Visualization and Communication Tool for Emergency Response

J. Gelernter
Gaithersburg, MD, USA
jgelern@andrew.cmu.edu

N. Maheshwari
IIIT Hyderabad
NBH 239, IIIT Hyderabad, Gachibowli,
Hyderabad, India - 500032

A. Sussman
Arlington, VA, USA
asuss262@gmail.com

***Abstract*—The current procedure for assessing emergency situational awareness in the USA requires Police, Paramedic and Fire First Responders to go on site. This observation is termed "size up". It is effective, but not efficient. Using advanced information and communication for size-up would save Responders time and allow them to begin actual response faster--possibly saving lives. The commercial software that exists for size-up is not in wide use. We have developed a software application called an Indoor-Outdoor Viewer for size-up for emergencies so that Responders can get information about the incident before they arrive at the site. It is an easy-to-use Viewer that shows building surroundings and their interiors, and allows Responders to mark the map to organize their approach. It will be compatible with real-time emergency data streams.**

Keywords*—emergency response software, pre-incident planning, size up, building visualization, preplan, crisis mapping*

I. INTRODUCTION

A. Problem and significance

First Responders spend time at the crisis locale to inspect and "size up" the situation, as mandated by NIMS (the National Incident Management System) of FEMA's Emergency Management Institute. The size-up data that Responders report they need is considerable [1], [2]. But the actual beginning of the on-scene response might be delayed by the preliminary collection, communication, and processing of information, when only seconds of delay can compromise victims' safety.

Many software applications for indoor preparedness do exist, but most of these require much preparation on the part of responders in order to use. Our talks with Responders suggest that size-up activities largely are performed manually.

Next generation emergency response tools, according to the Science and Technology Director of the U.S. Department of Homeland Security,[1] will provide situational awareness before Responders arrive on scene, saving vital time [3]. According to the Director's definition, our Viewer is a next generation tool.

B. What situational data do First Responders need?

Emergency tools require data to be entered for each situation specifically. A 2005 workshop, Information Needed by Emergency Responders during Building Emergencies [1], characterized this data as either static or real-time. Static information is already accessible to some U.S. Fire Fighters in the form of "pre-plans," which is how they refer to the not detailed indoor floor plans. Real-time information could include building sensor output such as elevator status, sprinkler activation, power and smoke control system status, or room temperature and video feeds [2].

C. Restrictions on obtaining that data

Commercial property owners wish to protect the safety of those who reside or use their buildings by not releasing building floor plans or sensor data. Consequently, some Fire Departments create floor plans of local buildings themselves.

D. Review of state-of-the-art emergency response software

Outdoor emergency response tools include ESRI's ArcGIS for Emergency Management,[2] the Next Generation Incident Command System (NICS),[3] the National Fire and Aviation Management Applications (FAM),[4] and the Android Tactical Assault toolkit (ATAK).[5] These operate outdoors using GPS coordinates and widely available geographic map data. Outdoor crisis maps can include locations from social media tweets (Project EPIC,[6] or Ushahidi[7]). The layering of weather and traffic data on an incident map has been demonstrated in research [4].

Others have solved technical problems that are relevant. Indoor localization is offered (Indoo.rs[8]). Other tools provide the ability to deliver dynamic alarms from buildings (Bryx911[9]), or see indoor floor plans (PreplanSource,[10] Intterra's Situation Analyst,[11] Rhodium Incident Management[12] and ESRI's Pre-Incident Plan Dashboard,[13] First Due Size Up,[14]

---

[1] Dan Cotter
[2] http://www.esri.com/software/arcgis/arcgis-for-emergency-management, Accessed September 23, 2018
[3] https://public.nics.ll.mit.edu/nicshelp/articles/frontpage.php, Accessed September 23, 2018
[4] https://fam.nwcg.gov/fam-web/, Accessed September 23, 2018
[5] https://web.archive.org/web/20150402141510/https://atakmap.com/, Accessed September 23, 2018
[6] http://epic.cs.colorado.edu/, Accessed September 23, 2018
[7] https://www.ushahidi.com/, Accessed September 23, 2018
[8] https://indoo.rs/, Accessed September 23, 2018
[9] https://play.google.com/store/apps/details?id=com.bryx.bryx911&hl=en, Accessed September 23, 2018
[10] http://www.preplansource.com/, Accessed September 23, 2018
[11] http://www.intterragroup.com/home, Accessed September 23, 2018
[12] http://irtsoftware.com/, Accessed September 23, 2018
[13] http://solutions.arcgis.com/local-government/help/pre-incident-plan-dashboard/, Accessed September 23, 2018
[14] http://firstduesizeup.com/, Accessed September 24, 2018

