A Mobile Alerting Interface for Drone and Human Contraband Drops

Chunge Wang[1] and M.L. Cummings[2]
Humans and Autonomy Lab, 304 Research Drive, Durham, NC, 27708, USA

In order to utilize complex surveillance systems to detect human and UAV intruders on prison properties and increase Situational Awareness (SA), prison officials need a mobile interface. To this end, we developed a reactive mobile alerting interface (MAI) along with our Prison Reconnaissance Information System (PRIS), which aims to allow prison personnel with minimal training to be alerted, understand the most up-to-date detection intelligence about the intrusion situation from PRIS on MAI, and project the situation into the future. This low-cost system provides SA about possible intrusions that were not previously available with legacy systems and processes. A review session and field experiment that collected feedback from two correctional facilities in North Carolina received positive feedback and valuable suggestions for the future development of MAI.

I. Introduction

Prison contraband smuggling is a serious problem worldwide [1-3]. In these settings, there is high demand for phones, drugs, weapons, and alcohol [3], [11]. For a large correctional facility, intruders can easily take advantage of its surveillance blind spots and make contraband drops without being detected. The Bureau of Prisons has confiscated 5,116 smuggled cellphones in 2016 alone, and this number increased by 28% in 2017 [2]. There were "a dozen attempts" of UAV smuggling on Federal Prisons from 2012-2017, besides those on state facilities [3]. One common way is that smugglers throw packages of contraband over the prison fence at night, which will be picked up and delivered to inmates by other prisoners or corrupt prison guards who have received information about the whereabouts of the package through various means [4-6].

Meanwhile, the proliferation of affordable recreational unmanned aerial vehicles (UAVs) on the market is exacerbating the situation. Smugglers across the globe have recently begun attaching packages of contraband goods to UAVs and airdropping them into prisons [7-9], [12]. Because drone technology is constantly improving, incidents of UAV smuggling have increased significantly, and intercepting UAV smugglers has become more difficult. Small UAVs can be controlled from far away and are speedy, making them especially difficult to detect. Insiders may use mobile phones to tell smugglers when and where to fly the UAVs to airdrop the packages. Then they fly packages from adjacent fields repeatedly until all packages containing illicit items are delivered [10].

With the recent adoption of UAV smuggling, intruder detection has become a more complex task and created a higher demand for prison officials' Situational Awareness (SA) in deterring smugglers before the contraband goods are delivered. SA is one's comprehension of events in an environment in regard to time and space. There are three levels of SA. The first level is accurately perceiving the situation. The second level is understanding the key elements and events within the situation. The third level is projecting the situation into the future and predicting how the situation will unfold [13].

Prison officials can potentially use a comprehensive intruder surveillance system to support their Level 1, Level 2, and Level 3 SA. Such a system should provide real-time surveillance information to help them decide whether to launch an investigation in a suspected drop location and plan out when and where to station patrols. Such a system should reliably detect both UAVs and human intruders, including the humans that may be controlling the drones from nearby. If designed properly, it will significantly improve prison officials' SA by alerting select prison officials, providing information about suspected intruders in real-time, and assisting in their decision-making about possible courses of action, including providing estimates of alert fidelity.

However, the frontend user interface (UI) design of SA-oriented systems for real-time alerts is difficult because the UI needs to receive and present constantly updating information from multiple heterogeneous data sources with varying degrees of uncertainty [14]. In the context of prison surveillance, besides the need for interpreting and

---

[1] Undergraduate Student, Department of Computer Science, AIAA Member
[2] Professor, Department of Electrical and Computer Engineering, AIAA Fellow

presenting detection data textually in real-time, the visualization of these data is necessary because an intruder can trespass on a large property from multiple directions. However, the visual representation of complex raw data that require quick user interpretation is not necessarily straightforward. An effective approach to visualizing these data should help prison officials immediately understand where the intruders are, how their location is changing, and estimates of certainty to raise prison officials' SA and assist in their intrusion response planning.

To this end, this paper discusses the design of a low-cost passive detection system meant to alert select prison officials when either drone or human intruders are present on prison grounds. Specific attention is paid to the design and development of a smartphone-based UI, and how the design promotes the three levels of SA. Feedback from actual prison personnel is provided, as well as areas for future research.

II. Background

Situational Awareness is the comprehension of events within one's environment and how these events will unfold. A general developed this concept during WWII to emphasize the importance of becoming aware of the critical elements in a situation before one's enemies do [17]. Gaining SA has become significantly more complex than simply becoming aware of pieces of data and necessitates an advanced level of situational understanding and ability to project the future states of complex systems with significant degrees of freedom. Many environments require SA, including threat response in potentially dangerous areas like prisons. Especially in such dynamic environments, many decisions need to be made within a short period of time, and response actions depend on an up-to-date and constant analysis of the changing elements within the environment [15].

