They liked the simplicity of activating and sharing layers with specific people, as well as having the software automatically alert someone if they need to evacuate. One of the evaluators liked the ability to drag a line between two points and see the distance between the points.

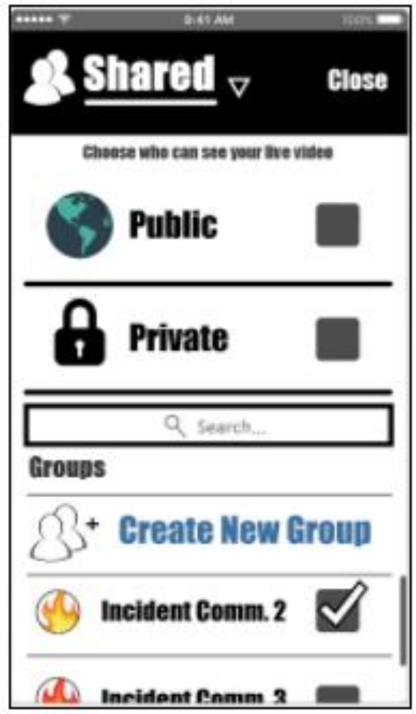
The problems the evaluators encountered during evaluation 2 are outlined in Table 3 of Appendix J, while their feedback on additional features to add is outlined in Table 4 of Appendix J. One major concern the evaluators noted was liability issues surrounding evacuation routes for members of the public. After discussions with the evaluators and our sponsor, we decided to only offer evacuation routes that direct members of the public out of an area of danger to a general safe zone, without directing them to a specific location. Additionally, we needed to focus on creating a unified design among the screens we currently had, so the interface would be consistent and standardized. We still needed to continue adding functions to the screens as well, but the evaluators were happy with the progress we had made from the first iteration.

We used the feedback we received from the evaluation to continue iterating and improving the interface designs by adding functions that would address the needs of each user group. We also attempted to create a more unified design among the screens. After having gone through multiple rounds of iterations, we presented the screens show in Figures 15-19 to our sponsor at the end of the project.

Figure 15 outlines how a field observer could start recording a video in LiveTexture, share that video with a specific group of people, add a description of the video, then annotate the video by adding markers that show where the smoke plume is as well as where ground crews need to dig a fire line.

While the final screens represent a large improvement from our original designs, many of the designs are not perfect and still have limitations. For example, in Figure 15, while the "picture in picture" or PIP view of the map in the first screen may help the user be more aware of both their location and surroundings, it may take up too much space on the screen. While we were not able to address these limitations, Simtable can discuss them in the future depending on their own visions for LiveTexture.

The user clicks the red record button and is prompted to select who they want to share their live video with.



The user closes the share screen and is able to add of description of what they are seeing in the video.

The user clicks the "Go Live" button and records a video of the scene. The user then annotates their view after recording, outlining the smoke plume and indicating an area for crews to dig a fire line.

Figure 15: Field Observer Sharing and Annotating

Figure 16 displays the “Layers” menu. Users can add “layers” of information to their individual maps on LiveTexture. For example, if a user wanted to overlay a map layer showing the locations of their family’s properties, they could do so. The crown icon indicates that the user owns the layer. The user can search and filter their layers, shown by the icons to the left and right of “Layers.” The pencil icon indicates that the user has editing permissions on the layer; while the eye icon (with no line through it) indicates the layer is currently visible to the user on the map. The eye icon (with a line through it) indicates the layer is not currently visible. The user also has the option to add additional layers. If the user clicks on a particular layer, they can view additional properties and options for the layer, such as the name of the person who created the layer and the options to share the layer with other users.

In Figure 16, we did not have enough time to figure out a way to visually distinguish to a user the difference between having viewing permissions for a layer versus currently being able to view a layer on the map.