Fire Rescue,[15] Blazemaker[16], FireScene,[17] FireWorks[18], StreetWise[19], Extinguish[20], Firehouse software[21], PreIncident Plan Dashboard,[22] Ringstor[23], FireRescue Systems[24], Perillon Incident Management Database System[25], RedNMX[26]). Closest to ours is PrePlanView,[27] an incident drawing and communication tool, but it does not show building façade or streets surrounding the site. Aggregating static and dynamic information from a variety of sources, along with security and privacy, qualifies our tool as an Internet of Things application [5].

E. *Novelty of our software viewer*

Currently no single commercial software provides indoor-outdoor context with street maps, along with real-time information, as will our tool. Our primary concern was the size-up phase, so our tool provides for visual situational awareness of the site at the time of the emergency, as well as a communication platform for police, paramedics and firefighters. Additional concerns in developing the Indoor-Outdoor Viewer were:

- Usability (to be easy to learn and use)
- Extensibility (to allow for data scale up)
- Interoperability (to allow for real-time data streaming)

F. *Our contribution*

This paper discusses the research behind the development of our tool for First Responder 'size up' of an emergency. It describes how the tool provide situational awareness. It provides also a communication platform to be shared among paramedic, police and fire teams, where responders can mark victim locations or conditions of hydrant water, wall collapse or preferred exit to be used during an emergency.

G. *Remainder of the paper*

The § Method section describes how we determined data and functionality requirements for our Viewer. The § Results section shows how the Viewer works and explains what parts of the data assembly could be automated for large-scale use. The § Discussion section reviews early evaluations of the prototype, priority in the data assembly, and future work. Contributions are summarized in the § Conclusion.

II. METHOD

A. *First Responder requirements for data content*

We spoke with police, fire and paramedic representatives in our area, and consulted a survey of First Responder information needs from [2]. The survey found that 94.5% of First Responders wanted building layouts, and 80.3% wanted 3D models of a building for emergencies of fire. Our model meets these requirements by showing the exterior of the building in 3D as well as the interior layout (also known as a pre-plan). Our model is a mashup that uses a base-map terrain, a 3D volume model, photographs of the exterior, and floor plans to show interior walls.[28]

The First Responder needs survey found also that 76.6% wanted positioning information, and 50% wanted elevator, power and lighting information from smart building [2]. For this reason, we plan to add this information later to our Viewer data by constructing a platform that allows sensor data to be interoperable with the building structure. Different levels of data verification then will be required, depending on the data source. Other First Responder interviews have been conducted specifically for the emergency of fire.

B. *First Responder requirements for functionality*

The Incident Commander and Responders on the team will be able to use the software to consult the site from the office or on the way to the scene. Viewer functions should continue to be upgraded based on when and how the Viewer is being used.

C. *Requirements for interoperability*

Our Indoor-Outdoor Viewer for Emergency Response now contains only data that is static. We could require the structural data to be in BIM format so that sensor data will be interoperable. The difference between any 3D geometric representation and a BIM is that the BIM contains potentially much more building information, such as electrical systems and HVAC equipment.

BIM files are used widely in the USA to design buildings and physical infrastructures.[29] BIM is a good choice therefore because (1) many building files will be available in BIM because it is a common format; (2) it is flexible enough to support indoor navigation [7]; and (3) it is predicted to become mainstream as the interface to show information for smart buildings [8].