Prison intrusion is a typical example of a complex dynamic environment that requires high SA. Intruders are constantly moving and may be communicating with people inside the prison. Prison officials are at a disadvantage as passive defenders of the prison property but must quickly gain SA immediately when intrusion begins. An insider may be feeding smugglers secret information about the prison, such as guard shift schedule, or even directly receiving packages for them. Also, smugglers can use UAVs to view activities around the prison through a camera at a safe altitude. In contrast, prison officials likely have less information about the smugglers' plan beforehand. To stop these smugglers, prison officials need to learn and stay informed about the presence and the shifting location of human and UAV smugglers without delay.

Therefore, without a comprehensive and usable surveillance system, prison officials will have inadequate SA that leads to intruder deterrence failures because 1) prison officials are unaware of the presence of intruders, 2) prison officials know less about the whereabouts of their opponents and 3) their opponents are focused on only one task—smuggling—while multiple tasks may be distracting prison officials. What is complicating this problem further is that most prisons cannot fund expensive radars, jamming equipment (e.g. an affordable Echodyne drone radar costs $30,000 each [Ref. 21]) and associated personnel. Thus, anti-drone technologies that may exist on the commercial market are likely cost-prohibitive for strained prison budgets. So, it is critical that any solution for improving SA for prison officials during their attempt to fend off smugglers be cost-effective and easy to operate and maintain.

The first level of SA is to become aware of the status, characteristics and dynamic elements in the situation. In the context of prison intrusion events, critical Level 1 SA information includes whether there is an intrusion happening around the prison property, the size of the prison property, the kind of intruder (human on foot or UAV), the speed and direction of the intruder's movement, etc. The second level of SA is the comprehension of the situation, which is based on the synthesis of Level 1 elements. It requires understanding the significance of the elements and the forming of a holistic picture of the environment. For example, based on a suspect's location and proximity to the prison or an image of the suspect, the prison official can infer their objective.

The third level of SA is the ability to project the situation into the future. One can achieve Level 3 SA through the knowledge and understanding of the elements within the environment from Level 1 and Level 2 SA [15]. Once prison officials gain Level 3 SA, they may be able to predict where the intruders will be heading towards and decide where they should send their patrols, especially if they have a network of sensors. With accumulated data from past intrusion events, prison officials can analyze these data, place their sensors in more optimal locations to detect intruders more accurately, and plan for future intrusions.

A technology-based surveillance system can promote SA better than human patrols at regular intervals because such a system can operate 24/7, send alerts with intelligence instantly, provide real-time tracking of moving intruders, and cover a larger area [16]. Such a system can give prison officials accurate information and valuable time to respond with appropriate strategies, aiding them in outmaneuvering smugglers.

However, building such a system for enhancing SA is difficult. A prison official's attention is typically divided among a number of tasks on a given day, potentially reducing SA for new, unexpected events. Thus, any technology aid must be user-friendly, and present succinct, digestible information in time to help prison officials make decisions efficiently under short time constraints. Thus, it is important to design any alerting decision aid to support all three levels of SA while adhering to established usability guidelines, and understand the demands placed on officials like those in stressful prison environments.

III. Mobile Alerting Interface

A mobile alerting interface (MAI) is a promising solution for increasing situational awareness and aiding prison officials in their surveillance tasks. The MAI presented here is an integral component of Prison Reconnaissance Information System (PRIS) developed by the Duke University Humans and Autonomy Lab (HAL Website: http://hal.pratt.duke.edu/) for detecting human and UAV intruders and promoting prison officials' SA. PRIS is disguisable, allows wireless updates and is so cost-efficient that its total set-up costs less than $700 USD because it relies on software instead of expensive hardware. PRIS's highly portable hardware infrastructure consists of 1) a micro thermal camera connected to a Raspberry Pi that analyzes thermal image data based on a Support Vector Machine (SVM) learning algorithm for recognizing human intruders, 2) a microphone connected to a Raspberry Pi that analyzes acoustic data based on another SVM algorithm for recognizing noise frequencies from UAVs, 3) a server that stores and transmits data, and 4) the MAI installed on a smartphone. When HAL's detection algorithms suspect there is an intruder, the Raspberry Pis send alerts to the MAI and upload relevant detection data to the server, which the MAI downloads and displays. Fig. 1 illustrates the PRIS architecture, and subsequent sections present details about the MAI.

Fig. 1 PRIS Architecture

A. MAI Platform Choice

The MAI is primarily developed for Android phones, which offer a wider range of affordable options than iPhones. However, because the MAI uses a cross-platform app development framework, it can also be installed as a Web App and an iOS App, thus making this a very flexible and cost-effective development platform.

