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Augmented Reality Farm MAPPER Development: Lessons Learned from an App Designed to Improve Rural Emergency Response

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ABSTRACT
Fire departments have right-of-entry to most commercial industrial sites and preemptively map them to identify the onsite resources and hazards they need to promptly and safely respond to an emergency event. This is not the case for private farms. Emergency responders are blind to resources and hazards prior to arrival and must spend critical minutes locating them during an emergency response at a farm location. The original 2013 Farm Mapping to Assist, Protect and Prepare Emergency Responders (Farm MAPPER) project was undertaken to develop a method to give emergency responders an up-to-date view of on-farm hazard information to safely and efficiently conduct emergency response activities on private agricultural operations. In 2017, an augmented reality version of Farm MAPPER was developed to combine the technological advantages of geographic information system-based data points with a heads-up display and graphical overlay of superimposed hazard imagery and informative icons. The development and testing of this iOS- and Android-ready prototype uncovered lessons learned applicable to other mobile-based apps targeting farmers, ranchers, and rural populations faced with limited or inconsistent mobile internet connectivity.

KEYWORDS
Augmented reality; emergency responders; farm safety; fire department agriculture; geographic information systems; GIS; hazards; injury; mapping; trauma

Introduction

Farming continues to be one of the most dangerous occupations in the US, resulting in an unfortunately frequent convergence of emergency responders with farmers, ranchers, workers, children, and visitors. Despite representing a relatively small population in the US, agricultural, fishing, and forestry workers endure more work-related fatalities than all other industries except transportation.[1]

Through farm consolidation, the number of US farms has declined in recent decades, while production has actually increased.[2] Farm consolidation has also created new risks. As farming practices continue to evolve – minimizing inefficiencies and maximizing profits – more operations are physically larger and often non-contiguous. These changes imply using public roadways to move farm equipment to non-contiguous fields[3] and employing non-family workers. Additionally, a substantial number of farms are welcoming visitors onto their property to enjoy agritourism. There are approximately 2.2 million farms[4] and 30,165 fire departments in the US alone.[5] In one of the least regulated industries, farms are one of the most visited rural job sites by emergency responders. In most rural communities, a high percentage of responders are volunteers, often called by a pager or radio to respond to emergencies. The number and significance of calls to farms, compounded by the rurality and geographic distance from healthcare facilities, increase the pressure on emergency medical services (EMS) and first responders to act quickly and efficiently on every call. Having the proper equipment and the latest technology available can be critical in life-saving efforts, and knowing the layout of the scene prior to arrival improves the safety, efficiency, and efficacy of the response.

Importantly, the safety of responders is of prime concern during emergencies. Between

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1986 and 1998, there were at least six firefighters killed responding to farm fires involving silo storage facilities.[6] Like other types of emergency response and preparedness, preplanning is a crucial step in keeping responders safe. It is critical to possess knowledge of the location of hazards on the response site to safely and effectively combat barn and silo fires or react to other emergencies.[6] Unlike in other industries, emergency responders generally do not have right-of-entry to private farms to map them for future emergencies.[7] Thus, responders will often enter a farm scene not knowing hazards in the environment. This can increase health and safety risk for responders and patients alike.

The mapping of a farm for emergencies with the cooperation of individual farmers is not a new concept. Purdue University developed a Farm Security Mailbox approach to inform first responders of a hidden box which contains pertinent farm information, including a hand-drawn map.[8] In principal, the hidden box concept is sound and provides useful information. However, emergency responders greatly benefit by having this information prior to arrival, either in the station or en route. This provides more time to call for additional resources, prepare the first team on scene, and coordinate efforts to both address the initial emergency and mitigate and additional hazards.

Farm Mapping to Assist, Protect and Prepare Emergency Responders (Farm MAPPER) is an interactive, device-agnostic, web-based prototype that provides emergency responders information about hazards, resources, and physical layouts of agricultural operations (Figure 1).[9] Farm MAPPER displays map icons representing items important in emergency events such as fuel storage, access points, water sources, electrical shut-offs, etc. After the farmer or fire department representative drops icons onto their farm map, the information is accessible to emergency responders in the fire station, en route via smartphone/tablet or onsite by scanning quick response (QR) codes located on mailbox posts at participating locations.[9,10] Maps can also be printed in preparation for responses in areas with low cellular/internet coverage.