---

[15] https://www.firerescue1.com/fire-products/fire-apparatus/incident-planning-software/all-products/, Accessed September 24, 2018
[16] https://www.fireplanningassociates.com/blazemark-overview/, Accessed September 24, 2018
[17] https://www.smartdraw.com/evacuation-plan/fire-scene-software.htm, Accessed September 24, 2018
[18] https://eprfireworks.com/uncategorized/pre-plan-module/, Accessed September 24, 2018
[19] http://www.streetwisecadlink.com/features/full_mdt/, Accessed September 24, 2018
[20] https://extinguishapp.com/, Accessed September 24, 2018
[21] https://www.firehousesoftware.com/products/fh-mobile/response/, Accessed September 24, 2018
[22] https://solutions.arcgis.com/local-government/help/pre-incident-plan-dashboard/, Accessed September 24, 2018
[23] http://ringstor.com/solution/, Accessed September 24, 2018
[24] https://www.firerescuesystems.com/, Accessed September 24, 2018
[25] http://www.perillon.com/, Accessed September 24, 2018
[26] http://www.alpinesoftware.com/features, Accessed September 24, 2018
[27] http://viewpointcommandsystems.com/preplanview.html, Accessed September 24, 2018
[28] The base map is Bing Aerial Imagery (from the NASA WorldWind platform), files for building footprint are downloaded from OpenStreetMap.org and extruded from 2D to 3D, the photographs are part of Google Street View, and the floor plans are courtesy of the building owner.
[29] BIM is supported by the AutoDesk company that makes AutoCAD and Revit software.

Note that conversion between any 2D or 3D floor plan and BIM presently cannot be fully automated; manual intervention is required. The large-scale version of this system might require a person working full time on data verification and also data conversion. Our Viewer can be modified by developers so that it can interface with their reporting and documentation software.

III. Results

A. *Prototype software viewer*

Examine a web-enabled version of our software without full functionality[30]. This version lacks the data upload interface and the ability to write on maps. It is not compatible with Internet Explorer and it works best with Chrome. To use the Viewer, Responders would enter building street address in the search box at top (Fig. 1). Hitting the "Search" (Fig. 1) zooms the globe to that location, and that building at the location. The building centers on the screen of a desktop or mobile device.

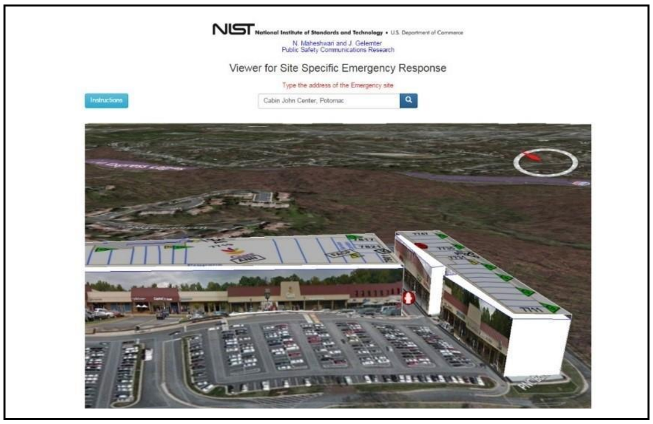

Figure 1: Screen shot of Indoor-Outdoor Viewer for Emergency Response, showing Cabin John Mall, Potomac, MD, with permission from Carl M. Freeman Companies.

We have designed a web or cloud application, rather than client-based. It has only a few controls so they will feel familiar to users, and little training should be necessary. We consider this an improvement over the assumption of the Federal Emergency Management Agency (FEMA)'s 2016 Core Competencies for Emergency Management. This document states that Responders should be able to understand complex systems (p.5).[31] But volunteer turnover may be high so that new people arrive routinely, and the stress emergency atmosphere wants balance from tools that need lower cognitive load.

B. *How First Responders will use the viewer*

The Viewer's primary purpose is incident pre-planning. In the event of an emergency, it can be used remotely as well as at the emergency site. Eventually it will collect sensor data about the incident and provide that data both to Commanders in Emergency Offices and Responders en route, or at the site. Additional data will be able to be added by Responders at their convenience, or in real-time at the site.

The Viewer is simple to use because it includes only basic capabilities for end users such as:

- Panning, zooming and tilting, and the ability to look at any building face
- Ability to mark locations on the outside or inside of a building to share with other Responders

Those in authority will need to mark the location of on-going operations on the map. For example, these might be staging areas, preferred exits, and victim locations. We have added the ability to mark the screen so that the Incident Commander's decisions can be shared.