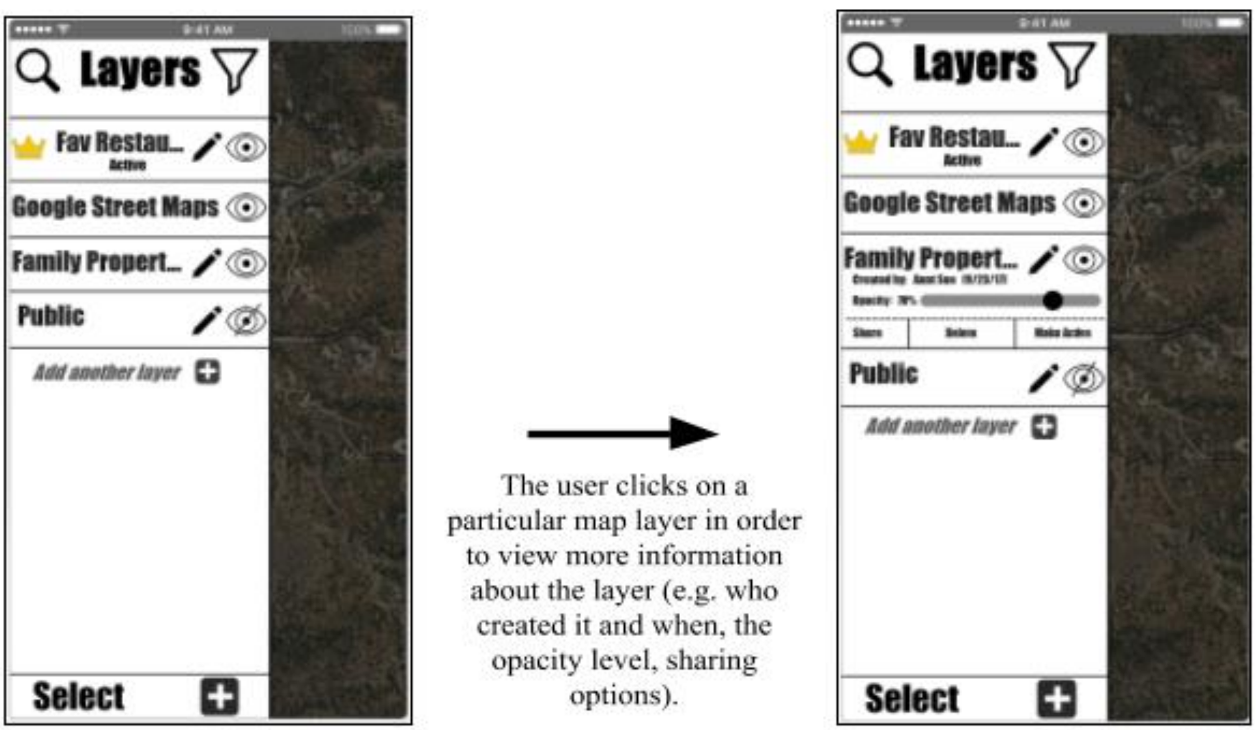


Figure 16: Layers Menu

Figure 17 shows the “Groups” menu. At this menu, the user can view all of the groups they are a member of. The user can search and filter through their groups, similar to layers. The user is able to view the names and profile pictures of each member in a specific group. They can also see the name of the owner of the group, start a chat with the group, share their location with the group, or add a member to the group.

Figure 17: Groups Menu

Figure 18 shows a view of the map with other users in the area. Each user is represented by a uniquely colored camera frustum, or field of view. This particular map would appear for a member of the general public in an active emergency. Thus, a small "tip" appears at the top of the screen indicating where the user can go (to the camera view) to record and report an emergency if they need to.

In Figure 18, however, the map does not indicate to the user which users in the area are actively recording a live video versus users that are just in their camera view.

Figure 18: Map View with Nearby Users Displayed

Figure 19 outlines how a member of the general public could interact with LiveTexture if they needed to evacuate. The user could find a link on social media or a news website to a map of LiveTexture. Clicking on the link would bring the user to the first screen, showing the current wildfire perimeter and evacuation zones. The user can see their location (indicated by the black "teardrop" icon) as well as the locations of other users in the area (indicated by the green circles). When the user clicks on a green circle, they have the options to call or video chat with another user, which could be helpful to check in on someone and see if they were in an emergency and needed assistance. The user can also click on the fire icon to see more information about the fire, such as percent containment. Since this particular user is located in an evacuation zone where people need to leave immediately, LiveTexture automatically sends the user an alert. The user can click on this alert to receive directions from the evacuation zone to a general safe area.

In Figure 19, however, the user should theoretically only have the ability to contact other users in the area who have made their information public. Additionally, liability issues may still exist with giving users personalized directions out of an evacuation zone. However, Simtable can discuss in the future whether or not they want to include this functionality.

The user clicks on another user's location icon in the area to view options related to that user (including call and video chat).

The user clicks on the fire icon to view more information about the fire (including percent contained and burn severity).