The original Farm MAPPER software was developed to address the unique needs of rural emergency responders during farm emergencies as described by Minor.[7] It was prototyped (Figure 1) and locally tested with fire departments and farmers in Wisconsin on several occasions (Figure 2). Acceptance was enthusiastic by both emergency responders and farmers, who found the mapping easy and expressed no reservations about placing data on maps that are password secured.[9]

Mock response testing also identified that accessing on-farm data once responders arrived on scene

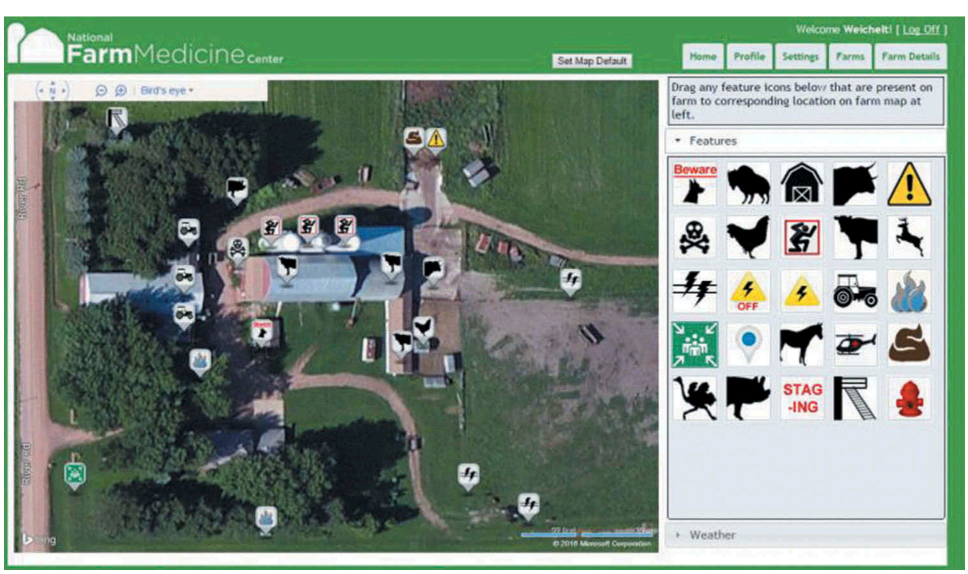


Figure 1. Farm MAPPER screenshot, Weichelt Farm.

Figure 2. Farm MAPPER testing with Pittsville FD in 2013.

was too late. When Farm MAPPER was first tested in 2013, emergency responders made the following request, "Give us the information before we leave the firehouse or get it to us en route."

The innovation of Farm MAPPER and its interest from media led to broad dissemination of the project. In 2013, the Farm MAPPER project was featured by the Associated Press and mentioned in the National Farm Medicine Center's (NFMC) annual "Year in Review" publication.[11]

> The center's top national story of 2013 was the Farm MAPPER pilot, which the Associated Press named its "Big Story" on May 24. The story featured farmers and firefighters in Pittsville, WI, successfully testing the Farm Center's online hazard mapping program. The story was carried by more than 200 media outlets nationwide including ABC News, Huffington Post, Yahoo News, Denver Post, Boston Herald, Seattle Post-Intelligencer, Bloomberg Businessweek, Brownfield Ag News and others.[11]

Upon Farm MAPPER's release in 2013, the NFMC recorded an estimated media circulation (unique visitors) of 120,012,138 and an estimated potential viewership of 158,744,950. The NFMC has also received requests for deployment of Farm MAPPER from emergency responder systems across the country and as far away as Sweden.[12] However, functional integration with dispatch systems and subsequent implementation into EMS operations is still limited.

Innovation

In a 2013 review article, Minor describes some of the challenges faced by rural first responders; however, there is no ready source of data that quantifies these challenges in terms of response time, responder injury, or property damage.[7] We have anecdotal evidence that rural emergency responders in Wisconsin and Illinois consider the lack of information about private farms an important problem that merits discussion and intervention. The innovation of the original Farm MAPPER is merely that the data collected for emergency responders is posted on a secure website that is available in real time. How this information is delivered to the first responders, either by direct access or a device like a QR code posted at the farm, will depend on the technological sophistication of the fire district.