The layout of the MAI adopts a minimalist design and contributes to improving the MAI's learnability, efficiency, and memorability [18]. The focus of this concise and intuitive design is to elucidate elements of the situation during an intrusion event, which is the basis for gaining a clear understanding of the situation and promoting SA [15]. In addition to the lock screen notification feature (Fig. 2), there are three main sections of MAI—Home, History, and Settings.

The Home Page directly displays a programmed Google Map that presents the current detection status of the detection devices (Fig. 3). Users can drag and zoom to interact with the Google Map to see the markers with pop-up windows more clearly if they are visually impaired. The History Page (Fig. 4) displays a menu bar that allows data export and filtering, as well as a list of previous detection events. There is also a Settings page, not pictured here, that enables the user to choose push notification settings.

MAI interaction procedures are similar to those of other apps on Android phones, so users with prior experience with similar apps will reach high proficiency in utilizing the MAI more quickly. The UI is friendly to color-blind users by avoiding using color schemes that include red, green and yellow [19]. It also emphasizes a minimalist approach to enable fast UI navigation and avoid consuming excessive cognitive resources. Sizable icons and labeled buttons are employed to increase their visibility and assist the user in understanding their functionalities. These design choices make the app more learnable because succinct textual and visual representations help explain the functional interactive elements of the MAI. The following sections describe the separate pages in more detail.