The user is located in an evacuation zone and needs to leave immediately. LiveTexture automatically alerts the user of their situation. If the user clicks the alert, they will receive an evacuation route.

Figure 19: General Public Viewing the Map and Receiving Emergency Information

Chapter 4: Recommendations and Conclusion

Recommendations

We recognize that the UI designs we created were simply the first step in developing the final interface end users of LiveTexture will use. However, we would like to additionally give Simtable various recommendations to help them continue the design process and think of ways to realize the full potential of the LiveTexture technology. In this section, we explain and justify the recommendations, and specify how Simtable can implement each one.

Future UI Design

Based on the valuable insights we gained from user interviews about functionalities to include in the UI design, we recommend that **Simtable conduct interviews with representatives from all potential LiveTexture user groups**. We were not able to interview every type of user that could theoretically interact with LiveTexture at some point. For the user groups that we were able to interview, we recommend that Simtable interview a broader range of users within each of those groups, to identify the full spectrum of users' needs and goals. We also recommend that Simtable use the interview data they gain to outline new user personas and context scenarios, as each type of model greatly helped us determine what types of screens we needed to design and for what purpose.

From the evaluations of the UI mockups by Simtable employees, we recommend that **Simtable conduct evaluations to assess the usability of the product as it develops and make necessary changes**. While we created prototype designs for LiveTexture's interfaces, the interfaces will undoubtedly continue to evolve both in terms of physical design and available functionalities. We recommend that **Simtable conduct rigorous evaluation and iteration processes each time the interface undergoes major changes**. Evaluating the interfaces during the design process allowed us to avoid any major pitfalls and add major necessary functionalities early on. We believe future evaluations will provide the same benefit to Simtable.

Based on the assessments of existing UIs that we conducted, we recommend that **Simtable further implement social interactions among users into LiveTexture to incentivize people to use the software and share out information**. Most successful UIs integrate some form of social interaction or competition between users and provide users with incentives to keep using the application. For example, Pokemon Go allows users to collect badges for accomplishing certain tasks. Pokemon Go also attracts users by allowing them to "gain control" over certain geographical areas. In a similar way, we recommend that **Simtable allow users to earn "coins" for submitting imagery from a certain location or helping to georectify an image**. If a user collects enough coins, they could potentially redeem a reward such as a gift card. We also recommend **Simtable design a leaderboard in the interface that displays users with the most coins**.

Additional Applications of LiveTexture

Based on the current capabilities of LiveTexture that we learned about, and based on discussions with interviewees, we recommend that Simtable consider potential applications of LiveTexture other than wildfire management. For example, LiveTexture could be used during the scenarios presented in Tables 1 and 2.

Table 1: Applications Suggested by Interviewees

Potential Area of Application	How LiveTexture Could Be Applied
General Emergency Management	LiveTexture could allow visual communication among personnel in real time and the ability to keep track of resources in the field.
Military	LiveTexture could allow real-time tracking of soldiers in the field and allow soldiers to prepare for a battle by viewing the area in 3D in advance.
Transportation Sector	LiveTexture could enable first responders to visually communicate the scene of an accident to medics and other personnel before they arrive. LiveTexture could also enable traffic technicians to monitor the flow of traffic in one, centralized 3D view (instead of having to look at multiple 2D camera views at once).

Table 2: Applications We Suggested:

Potential Area of Application	How LiveTexture Could Be Applied
Oil and Gas Industry	If a disaster such as an explosion occurs, workers could use LiveTexture to have a 3D map of the area that updates in real time. LiveTexture could obtain imagery from the public to see how the explosion unfolds. Oil companies could also use LiveTexture to keep track of resources and people.
Amusement Parks	Workers could use LiveTexture to keep track of incidents that occur and visually communicate the state of an incident to others.
Home Theater Entertainment	Members of the general public could use LiveTexture to watch an event (e.g. sports game, festival, or concert) in 3D and in real time.
Electric Utility Industry	Electric utilities could use LiveTexture to pinpoint outage locations or track people who are still without power during a major storm.
Public Beaches	Lifeguards at public beaches could use LiveTexture to keep track of incidents and be able to send the right resources to the scene.

Conclusion

One of the most important steps in designing a useful and successful product is developing a functional and user-friendly UI. LiveTexture's UI will one day enable firefighters and emergency personnel to successfully perform their jobs to the best of their abilities. The interface will allow users to easily interact with LiveTexture, communicating and visualizing wildfires in real time. Such a capability could have the potential to save the lives of firefighters and civilians alike. LiveTexture has the capacity to revolutionize the ways we gather, share, and view information.