The MAPPER project has also led to many discussions with stakeholders interested in wider adoption, including a 2016 partnership with Penn State's Farm/Agriculture/Rural Management – Hazard Analysis Tool (FARM-HAT),[13] which began a development process to bring the two systems (MAPPER and FARM-HAT) together under one modularized suite. The first module of the suite (a prototype of FARM-HAT) is now housed at SaferFarm.org and provides a fresh approach to on-farm safety audits and new feature enhancements that were otherwise unavailable in previous paper-based systems such as farm and audit history, hazard scoring, and mobile-friendly touch-screen drag and drop hazard mapping.[14] Other program features will soon include photo capture and comparisons, weighted scoring and calculations, historic data storage of all system interactions, and custom reporting for different user levels (farm, organization, researcher, and system administrator).[15]

Despite the frequent adoption of cutting-edge technology in agriculture, those that promote health and safety have lagged behind. A literature review discovered few studies leveraging informatics-based approaches, specifically augmented reality (AR) or virtual reality (VR) in a farm safety environment, and none with rural firefighters and emergency responders. This next-generation pilot project incorporates AR into the existing Farm MAPPER graphical user interface, making it a truly mobile app (Figure 3). It is anticipated that media exposure featuring the AR version of Farm MAPPER (MAPPER:AR) will create new opportunities to further disseminate the program as well as discuss other farm safety topics with a national audience, creating new lines of communication with farmers and their influencers described within Lee and colleagues' socio-ecological model[16] firefighters being among them.[17]

Introducing AR

Like that seen in the global sensation Pokémon Go, AR creates a visual mix of real-world and digital images.[18] First introduced to the technology market with the adoption of smartphones and their on-board cameras, AR use has expanded. AR's applicability spans across multiple uses and industries including construction and damage assessment, surgical procedures, child pedestrian safety, transportation, and macular degeneration and health interventions.[19–23] This rate of growth is expected to grow substantially,[24] and Salesforce already identifies AR developers as being among the highest-paid tech specializations.[25]

With Farm MAPPER, AR technology provides a means to superimpose hazard locations (virtual data) on a visual display of farm data in real time (Figure 4). Using a smart phone or tablet, Farm MAPPER was previously viewed as a static overhead view of the farm with icons indicating the locations of hazards, needed resources, farm entry point resources, etc. The integration of AR creates the opportunity to present both a real-time depiction of icons superimposed on a real vision of the farm location as well as the previously used bird's-eye view of the farm. The added information made available through an AR depiction and the heads-up orientation may offer substantial advantages and is the research question to be addressed by future projects. AR as a viewing technology to Farm MAPPER will potentially speed emergency response and improve

Figure 3. Farmer field test.

Figure 4. Early conceptual mockup of the MAPPER:AR application.

responder safety and efficiency. We expect the marriage of MAPPER and AR will reduce responder injury, expedite victim rescue, and enhance structure protection.

Markerless AR

Traditionally, integrating AR into applications (apps) is done via Marker identification.[26] This technology utilizes image recognition algorithms to detect uniquely identifiable graphics, like QR Codes, from the camera's display to overlay digital content onto the screen in real time. This type of AR has been popularized by many products including the Nintendo 3DS,[27] and is most effective for close-range to room-scale AR.

As mobile devices have become increasingly powerful with additional sensors, high-resolution cameras, and related technologies, a more adaptable form of AR known as Markerless tracking has emerged. This type of AR uses more sophisticated device capabilities and sensors to compute, track, and superimpose digital content based on the user's natural environment, landmarks, and device orientation. Markerless AR apps have grown popular in many sectors of the app industry. Such technology appears within design products, business and content products, facial communication systems, and many others.[27] The MAPPER:AR prototype required the use of Markerless AR since it is based on GPS coordinates in evolving locations and at greater distances and unpredictable environments than what marker-based AR could support.