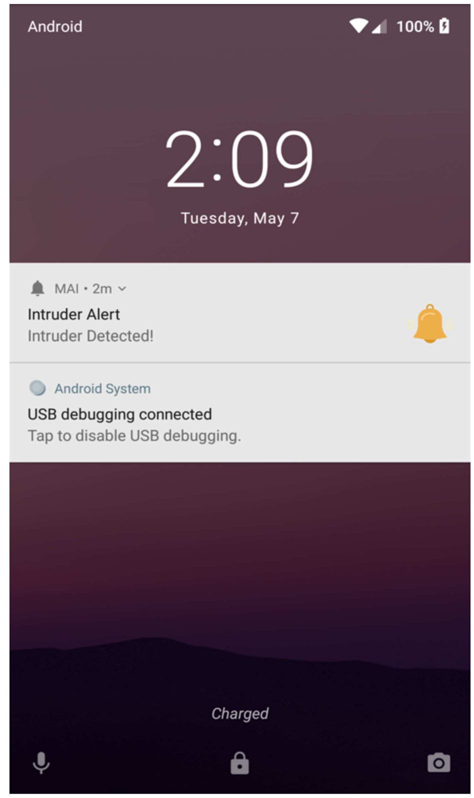

Fig. 2 Push Notification Intruder Alert

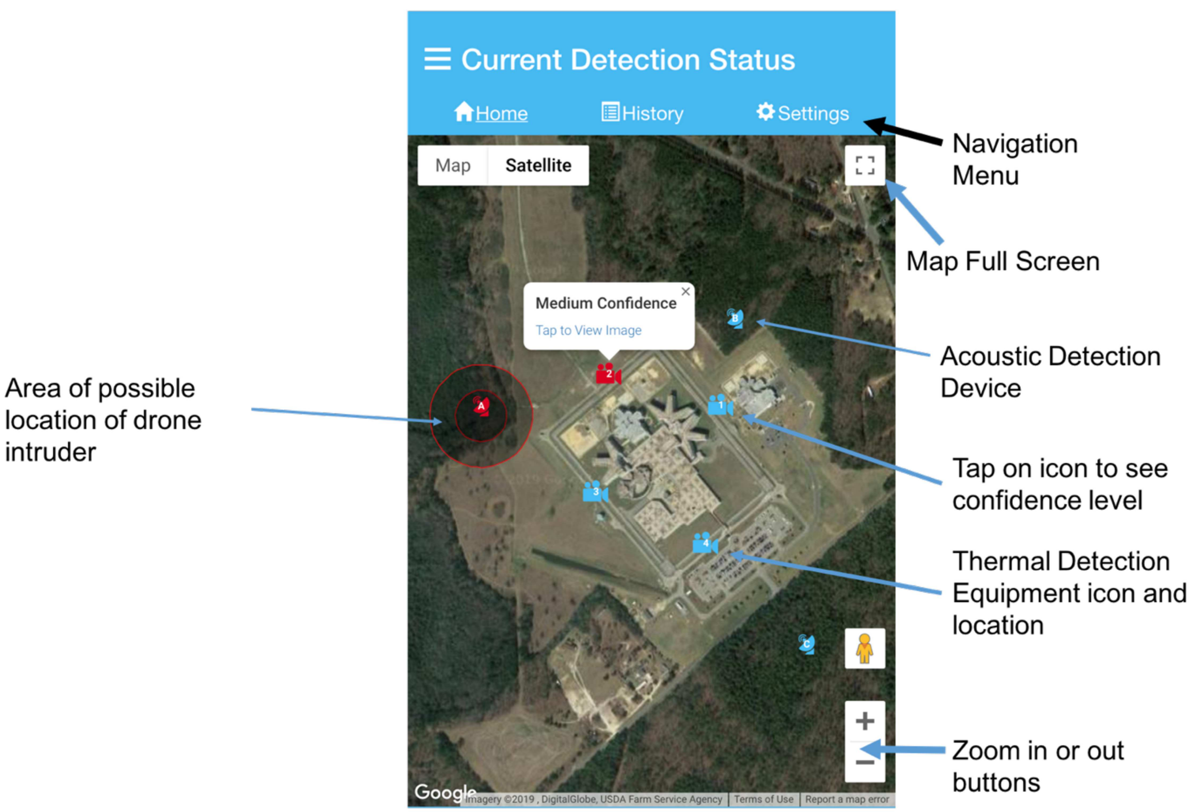

Fig. 3 PRIS MAI Home Page

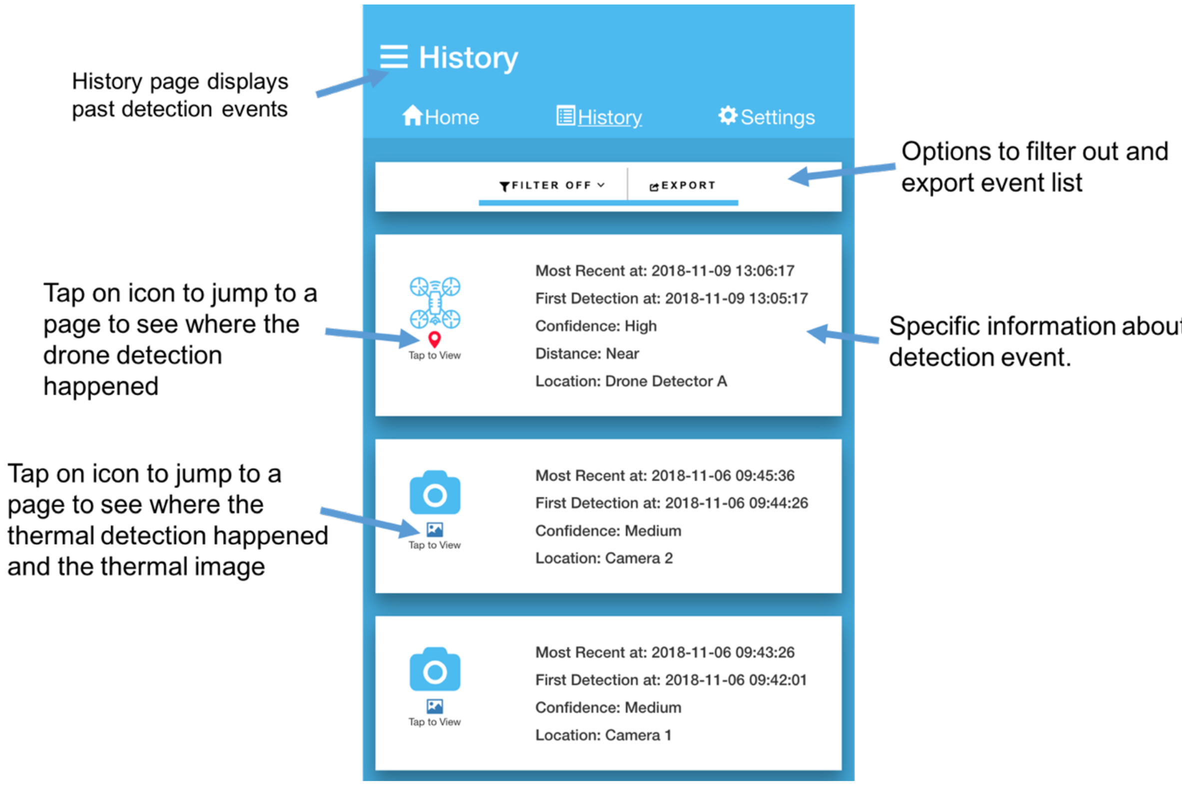

Fig. 4 MAI History Page

B. Push Notification and Alert

MAI employs OneSignal, a high-volume push notification service to send reliably push notifications. If the mobile phone's screen is closed, the surveillance system will alert the user by sending push notifications with customized warning text that will stay on the lock screen along with auditory and tactile signals to grab their attention (i.e., the phone can play a ringtone and vibrate). When the users turn the screen back on, they will see that there is an intrusion event, as shown on Fig. 2. If users are engaging with other applications, notification will appear at the top of the screen.