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Appendices

Appendix A: Field Observer Interview Questions

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting semi-structured interviews with those involved in fire-prevention and management to learn more about information flow during a wildfire. Our goal is to gain a better understanding of the current system of information flow during an emergency.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous (though it would be useful for readers to know who you are as an important person within the state). If interested, a copy of our results can be provided at the conclusion of the study.

Part 1: Learning about the Field Observer Position

1. Tell us about your position in the field at Prescott National Forest.
2. What means of communication do you currently use at Prescott?
    a. Do you notice any major limitations with the current communication system you use?
    b. Do you have the ability to communicate directly with specific individuals both on the ground and in the air? If so, how do you do that?
3. When a wildfire does occur:
    a. What is the current process for a civilian reporting a fire? What data is typically immediately available from the civilian?
    b. Who needs to know the information about the fire first?
    c. What is the current process for a field observer/lookout reporting a fire? What data is typically immediately available from the field observer?
4. When coordinating a wildfire response:
    a. How do you identify the location of the fire?
    b. Do you use paper maps or computerized maps?
    c. How long does it typically take to get responders out into the field to start fighting the fire?
    d. How do you inform visitors to the park of the emergency? What information do they need to know about the fire?
    e. Do you typically communicate with outside agencies? If so, whom and how do you communicate with them?
    f. Do you access social media in any way during the wildfire response?
5. Do field observers typically have Wi-Fi/mobile data connections out in the field?
6. How important would it be to have offline functionality for LiveTexture?

7. Part 2: Building up ideas for the *Professional* user story user experience
8. What are important features or permissions that a field observer should have? (What does a field observer’s job require him/her to do? What are the absolutely necessary functions?)
    a. How should these be different from what the general public has access to?
    b. What would the minimum viable product be? (minimum usable product)

9. What is the easiest way to integrate our technology into what they currently do?
10. Ideally, how would the general public be involved in this project? (adding data?)
    a. Do you view the crowdsourcing of smoke detection as an optimal solution for fire management?
11. Do you happen to have any colleagues in the field that you think would be willing to talk with us about LiveTexture?

Appendix B: Public Information Officer Interview Questions

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting semi-structured interviews with those involved in wildfire and emergency management to learn more about information flow during a wildfire response. Our goal is to gain a better understanding of the current system of information flow during an emergency.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous (though it would be useful for readers to know who you are as an important person within the state). If interested, a copy of our results can be provided at the conclusion of the study.

1. Please describe your role as a VSOT / PIO.
    a. What is the first priority in an emergency as a VSOT or PIO?
        i. Goals - What makes a good day? A bad day?
        ii. Problems - What activities currently waste your time?
        iii. As a PIO, from whom do you receive emergency information to send to the public?
    b. What sort of difficulties do you find in the job you do? Do you ever experience problems with miscommunication?
    c. Can you think of any tools or forms of communication that would make your job easier or faster to perform?
2. What is the overall goal of VSOTs? What are you trying to achieve?
3. What is the overall goal of PIOs? What are you trying to achieve?
4. During a wildfire, what specific types of information does the public need to know?
5. Typically, when you find a post on social media about an emergency, what kind of information can you gather?
    a. What information are you generally missing?
6. After you find a post on social media about an emergency, what is typically the next step?
    a. What types of posts do you typically process (text, imagery)?
    b. Do you ever need to contact the person who made the post?
    c. If so, why and how do you go about that?
7. How would an application such as LiveTexture help you in the work that you do?
8. Do you think that if a member of the public were to report an incident related to the emergency, should the rest of the public be able to see that incident?

Appendix C: Fire Chief Interview Questions

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting semi-structured interviews with various fire managers to learn more about the flow of information during a fire response. Our goal is to gain a better understanding of how information is conveyed to various members in the fire department.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous (though it would be useful for readers to know who you are as an important person within the fire department). If interested, a copy of our results can be provided at the conclusion of the study.

Understanding the Current System

1. Simply put, what is your job as a fire chief?
    a. How do you communicate amongst the various fire personnel?
    b. Does the current system work well?
2. What are some of the biggest challenges that you face in your day to day operations?
    a. Does your current technology work well in the field?
    b. Is there anything you wish you had access to that you do not have access to currently?