To envision how the Indoor-Outdoor Viewer could be used in an emergency, we have created a demo showing software with simulated data[32]. The demo runs in time sequence showing an incident in the eastern United States. First, smoke sensors, and then fire alarms go off in a strip mall supermarket. It shows how the Incident Commander (here, Fire Chief Smith) can communicate with others about which entrance to use. Then it shows which emergency vehicles arrive at the site and where they stop. Finally, pictured is responder movement outside and then inside the building.

C. *Current content, and potential to automate content*

1) Building name: Department of Transportation plans for a national database of building addresses in the USA are on-going[33]. Building names and addresses, and geolocations should be linked to the floor plan, footprint and other building content so that a site and its surrounding could be downloaded easily in an emergency. The building metadata might include contact information for the owner or manager of the property. That way, owners might input additional safety information such as building construction type, whether hazardous materials are stored there, hours of full occupancy, or whether young, elderly or handicapped folks use the premises regularly. Locations of Knox box, FDC hookup, gas shut off, fire alarm control panel, and other specifics could be marked on the building map. Eventually, this data should link to dynamic data from the emergency such as photo and video or tactical location marks on the map by members of the Responder team.

2) Indoor map: A random indoor map in a collection will have different levels of detail. One way to get map consistency would be to determine the minimum level of detail required and strip the more detailed plans of extra information. The indoor maps could be stored in a cloud database and downloaded as needed, if building owners did not wish Emergency Services to have continual access. Security concerns are significant. The security infrastructure

---

[30] https://mig.nist.gov/sser, Accessed September 25, 2018

[31] https://training.fema.gov/hiedu/docs/emcompetencies/ngcc%20final%20competencies%204-28-2016.pdf, Accessed September 23, 2018

[32] http://lsi.iiit.ac.in/nishith/Cesium/, Accessed September 25, 2018

[33] https://www.transportation.gov/nad, Accessed September 23, 2018

required for the data, however, is outside the scope of this paper.

3) Building footprints and structures: OpenStreetMap includes 2D footprints for about 30.5 million buildings across the United States, and Microsoft Bing has added about 124.5 million to that by using neural networks and other algorithms to create footprints from Bing imagery.[34] Additional data might be assembled from state geospatial portals.[35]

Fashioning a building's exterior in 3D could be done automatically by extruding the 2D footprint, given building height information and number of floors. (Height is sometimes included in the OpenStreetMap data, and sometimes in geospatial portals for the U.S. states.) Then the 2D footprint could be aligned on the 3D globe automatically by mapping coordinates in the file to coordinates on the globe.

4) Building façades: Our prototype uses photos from Google Street View. Copyright precludes any large-scale download of building façades. For façade pictures, we provide First Responders with a data upload interface that specifies photo upload format, although building owners could add this too if they wanted. Heading can be captured in higher end cameras by attaching GPS to a camera mount. The photo should specify which side of the building is pictured so that it could upload correctly. We could reduce number of pixels-per-inch of these photos to speed up the rendering on the prototype if assembly times are too slow. We intend for these photos to be stored in the indoor map database along with the floor plans.[36]

5) Real-time data streams: On-site photo and video might be taken by Emergency Responders. Alternatively, video might come from surveillance cameras inset on a First Responder vehicle or worn by the Responder during an operation. Either way, the data could be added as soon as it is obtained. Most photos and videos taken outdoors will have location coordinates attached; what is taken indoors needs to have the responder include the room location. Photo and video likely will be shown to the side of the screen, rather than overlaid on the image.

Future plans might include adding bystander photo, video or tweets found automatically by keyword sent from the building's immediate vicinity. Additional verification would be needed for data contributed from bystanders. Other information streams will come from facilities control systems and sensors. Responders need air temperature in a building, and elevator and water (hydrant status). Police want to know the location of the Fire and Paramedic teams, for example, and they will mark tactical data such as location of a preferred exit or trapped victim.

IV. Discussion

Early evaluations of prototype. We showed initial versions of the prototype to Emergency Commanders in our area. A comment from a Fire Chief, February 1, 2017 was that "[t]he Fire Service is starving for this kind of stuff." He asked us whether he might share our early version with some of his colleagues to get their feedback, too. A comment from a Police Chief, December 22, 2016 was "[T]his definitely would help. No doubt about that. ... A basic tenet of SWAT is 'why go into a room if you don't have to'. To know how a room is configured is jumping over a mountain. [This prototype could make the job] a whole lot safer for police and help them catch people faster."