These tactile and auditory signals effectively gain users' attention when they are not engaging with their mobile phones at all. If users are using the PRIS app, a pop-up window will appear that requires users to acknowledge the alert by tapping on the pop-up window before they are allowed to interact with the app further. The mandatory engagement with the pop-up window effectively redirects the user's attention to the emergency.

C. Home

The Home Page contains an interactive map for users, so they can see the live status of detection devices and their respective locations on the map. This is crucial for promoting Level 1 SA. The interactive map is based on the Google Maps API. The interactive map promotes Level 1 SA by reacting to new alerts and changing its display in real-time, allowing users to instantly become aware of the presence of intruders near the facility. It adopts a bird's eye view over the correctional facility with markers representing detection devices, which are placed on the map based on their approximate GPS coordinates.

When a detection event occurs, the labeled detection device markers will change colors and allow users to tap on them to view a pop-up window that shows the confidence level of the detection algorithm (i.e. the higher the confidence level, the more certain the detection algorithm is about the presence of an intruder). For acoustic detection, MAI displays rings around the suspected drone, as depicted in Fig. 3, which indicate the area that the drone could be in. This information combined with the pop-up confidence estimate help prison officials understand the constantly updated elements of the current situation, i.e., how likely it is that an intruder is present, where the intruder may be, and whether the new event is worth investigating, effectively promoting Level 2 SA. Any subsequent alerts, which are updated approximately every 30 seconds, allow prison officials to predict actions over time, enabling them to gain

Level 3 SA by projecting the situation into the future and to infer where the intruder will be heading. This is explained in more detail in the next History section.

When a thermal detection event occurs, i.e., an unauthorized human is potentially detected on prison grounds, users have the option to select the camera icon as depicted in Fig. 3, which will allow them to see the actual most-up-to-date still image of the suspected intruder (Fig. 5). These pictures allow the user to assess whether the underlying machine learning algorithm was correct in its detection and alert and to decide whether to act on the information.

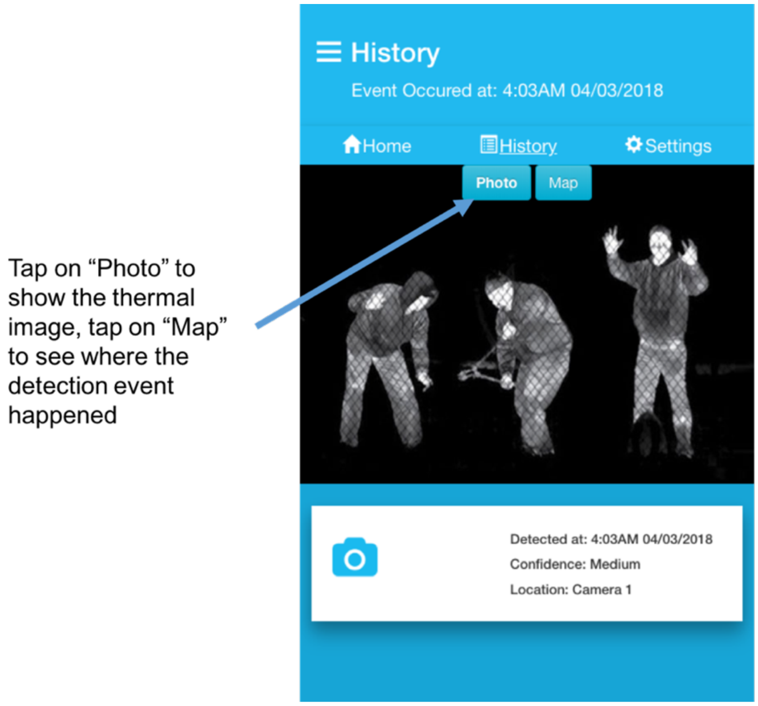

Fig. 5 Thermal Detection Event

D. History

The History Page is where all current and past detection data are presented in a readable format (Fig. 4). All detection events are listed, both thermal and acoustic, and include the newest thermal images and possible location of the UAV. All detection events within a certain time frame contain more details such as the most recent time of detection, the initial time of detection, the detection device triggered, how confident the algorithm is about whether there is an intrusion, and the area the UAV may be in as compared to the acoustic detector. This feature can improve prison officials’ Level 2 SA by allowing them to quickly comprehend more details on the situation.

If prison officials need to see even more details about the event, they can tap on the “Tap to View” icon, which will redirect them to a page specifically generated for the event. On this page, they can view a map that shows the location of the device that detected the intruder, so they do not have to go back to the Home page to remind themselves of the location of the device. Also, it shows the thermal image of the suspect or the area around the acoustic detector of where the UAV may be present (Fig. 5). With the extra information from records on the History page, prison officials can predict how the situation will evolve and make sound decisions immediately about how to deal with intrusion events. Furthermore, they will be able to create plans and adjustments to the placement of the detection devices to deter future intruders based on historical records. So, the History page can also raise Level 3 SA.