Appendix D: Firefighters Interview Questions

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting semi-structured interviews with firefighters to learn more about the flow of information during an emergency and about an ideal user interface to convey said information. Our goal is to gain a better understanding of the current system, and learn where and how the system can be improved.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous. If interested, a copy of our results can be provided at the conclusion of the study.

Part 1: Understanding the Current System

1. What is your role within the department?
    a. What do you do in a typical day in the field?
    b. What challenges do you face?
2. How is information relayed to you in the current system?
    a. Does the current system of communication work well?
    b. Is there anything you know of that could easily be improved?

Part 2: UI Recommendations

1. What video games have you played that you would say had a simple and effective user interface?
    a. Anything unique about them?
    b. What about them made them easy to use?
    c. What about them made them effective?
    d. How did they offer information in a clean way?
2. What phone or computer apps have you used that you would say were easy to use and effective?
    a. Anything unique about them?
    b. What about them made them easy to use?
    c. What about them made them effective?
    d. How did they convey information?
3. Do you have experience with augmented reality?
    a. What applications have you been exposed to with augmented reality?
    b. Did they have effective UIs?
4. In your job currently, what could an augmented reality view offer you?
    a. What information would you want to be available upon arriving at the scene?
    b. How could this info be conveyed to you?

Appendix E: Younger General Public Interview and Discussion Questions

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting semi-structured interviews with the younger generation of the general public to learn more about their experiences with various user interfaces. Our goal is to gain a better understanding of what the public considers to be an effective user interface, as well as why they prefer different elements.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous. If interested, a copy of our results can be provided at the conclusion of the study.

UI Recommendations

1. What video games have you played that you would say had a simple and effective user interface?
    a. Anything unique about them?
    b. What about them made them easy to use?
    c. What about them made them effective?
    d. How did they offer information in a clean way?
2. What phone or computer apps have you used that you would say were easy to use and effective?
    a. Anything unique about them?
    b. What about them made them easy to use?
    c. What about them made them effective?
    d. How did they convey information?
3. Do you have experience with augmented reality?
    a. What applications have you been exposed to with augmented reality?
    b. Did they have effective UIs?

Appendix F: Formative Evaluation Protocol (Wong, 2017)

How we conducted our formative evaluations:

1. **Established a list of recommendations.** In the context of UI development, formatives are a set of recommendations about how an effective UI should look and function. The chosen formatives allow evaluators to get a sense for what developers want in their UI.
2. **Selected our evaluators.** We selected the Simtable team as our evaluators, as they have significant UI experience and knowledge concerning the domain of our project.
3. **First evaluation phase.** Evaluators first interacted with the UI to get a feel for how it flowed by "clicking" on various buttons and going through the different "screens." We asked the evaluators to identify features of the UI they wanted to evaluate.
4. **Second evaluation phase.** The evaluators took the formatives we chose and applied them to the features they identified in the first phase. We asked the evaluators to analyze individual elements and how well they fit into the design as a whole.
5. **Recorded problems.** The evaluators recorded problems or inconsistencies they noticed while interacting with the UI. We asked the evaluators to use as much detail as possible.
6. **Debriefing session.** We asked the evaluators to collaborate and complete list of problems, then propose solutions for each problem. We asked the evaluators to refer back to our formatives, or the ideal qualities we wanted our UI to have.

Appendix G: Formative Evaluation Recommendations (Nielsen, 1995)

Recommendations from experts in the field on how a usable UI should look and function:

1. **Visibility of system status.** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. **Match between system and the real world.** The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. **User control and freedom.** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
4. **Consistency and standards.** Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. **Recognition rather than recall.** Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
6. **Flexibility and efficiency of use.** Accelerators — unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
7. **Aesthetic and minimalist design.** Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Appendix H: User Personas

Field Observer

Goals

- Report smoke/fire as quickly as possible while communicating efficiently with emergency response.

Location/Environment

- Areas with low/zero cellular connectivity

Needs, Wants, Requirements

I have to
- Create and communicate a summary of current events: fire hazard conditions, fire emergencies, updates of wildland firefighting activities
- Communicate with fire crews, dispatchers, other lookouts, and air attack.