Location-based AR

A growing subcategory of Markerless AR is location-based AR.[26] In addition to using the device's many integrated sensors to calculate the device's orientation in 3D space and other characteristics, location-based AR mixes markerless AR capabilities with global positioning system (GPS) data, presenting custom content around the user's current physical location. Two largely popular apps that utilize location-based AR include Yelp! and Pokemon GO.[18,28] Such technology enables MAPPER:AR to utilize markerless AR applications over large, complicated physical spaces with common features that can be geo located, i.e., the buildings, storage areas, electrical shutoffs, and water resources available on a farm.

Device requirements of location-based AR tracking

Developing a location-based AR system can be a complex initiative that requires collective synergy between a multitude of device sensors and hardware features. Thankfully, the most popular brands of smartphones developed in recent years all provide the necessary components to develop such applications.

Methods

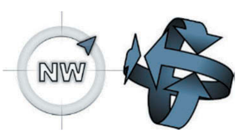
The overall goal of this pilot project was to improve the preexisting Farm MAPPER platform and its usefulness, and further disseminate the tool to farmers and first responders. We integrated AR features that utilize onboard smartphone/tablet hardware and software such as the camera and GPS (see Table 1). Beginning with initial conceptual designs and wireframes, the team established a technical framework, integrated icon drag-and-drop placement functionality (based on existing geospatial data), and periodically reviewed progress with project advisers.

Due to current technology limitations of web browsers and plug-ins, it was anticipated that development as a web-based platform was not feasible for AR at the time. Thus, we proceeded with Android and iOS, to create a native mobile application, downloadable via their respective app stores. Furthermore, given the impromptu emergence and popularization of location-based AR, ushered in by a new wave of smartphone capabilities, a lot of relatively uncharted territory still persisted throughout this project's lifecycle. With limited data to base projections on, it was not feasible to construct finite timelines or absolutes at the project start.

Results/lessons learned

he development of this prototype was a novel undertaking that demanded significant investment into newly available technologies that have not yet been

Table 1. Components of the application.

Camera Rear-Facing	The device's physical camera acts as the eyes of the user for their augmented reality experience. By delivering a live feed of the rear-facing camera to the screen, users are able to "see through" their phone to the other side.	
Sensors Magnetometer Accelerometer Gyroscope	In order to overlay digital content onto the camera display in a proper arrangement, the app must continually assess the specific orientation of the device in the user's hands. To obtain the precise device characteristics, sensor data from the magnetometer (compass), accelerometer (acceleration), and gyroscope (rotation) have to be calculated and computed each frame.	
GPS Latitude Longitude (Location Data)	The app's intent and purpose is to overlay location-specific data derived from the user's current world location in connection with item locations from a database. Using the device's GPS hardware, it becomes possible to pinpoint – with relative accuracy – the location of the device using latitude and longitude coordinates. This location data can then be compared with the item marker data (latitude/longitude).	
Maps Aerial View	Although not directly related to the AR view and functionality, the existing Farm MAPPER application uses aerial mapping technology to display markers of interest within an area. By supplying this data in two formats, we can offer a choice to the user so they can see at-a-glance where important items are and switch to AR view for real-time discovery.	
Database Users/ Locations	A database needs to store, query, and retrieve data about particular locations.	App query ↔ DB → App Results

tested in our field. Access to a diverse network of agricultural safety and health peers was critical throughout this process. This network produced important development feedback as well as intellectual and financial support. However, even with a well-developed network of peers, the initial acquisition of programming expertise was difficult to solidify, extending the project start by nearly 6 months. These same networks will also be critical for the further refinement and dissemination of the final products. The following sections detail the phased developmental approach of this project and the lessons learned that are applicable to other organizations' future adoption of AR and related mobile-based technology for agricultural health and safety applications.

Phase 1: conceptual exploration and experimental mockup

The most time-intensive and sophisticated part of this app project was related to the location-based AR functionality. To effectively gauge and evaluate potential solutions while building out the tentative groundwork for the eventual product, these preliminary initiatives were undertaken with consideration of the previously described requirements. These topics were researched early in the project and experimented with to weigh the feasibility and value of each in relation to creating a functional prototype within budget and scope:

- Concepts using both native and hybrid app development methodologies;
- Concepts using third-party frameworks to assist with the base legwork for AR;
- Concepts using various non-framework AR snippets and partial implementations;
- Concepts using custom AR implementations via white paper data.