E. Security and Real-Time App Update

The MAI is designed to be used by select individuals, since some personnel could be compromised and participating in the contraband smuggling operation [20]. Therefore, the MAI design uses Meteor JS app development framework, MongoDB database, and Loopback API to incorporate easily customizable and secure authentication features that require access tokens and user authentication by the PRIS server before the user can receive any alerts or detection information.

Also, to allow full-stack reactivity, the MAI utilizes Meteor JS that can update the app UI immediately when changes in the server database occur and display new data. Prison officials do not need to routinely manually refresh the MAI to synchronize the app data with the server.

F. Settings

The MAI Settings page, not pictured here, allows users to log in and out of their accounts and customize their notifications based on their preferences and user context. They are allowed to turn off vibration, sound or notifications separately or completely. These options apply to contexts such as when prison officials go off-duty or need to operate in an environment with no disturbances but still need to be informed of intrusion events.

IV. Feedback

A preliminary design review with prison officials at Scotland Correctional Institution (NC) was conducted in Spring 2018. Prison officials were shown pictures of the MAI mock design and encouraged to offer feedback. The objectives of the review were to understand user expectations and whether users with no special training would find the design of the MAI intuitive and establish the essential features of the MAI prototype required for promoting prison officials' SA. In general, the prison officials had few technical comments and found the UI design intuitive and aesthetically pleasing.

The prison officials expressed their desire for an interactive map and certain advanced functionalities. They believed the map should have touchscreen-based interaction functionalities (i.e. pinch and zoom, and drag), so they can obtain a more detailed view of locations of the detection devices. The advanced functionalities the prison officials proposed include showing a live update of the flight path on the History page and an estimate of the height of the drone. To accommodate these user needs, MAI includes an interactive map that has the above-mentioned touchscreen-based tactile interaction functionalities, the option to switch between satellite and map view, and tappable markers that show pop-up windows to present detection information. Also, it can graphically represent the possible area of the UAV's location. The novice-friendly customized map presents the detection event information graphically and assists in promoting Level 1-3 SA.

Table 1: MAI Question Feedback from Dan River Work Farm Senior Officials

	User 1	User 2	User 3	User 4	User 5	User 6
Is using this app intuitive and straight forward?	5/5 Very Intuitive	5/5 Very Intuitive	5/5 Very Intuitive	5/5 Very Intuitive	5/5 Very Intuitive	5/5 Very Intuitive
Is learning how to use this app easy?	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy
Can you find the functionalities on the app based on the text and buttons?	5/5 Completely	5/5 Completely	5/5 Completely	5/5 Completely	5/5 Completely	5/5 Completely
Do you understand what confidence level is now?	Yes	Yes	Yes	Yes	Yes	Yes
How much do you think the app may help you make better surveillance decisions?	5/5 Very Helpful	5/5 Very Helpful	5/5 Very Helpful	5/5 Very Helpful	5/5 Very Helpful	5/5 Very Helpful
Is navigating the app easy?	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	4/5 Easy
Did the push notification work as you expected? If not, please specify	Implicit Yes (Blank Entry)	Implicit Yes (Blank Entry)	Implicit Yes (Blank Entry)	Implicit Yes (Blank Entry)	Implicit Yes (Blank Entry)	Explicit Yes (Wrote Yes)
Is the app aesthetically pleasing?	5/5 Very Aesthetically Pleasing	4/5 Aesthetically Pleasing	4/5 Aesthetically Pleasing	5/5 Very Aesthetically Pleasing	5/5 Very Aesthetically Pleasing	5/5 Very Aesthetically Pleasing
Is using the interactive map and interacting with the markers on the map easy?	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy	5/5 Very Easy
Was the push notification too frequent?	It's Perfect	It's Perfect	It's Perfect	It's Perfect	It's Perfect	It's Perfect
Do you think you can use how to use the app even if you stop using it for a month?	All of It	All of It	All of It	Most of It	All of It	All of It
Is using this app frustrating?	1/5 Not at All	1/5 Not at All	1/5 Not at All	1/5 Not at All	1/5 Not at All	1/5 Not at All

In addition, the prison officials at Scotland Correctional Institution voiced their confusion about the conceptual meaning of confidence levels. They wanted to be able to decide instantly whether a detection event is worth further investigation based on the confidence level. This suggested that the concrete definitions of different confidence levels must be pre-established and explained to prison officials before they adopt the MAI. Moreover, the prison officials want to be able to set different access levels for the MAI themselves and decide which sensitive data to display to users with different levels of access permission. Therefore, the MAI was developed in a full-stack development framework that can easily provide both longer-term server-side and client-side development and security functionalities.