I need to
- Record and report temp, wind speed and direction as well as other weather conditions
- Observe and fire and smoke behavior in my assigned area
- Have knowledge of weather systems and different fire behavior and characteristics

Pain Points

- Estimating fire distance and bearing is difficult and time consuming
- Having clear and coherent communications between different people is difficult

Possible Design Imperatives

- Finding exact distance between tower to fire
- Annotate imagery, drawing lines and marking out points of interest
- Georectify wildfire, obtain size of smoke column + perimeter
- Stream imagery of fire
- Offline recording capabilities

General User <30 Years

Goals

- Evacuate safely and inform family/friends of an emergency

Location/Environment

- Residential areas
- Near emergency area

Needs, Wants, Requirements

I need to

- Know if I am in a dangerous area or if the fire is close
- Know what to do and who to contact in an emergency situation

I want to

- Know the current location and movement of the fire
- Know if my family/neighbors are safe

I have to

- Know what stage of an evacuation I am currently in

Pain Points

- Learning new technologies is difficult
- I would be able to plan better for an evacuation if I had sufficient information
- I am not always able to figure out my location on a evacuation map

Possible Design Imperatives

- Real-time updates on emergency
- Easy to use, simple descriptions
- Minimal clicks, easy to navigate UI, can find all necessary features easily
- Be able to share my location and camera in real-time

VOST (Virtual Operations Support Team)

Goals

- Update firefighter/PIO with critical information garnered from social media

Location/Environment

- Fast internet access
- Offsite

Needs, Wants, Requirements

I have to
- Monitor, curate, and amplify social media content

I need to
- Select, organize, and present online content

I want to
- Lend support to those working onsite

Pain Points

- I find it difficult to find relevant photos taken in a certain area
- Filtering and scrolling through social media is a large timesink

Possible Design Imperatives

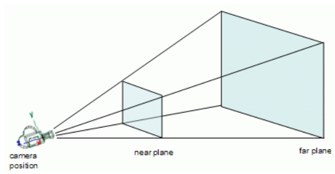
- Quickly determine the location of an image
- Share and spread information easily
- Find and see imagery of an incident from the internet
- Verifying incidents/calls

Appendix I: Evaluation 1 Feedback

Table 1: Problems Encountered in Evaluation 1

Features Evaluated	Problems Encountered	Severity Rating	Proposed Solution(s)	Visual of Changes
Buttons (in general)	Too many buttons; Buttons are annoying to press	7	Swipe between screens instead	
Record button	Red “REC” button in camera view could be awkward to press for someone holding a phone in their left hand	5	Move important buttons to the center of the screen	
Pixel Use	Blue bar at bottom of 2-D map view takes up too much space (wastes too many pixels)	6	Eliminate the blue bar	
Graphics	Location icon in 2-D map view and menu graphics are distracting	4	Make graphics and text as simple as possible	
Startup screen	Users will want to open LiveTexture and immediately start recording	9	Change startup screen to the camera view	
Blue/green user icons	Need more functionalities for when someone presses on another user’s icon	8	Single press brings you into the other user’s camera view; Long press gives you user information;	

Table 2: Suggested Functions to Add From Evaluation 1

Feedback	How to implement	Purpose of Change	Visual of Changes
When user one clicks on user two's icon in the map, user one can see what user two is seeing in their camera	User two is represented in the map by their camera "frustum," or field of view (see image below). When user one clicks on user two's camera frustum once, user one enters user two's camera view 	Allow users to see another user's actual field of view in the world, so they can easily understand the other user's point of view	
Users can scrub time on the map to see where other users' frustums move geographically	Press and hold on the map, then drag to scrub time and see where other users' cameras move	Allow users to see other user's views from the past so they can visually see how a certain view changed over time	
Users can scrub time to view fire progression	Drag left shows the user past fire perimeters, drag right shows the user future predictions	Make it easy for users to understand how to scrub time	
Allow users to see a list of live videos streaming in the area	Swipe up from bottom of screen to see live videos in the area	Allow users to easily see live videos organized into one place to get a sense for what is happening in the area at the time	
Indicate application of a filter	Indicate to the user that a filter is being applied with a visual icon (box displayed at the top that can be easily deleted)	Make the current status of the system visible to users	
Allow users to create groups with other users	Users can select specific people to create a group where they can share map information and be alerted if someone in the group takes a live video	Enable users to share information with specific people; Enable more complex levels of communication	