Native and hybrid methods

Developing applications natively for both iOS and Android requires the use of entirely different programming languages, development tools, and deployment tactics. Apple's iOS uses Objective C or Swift programming languages, Xcode development environment, and a Mac computer. Google's Android uses Java, Android Studio, and a Mac or PC. Overtime, an assortment of cross-platform development tools surfaced. Such products typically allow development of a single "universal" application using a common programming language (e.g., JavaScript, C#, or C++). Modern hybrid apps also include extensions and the ability to tie into native device features and functionality for added features and performance.

Third-party frameworks

Integrating an accurate, location-based AR system comes with great complexity that cannot be overstated. It requires meticulous utilization of almost every one of the device's sensors alongside GPS, advanced mathematical computations, and a dynamic digital and real-world overlay system, all while retaining performance and responsiveness. A number of AR frameworks exist that can assist with basic AR capabilities without having to invest a substantial amount of time and effort redeveloping such features from scratch. Unfortunately, the majority of freely available frameworks still rely upon marker identification techniques, rather than markerless location-based AR needed for this project. Furthermore, many of the frameworks are severely outdated, discontinued, or only available for one platform.

Non-framework AR snippets

While reviewing and testing existing source code others had made available online for base AR handling, there was little evidentiary value available especially given the requirement of compatibility with both Android and iOS. The majority of repositories online were either outdated by 2–4 years or only offered for one platform or the other (e.g., OpenCV-Markerless-AR, HDAugmentedReality, or ARKit-CoreLocation). Had the focus been to only develop an iOS app, then some of these existing code bases could have been embraced more readily. However, it was not possible to port any of them over or update them for shared functionality on both platforms within the allocated time and with respect to the completion of the other components of the app in a timely manner.

AR implementations and white paper data

Referencing and reviewing recent publications, including whitepapers, the raw math formulas and calculations required to map digital content within the real-camera view based on the device's gyroscope, compass, GPS position, and other sensors were considered. This was necessary for a from-scratch approach to the AR aspect. As expected, the required mathematics to do this properly is quite complex, tying together many equations and variables ranging from the Harvensine formula for calculating the great circle distance of two points on Earth to much more sophisticated requirements for correctly positioning 3D elements within the real world, as broadly summarized by Comport and colleagues.[Cite] Instead of trying to reinvent a manual implementation of these formulas into a new system for two separate platforms, it was more practical to embrace a third-party cross-platform framework that had already invested many thousands of hours across years of time to create an optimal solution for calculating and displaying points in 3D space from the user's position.

Phase 2: formal app groundbreaking and AR implementation

The most suitable approach to location-based AR, as determined during phase 1, was integrated into the actual app. In short, the timeline of the project, requirements for multi-platform functionality, and budget were prominent factors in electing the hybrid app approach, utilizing an existing third-party framework to simplify base AR. Additionally during this phase, refinements and expansions continued, and preliminary design work on the main interface and overlay began. Dummy location data and points of interest allowed for basic app interactions prior to database integration. During this phase, we also completed reviews, updates, and testing of all libraries and packages to the latest versions.

Phase 3: aerial map view and database synchronization

During this third phase, improvements and additions continued with the user interface, feature set, and AR capabilities, while shifting more focus toward integration of an overhead map view along with database querying capabilities (in unison with the existing Farm MAPPER web application). We found that after continued evaluation of each overhead map application programming interface (API), ArcGIS (a geographic information system) performed better than Google Maps for several reasons. First, ArcGIS had made great strides in mobile usability in recent updates and performed quite similarly to Google Maps when implemented. It also had a more straightforward integration approach than we experienced with the native Google Maps components in conjunction with the rest of the app. Finally, and most importantly, we compared and analyzed the satellite imagery and ArcGIS pulls data from many more sources than Google/Bing (including local county map records, DigitalGlobe, Microsoft, CNES, etc.). For example, ArcGIS was the only source that had been updated within the past 6–12 months to reflect a new metal roof on a neighboring house and a distant farm (see Figure 5), while Google and Microsoft maps generally featured satellite imagery that was at least a couple years outdated. After further exploring integration and usability, we moved toward the ArcGIS implementation for the overhead maps section.