Priorities in data collection include buildings representing high-population sites such as malls, airports, stadiums and campuses. Also, collection should include public buildings with gatherings of the weak, such as elementary schools, hospitals and senior care facilities. Eventually, the Viewer would be usable widely if we were to assemble a database of indoor maps of buildings throughout the country, to complement the façade photographs, and building footprints.

Future work on a large-scale version of the software would be more efficient if there were a national database of indoor maps. These maps could be encrypted for added security. The maps could be downloaded easily when needed by Emergency Responders. The capability of layering sensor data on the map should be added, and that data should be sent over a secure connection.

V. Conclusion

Our Indoor-Outdoor Viewer is a visualization and communication software that supplements–and may one day substitute for–First Responder on-site observation. It allows indoors and outdoors to be viewed simultaneously on a desktop or mobile device, and it will allow data streams to be layered above static building maps. It has few controls with the aim of keeping training minimal, and remaining easy to use in conditions of high stress. Local Responders' initial comments about our prototype software have been enthusiastic. Future development will allow for compatibility with real time sensor data from building emergency control systems, and locations of Responder vehicles around the site. We will add a data-upload platform to allow Responders to update building names or add façade photos.

Acknowledgment

Part of this research was funded by the National Institute of Standards and Technology (NIST) Public Safety Communications Research (PSCR). This funding body had no

[34] https://blogs.bing.com/maps/2018-06/microsoft-releases-125-million-building-footprints-in-the-us-as-open-data/ Accessed September 23, 2018

[35] Here is the geoportal for the state of Maryland, for example https://imap.maryland.gov/Pages/data.aspx, Accessed September 23, 2018

[36] Alternative to using 3D files for volume and photos for building exterior would be to use LiDAR data. However, only LiDAR that is high resolution would be useful for our single-building use, and the oblique photographs necessary to realize a 3D shape from the LiDAR data points are not widely available.

role in the study design, or in the collection, analysis or interpretation of the data, or the writing of the manuscript.

REFERENCES

[1] Jones, W.W., Holmberg, D.G., Davis, W.D., Evans, D.D., Bushby, S.T., Reed, K.A., (2005). “Workshop to Define Information Needed by Emergency Responders during Building Emergencies,” *NIST IR 7193*, January, 2005. http://fire.nist.gov/bfrlpubs/fire05/art017.html

[2] Li, N., Becerik-Gerber, B., Krishnamachari, B., Soibelman, L., (2014). “A BIM centered indoor localization algorithm to support building fire emergency response operations,” *Automation in Construction 42,* pp. 78-89.

[3] Cotter, Dan (2016). “Enabling operational innovation and building resilience,” *National Geospatial Preparedness Summit*, Slide talk, September 14, 2016.

[4] Kuhnert, M., Wietfeld, C., Paterour, O., Georgiev, A., Petersen, K., Büscher, M., Pottebaum, J. (2015). “Next Generation, Secure Cloud-based Pan-European Information System for Enhanced Disaster Awareness,” *Proceedings of the ISCRAM Conference - Kristiansand, Norway, May 24-27, 2015* [8 pp]

[5] Balfour, R. E. (2015). “Building the Internet of Everything (IoE) for first responders,” *IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE), 1 May, 2015, Farmingdale, NY, 2015 Long Island Systems, Applications and Technology.*

[6] Nunavath, V., Prinz, A., Comes, T. (2016). “Identifying First Responder Needs: Supporting Search and Rescue Operations for Fire Emergency Response,” *International Journal of Information Systems for Crisis Response and Management (IJISCRAM) 8*(1), 22 p.

[7] Isikdag, U., and Zlatanova, S., Underwood, J. (2013). “A BIM-Oriented Model for Supporting Indoor Navigation Requirements,” *Computers Environment and Urban Systems* 41, pp 112-123.

[8] Zhang, J., Seet, B-C., and Lie, T.T. (2015). “Building Information Modelling for Smart Built Environments,” *Buildings 5 (1),* 100-115.