After the MAI prototype was completed in Summer 2018, the HAL research team conducted a field test at Dan River Work Farm (NC), a minimum-security prison, with six senior prison officials in Spring 2019. The test involved both MAI and the PRIS acoustic SVM detection sensor. An Android smartphone with the MAI pre-installed was used, as well as two drones (DJI Mavic and DJI Phantom 4), and an acoustic sensor that consists of a Raspberry Pi running the acoustic SVM algorithm and a microphone. All acoustic detection SVM analysis results are transmitted to a server and MAI wirelessly via the 4G network. All six prison officials tested the MAI and completed written surveys after the test.

Despite information transmission delays possibly due to the poor cellular reception in the area, the acoustic SVM detection sensor and MAI performed reliably during the test and received very encouraging feedback from the six senior prison officials. According to the results from the written surveys only for MAI, all of them reported that the MAI control mechanisms were very memorable and intuitive, the user interface was easy to navigate and aesthetically pleasing, using the interactive map was “very easy,” the push notification alert system worked as expected and the alerting frequency was “perfect.” Most importantly, all test users stated clearly that they believe MAI will be “very helpful” in assisting their intruder surveillance endeavors. Without much explanation from HAL team members, every prison official believed they gained a clear understanding of the meaning of confidence level after testing MAI and will send out patrols based on reported confidence levels.

Some general criticism/suggestions include: 1) the interactive map update was a “little slow” (likely caused by poor cellular reception in the area), 2) compass directions are needed on the map, 3) a comment section for each detection event was requested for recording investigation results for future analysis, and 4) more information regarding the detection event on the push notification was needed (MAI push notifications are ready to be customized for future users). Table 1 shows the answers to the questions on the user feedback survey.

V. Conclusion

At the current stage of the MAI’s development, most of the UI elements and functionalities have been completed. Only user authentication is still under development. The MAI is able to reliably sync textual and image data with the server, receive push notifications from Raspberry Pi, collect and export detection data and present dynamic information in real-time textually and visually as originally designed. The user feedback from Scotland Correctional Facility and Dan River Work Farm indicates that the control mechanism design and the alerting system design of MAI are user-friendly, reliable and learnable.

Due to the MAI’s high mobility, usability and effective integration with the PRIS infrastructure, MAI has demonstrated strong potential for raising prison official SA and facilitating the decision-making process regarding responding to the presence of contraband smugglers. As PRIS and the MAI’s functionalities develop further, MAI’s design approach may offer a significant contribution to the development of other relevant software for promoting SA for emergency response in the future.

The future development of MAI will entail extensive long-term testing in actual environments susceptible to human and UAV intruders, and will include further measurement of its ability to improve SA. Additional server security, data analytics features, and user authentications will be explored. If MAI displays strong performance after deployment, integrating the MAI’s ability to alert features with wearable technologies is another feature worth exploring. Wearable technologies are able to display detection information from the MAI and alert users even more directly because wearable technologies (e.g. smartwatch) are in closer contact with the user’s body than mobile phones and are also able to vibrate, play sound alerts and show basic detection information. A combination of smartphone UI and wearable device UI can potentially raise prison officials’ SA even more.

Acknowledgements

This work was supported by the North Carolina Department of Corrections and U.S. National Science Foundation under Grant No. 1734206. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of North Carolina Department of Corrections and the National Science Foundation. We would also like to express our gratitude to Dan River Work Farm and Scotland Correctional Facilities in North Carolina for providing us their valuable space, personnel, knowledge and time for the development of PRIS.

References

[1] A. E. Marimow and P. Hermann, "Guards and Inmates Charged in Widespread Bribery and Smuggling Operation," *The Washington Post*, 05-Oct-2016. [online article]. URL: https://www.washingtonpost.com/local/public-safety/prosecutors-to-announce-charges-in-widespread-conspiracy-inside-md-prison/2016/10/05/038d6234-8b06-11e6-875e-2c1bfe943b66_story.html?utm_term=.cbb9eb4f8703 [retrieved 10 May 2019].

[2] S. Horwitz, "Justice Dept. Scrambles to Jam Prison Cellphones, Stop Drone Deliveries to Inmates," *The Washington Post*, 08-Jan-2018. [online article]. URL: https://www.washingtonpost.com/world/national-security/justice-dept-scrambles-to-jam-prison-cellphones-stop-drone-deliveries-to-inmates/2018/01/08/42492896-f4a0-11e7-b34a-b85626af34ef_story.html?noredirect=on [retrieved 10 May 2019].