Phase 4: final feature integration and prototype completion

Finalization steps commenced in this phase included additional graphical user interface options and other feature capabilities. This process also included building production versions and deploying to numerous devices. This culmination phase unveiled useful software, hardware, and geographical location findings applicable to future research and development projects.

Figure 5. Google vs. ArcGIS comparison imagery.

Hardware considerations

Modern smartphones have greatly advanced in the accuracy of their integrated GPS sensors, especially with the advent of Assisted GPS (A-GPS), which pulls in data from traditional satellites as well as cell towers to improve location accuracy. Even so, the precision is still generally limited to 5–15 m (16–50 ft) of accuracy both vertically (altitude) and horizontally (latitude/longitude), with altitude accuracy being even more unpredictable in most of our field tests. Standalone Bluetooth GPS systems could potentially improve the accuracy to ±2.5–3 m, but these come with their own compatibility concerns when attempting to interface for cross-platform apps and frameworks (i.e., only a few are MFi/Apple certified and many would require proprietary coding to directly tap into the raw data). Costs of external GPS systems range from $100 to $7000 USD, depending on accuracy, although few under $600 would consistently provide much greater accuracy than the default built into modern smartphones.

Geographic location considerations

Since the app depends on standard latitude and longitude coordinates to both track the user's location and plot markers in 3D space, when the GPS signal is hindered, so is the accuracy of tracking specific locations in space in relation to the user's perceived current location. In rural areas where cellular towers are scarce and/or GPS satellites are obstructed by covered paths and other natural barriers, the GPS accuracy can readily dip to 30 m (100 ft) or less. This means that the coordinates specified for a particular marker may appear in the AR view at distances of ±100 ft from the true location, depending on how accurate the user's current location is reported. Likewise, relying on GPS for AR systems when indoors or among overreaching structures is fully unstable, and using WiFi location as a fallback (where available) can easily have variance of 90+ m.

Software considerations

Developing AR solutions based on the user's real-world location requires tying together many different aspects of the mobile operating system and available APIs. This includes interfacing with the device's camera, network connection and GPS data, magnetometer, accelerometer, and gyroscope. All the data work together using sophisticated mathematics and algorithms to plot virtual markers in relation to how the user is currently holding their phone and where they are standing compared to previously defined GPS markers. To accommodate cross-platform compatibility (Android and iOS) and save many thousands of development hours, existing third-party solutions were evaluated to assist with this project. The longest standing and most accurate for location-based, markerless AR in our testing proved to be Wikitude, which readily handles the AR computations and integrates well with other cross-platform development libraries. The majority of AR foundations are still based on marker-based AR (e.g., tracking QR codes or similar images to display virtual content).

Limitations

These types of systems and the images presented via heads-up display are dependent on the date/time that the satellite image was captured, e.g., an older satellite image may not depict a newly built or remodeled structure, something that can be common on farms. Furthermore, some MAPPER:AR features have been simplified in part for user experience reasons and also to work around current technical limitations of the hardware/software. For example, preliminary field tests found that altitude/vertical GPS accuracy is still poor on smartphones, with common variances of 20–40+ feet reported, so it was more sensible to just have all AR icons on an even plane to focus more directly on representing the approximate horizontal location of each item on the property. The feedback and lessons learned herein are specific to the technical development of the application (from the programmer/development team) and do not include qualitative data from usability testing with targeted users groups. Formal usability testing will likely unveil other limitations not yet considered.

Beyond development and testing phases, barriers to adoption and operationalized implementation may also arise. One of the greatest impediments to rural adoption will be the availability of sufficient data networks. However, we believe this problem will continue to diminish overtime as rural areas advance in technological sophistication, driven by public and private sector commitments.[29–31]

Discussion

We believe, based on the press coverage and generally positive reception we have received to the original 2013 Farm MAPPER concept, this new app responds to a widely recognized need by rural emergency responders and has potential to be a product with national dissemination and use.[32,33] The functionality added to the original Farm-MAPPER application is anticipated to augment future studies and user interest in emerging mobile technologies across agricultural health and safety.