Offer more ways for users to share information on social platforms	Option to share maps and live camera views through text messages and emails as well as Twitter and Facebook	Expand the reach of data from LiveTexture to inform more people on social media platforms	
Users can add “layers” to a map, such as roads, elevation, or fire perimeters	Allow users to access a list of their layers, which they can share out to other groups	Give users control over what information is shared with who	
Users are defined by their name as well as their role (e.g. “field observer”)	Users define their “role” in their profile; Other users can search for people both by name and by role (most applicable to field observers)	Make it easier for users to search for and find other users	
Offer a “spectator mode”	Click on another user’s icon once and “fly in” to a 3rd-person, “off-the-shoulder” perspective; Double-click for first-person view; Press and hold for user info	In 3rd-person, allow users to see someone else’s camera view and the surrounding environment at the same time (as a spectator)	

Appendix J: Evaluation 2 Feedback

Table 3: Problems Encountered in Evaluation 2

Feature Evaluated	Problems	Severity Rating	Proposed Solution(s)	Visual of Changes
Fire icon	Cylinder-shaped icon to indicate fire location in camera view is a bit too general	5	Use a floating marker/icon above the fire	
User icons	Box that appears when you click on another user's icon in the map is too small and has too much text	6	Tap once to go into 3rd person view, tap twice to go into 1st person view, press and hold to see contact icon/access user info	
Overhead map view	Button in top right of map view (showing overhead view) is confusing	8	Replace with small PIP; show camera view in top right corner of map screen; easily switch between camera and map	
Record button	Confused why record button is on map screen	7	Maybe keep it, but show that you are recording in camera PIP	
Naming Conventions	Users have "networks" or "groups" but not friends	5	Same as feedback (just change wording)	
Icons	Differentiate between live and past views	4	One color icon for live views, another color icon for past views	

Annotating camera view	Allow users to add textual descriptions when annotating an image	7	Add text option to toolbar	
Evacuation Routes	Too much liability with giving people evacuation routes	8	Remove the function or transfer people to Google Maps	
Annotating camera view	No way for the user to confirm they are done annotating an image	5	Have "Done" button or check mark to complete annotations	
Button	Record button is too small and too low	5	Make record button bigger and move higher up	

Table 4: Suggested Functions to Add From Evaluation 2

General Feature	Feedback	How to implement	Purpose of Change	Visual of Changes
Annotating camera view	Liked how you can click and drag a line between 2 points on the screen to get distance between them	Have the line the user draws appear in 2D and 3D views	Any annotations the user makes should be consistent between the 2D and 3D worlds	
Onboarding	Authenticate a user by having them submit their phone number and verify through text message	User has to login to edit the map, but does not have to log in to simply view a map; submit phone number when they login, then enter code that was texted to them	Make sure the user is a real person	

User icons	Be able to click on someone’s icon (most likely will be their camera frustum) and look at their past public videos	Include option to see user’s past videos when click on icon	Allow users to build up a profile of past video content; allow other users to easily access that content	
Settings – Recording	Either always go live when I start recording OR wait until I am done recording to post my video	Same as feedback	Give users more options when recording; Some may always want to go live while others may not want to	
Social networking between users	Eventually be able to search for and subscribe to specific users to help make the software go viral	Recommendations for future	Make using LiveTexture more of a social experience for users	
Groups	Allow for users to designate group administrators when creating a group	If group is closed, it has an admin who is the only person who can add/remove users; If group is open, anyone can add anyone	Design information sharing like Google Drive; Allow users to define who can do what with the information they share	
Menu	Add “My Groups” button	Same as feedback – groups allow you to share certain map layers with specific people	Allow users to easily view their current groups and create new ones	
Map layer access	Restrict users’ access to certain layers	Require users to enter a code or password to view the layer	Restrict access to layers with confidential info.	
Map layer creation	Be able to create your own layers (such as identifying where you family’s houses are on	Add new layer, annotate the map, then save it to your layers → Recommendation	Allow users to create personalized maps with their	

	a map)		own layers of information so it is easier for them to understand	
Users	Make sure you know if someone is a verified user	Show official/verified symbol next to user's name	Allow users to see if another user is a legitimate person	
Notifications	User should be notified if: someone follows them, someone they are following goes live, or someone requests to annotate their imagery	Have pop up appear at the top of the screen; show notification in menu screen	Indicate changes in the status of the system clearly and visibly to users	
Annotating camera view	Only annotate imagery after the fact (after you took a picture or video)	Press and hold image after it was taken to have annotating tools appear; Include undo button	Difficult to annotate a camera view while you are taking a video	
Reporting	Bee able to report someone for posting bad/inappropriate content	Report button available when watching another user's live view	Keep track of and punish bad users to filter out irrelevant information	