[3] W. Abbasi, "Inmates Fly Mobile Phones, Drugs and Porn into Jail - via Drone," *USA Today*, 17-Jun-2017. [online article]. URL: https://www.usatoday.com/story/news/2017/06/15/inmates-increasingly-look-drones-smuggle-contraband-into-their-cells/102864854/ [retrieved 10 May 2019].

[4] WITN "Trio Charged with Throwing Contraband Over Prison Fence," *WITN - Content - News*. [online article]. URL: https://www.witn.com/content/news/Trio-charged-with-throwing-contraband-over-prison-fence-476374603.html [retrieved 10 May 2019].

[5]"Supply and Remand," *The Economist*, 05-Dec-2013. [online article]. URL: https://www.economist.com/britain/2013/12/05/supply-and-remand [retrieved 10 May 2019].

[6] A. Fantz, "How Prison Guards Go Bad," *CNN*, 27-Jun-2015. [online article]. URL: https://www.cnn.com/2015/06/25/us/new-york-prison-break-contraband-smuggle/index.html [retrieved 10 May 2019].

[7] "Big Rise in Drone Jail Smuggling Incidents," *BBC News*, 23-Feb-2016. [online article]. URL: https://www.bbc.com/news/uk-35641453 [retrieved 10 May 2019].

[8] M. S. Rosenwald, "Prisons Try to Stop Drones from Delivering drugs, Porn and Cellphones to Inmates," *The Washington Post*, 13-Oct-2016. [online article]. URL: https://www.washingtonpost.com/local/prisons-try-to-stop-drones-from-delivering-drugs-porn-and-cellphones-to-inmates/2016/10/12/645fb102-800c-11e6-8d0c-fb6c00c90481_story.html?utm_term=.fdbba4c08930 [retrieved 10 May 2019].

[9] "Charges over Drone Drug Smuggling into Prisons," *BBC News*, 15-Mar-2018. [online article]. URL: https://www.bbc.com/news/uk-england-43413134 [retrieved 10 May 2019].

[10] B. Welch, "What Happens when a Prison is Attacked by Drug-smuggling Drones," *VICE News*, 29-Sep-2018. [online article]. URL: https://news.vice.com/en_us/article/438a59/what-happens-when-a-prison-is-attacked-by-drug-smuggling-drones [retrieved 10 May 2019].

[11] Kalinich, David B., and Stan Stojkovic. "Prison Contraband Systems: Implications for Prison Management." *Journal of Crime and Justice*, vol. 10, no. 1, 1987, pp. 3., doi:10.1080/0735648x.1987.9721332.

[12] T. Samilton, "Prisons Work to Keep Out Drug-Smuggling Drones," *NPR*, 15-Nov-2017. [online article]. URL: http://www.npr.org/2017/11/15/564272346/prisons-work-to-keep-out-drug-smuggling-drones [retrieved 10 May 2019].

[13] R. W. Pew and A. S. Mavor, *Modeling Human and Organizational Behavior: Application to Military Simulations*. Washington, D.C.: National Academy Press, 1998, pp. 173-176.

[14] Oliveira, Natália & Jorge, Fabio & De Souza, Jessica & Junior, Valdir & Botega, Leonardo. (2016). Development of a User Interface for the Enrichment of Situational Awareness in Emergency Management Systems. Vol. 491. pp. 173-184. 10.1007/978-3-319-41929-9_17.

[15] Endsley, Mica R. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 37, no. 1, 1995, pp. 32–34., doi:10.1518/001872095779049543.

[16] Butler, Walker, et al. "Benefits of Wide Area Intrusion Detection Systems Using FMCW Radar." *2007 41st Annual IEEE International Carnahan Conference on Security Technology*, 29 Oct. 2007, doi:10.1109/ccst.2007.4373486.

[17] Stanton, N.a, et al. "Situational Awareness and Safety." Safety Science, vol. 39, no. 3, Dec. 2001, pp. 189-190., doi:10.1016/s0925-7535(01)00010-8.

[18] J. Nielsen, *Usability Engineering*. Boston: Academic Press, 1993, pp. 26-37.

[19] "Facts About Color Blindness," *National Eye Institute*, 01-Feb-2015. [online database]. URL: https://nei.nih.gov/health/color_blindness/facts_about [retrieved 10 May 2019].

[20] P. Yeung, "Steep Rise in Prison Officers Smuggling Drugs into Jails," *The Guardian*, 01-Sep-2018. [online article]. URL: https://www.theguardian.com/society/2018/sep/01/rise-in-prison-officers-contraband-smuggling [retrieved 10 May 2019].

[21] "Echodyne Adds Small, Affordable Radar to Counter-UAS Technology » UAV DACH e.V.," *UAV DACH e.V.*, 18-Jul-2018. [online article]. URL: https://www.uavdach.org/?p=545451 [retrieved 10 May 2019].