For example, an advisor of this project will utilize the Farm MAPPER system in the Upper Midwest Agricultural Safety and Health (UMASH)-funded project that leverages rural firefighters as third-party safety auditors on farms.[34] In this translational project, rural firefighters will be trained to preplan and inspect farms using Farm MAPPER and an auditing tool available atwww.SaferFarm.org, a mobile friendly, web-based version of FARM-HAT.[13,14] To date, one group of 13 trainers, representing 7 fire departments in Wisconsin and Minnesota, have been trained to utilize and further disseminate the original Farm-MAPPER and SaferFarm.org technology. As a part of the field training, these first responders were also introduced to Farm MAPPER:AR. There was wide agreement that AR was an impressive and more engaging means of preplanning and responding to an agricultural emergency. The same technology was thought to hold great potential for the SaferFarm.org tool as well, implicating the future combining of the tools. An additional group of 10–15 responders will also be trained in 2018. It is expected that this network of rural emergency responders will be a primary target for dissemination. It should be noted that the insurance companies that insure these fire departments and farms are also supportive of the increased ability to preplan and respond to farm emergencies. This could be another route for dissemination, especially given their financial incentive to keep farms and firefighters undamaged.

Conclusion and implications for the future

The integration of another visual layer of technology may provide real-time, on-site, mixed reality information, supplementing Farm MAPPER's satellite imagery for emergency responders to potentially improve situational awareness, efficiency, and safety during the emergency response. The overhead maps (satellite imagery) remain important for planning and responding. However, the addition of AR gives incident commanders and responders real-time information during the response.

In addition to usability testing of the prototype, further research is needed to assess the application of this technology in the field of agricultural health and safety. It has been suggested that safety auditing tools could be more useful and attractive to users if AR technology was utilized. This software application and the linkage of AR technology to other field applications will be a major point of interest to the agricultural community and to safety stakeholders in the coming years.

Many advancements continue in the study of AR. Google recently announced a technology known as Visual Positioning Service to accurately support indoor GPS-like tracking, which itself is a side component of its more expansive Tango AR infrastructure and future vision.[35] Apple has likewise introduced its own ARKit framework for building AR apps for iOS devices, with their forthcoming line of iPhones set to more fully embrace such technology.[36] As cellular networks continue to expand and evolve, as well as the constant improvements to internal device hardware, many more mainstream applications for AR are anticipated in coming years. Specifically with regard to emergency responders, AR technology could be a key technology in developing real-time accountability for command units tracking their responders inside a structure or across complicated landscapes. One fire chief involved in this development said a technology that could track individuals as they worked through a multiple story, complex structure would be a "Holy Grail" of improved fire command ability. Farm MAPPER AR is improving the likelihood of that eventually being a reality for all responders, albeit specifically for agricultural environments.

With more efficiency than traditional interventions and structural displays, the dissemination of mobile-based technology, including AR, can be swiftly delivered to trainers and educators who can further leverage with in-person safety training and events (e.g., classroom instruction, farm shows, and expos). Initial discussions with high school agricultural educators and Future Farmers of America advisors strengthened our intuition that advanced technology may often be a better investment than a mobile training equipment/display. For example, an interactive AR/VR all-terrain vehicle simulator app could be more attractive to youth and significantly more efficient to disseminate via email to thousands of teachers versus one display unit that travels from expo to expo.

Additional resources will be necessary to fully develop and disseminate the app. We are currently working on several related projects that are helping us establish experience to compete for additional funding and develop networks for dissemination. In addition to the previously mentioned projects, other example is a USDOT-funded project we are working with at the University of Nebraska related to development of wearable systems to protect first responders in HAZMAT situations. Initial discussions with first responders in the Omaha area have identified additional potential funding sources as well as government sector agencies that are interested in disseminating this type of technology.

We further anticipate that this technology and its potential for future translational research will spark new discussions with state and federal officials. It is also anticipated that discussions will be pursued with regional and national EMS and fire organizations such as the International Association of Fire Chiefs, the National Volunteer Fire Council, and the National Fire Department Safety Officers Association. Other applications of this technology will surely surface in agricultural health and safety including uses in educational programming, youth tractor safety trainings, high school and college coursework, or the Progressive Agriculture Foundation's Safety Days®.[37]

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Institution and Ethics approval and informed consent

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