Raven Eye: A Mobile Computing Solution for Site Exploitation

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Abstract: Site exploitation (SE) remains a critical mission for operators on the battlefield. Since SE is a fairly new operation in the military, soldiers face specific challenges that hinder them from conducting a successful SE operation. This paper details the design of a system, *Raven Eye,* which endeavors to improve the efficiency and effectiveness of SE. Raven Eye is an Android based system that collects, stores, and sends SE data. Raven Eye allows operators to collect exploited site data by capturing photos, videos, and biometrics. Operators can annotate and tag recorded items. Lastly, the operators transform data stored and collected via Raven Eye to a standardized report that accelerates follow-on analysis by intelligence personnel.

Keywords: Site Exploitation, Android, Military Intelligence, Scrum Methodology, Forensic Science, Graphical User interface

1. Intro/Background

Figure 1. The Raven Eye system (left) is used by a soldier (center) to exploit a sensitive site. A screen capture from the system (right) shows tracked, virtual tags (yellow numbers) which annotate and geo-locate items of interest as the soldier navigates the scene.

Site exploitation (SE) is a critical mission for operators on the modern battlefield. However, the execution of a thorough SE takes a significant amount of time. Prolonged search and inventory activities place operators and their primary mission at higher levels of risk. Likewise, incomplete or incoherent site inventories can delay analysis of site artifacts and data, reducing the potential intelligence value of exploitation. Specific challenges include:

- Rapid site search and inventory
- Rapid post-mission synthesis of site information
- Ontological organization of collected evidence
- Reduction of hardware weight and volume
- Accurate site reproduction
- Hidden chamber/material detection

His paper describes Raven Eye which seeks to address these challenges. Raven Eye, shown in Figure 1, is a mobile computing system combining photos, videos, annotation, storage, and site mapping capabilities. It gives the user one tool that quickly and comprehensively completes all the necessary sub-tasks for data collection of an SE without overburdening the user. Furthermore, the system stores and organizes collected data into a report which can be auto-populated and sent to data analysts for review immediately following SE missions.

According to FM 3–90.15, *Site Exploitation Operations Manual* (2010), SE is a systematic search for the collection of information, material, and persons from a designated location. This allows analysis for information requirements, facilitates subsequent operations, and supports criminal prosecution. SE consists of two phases: prioritizing information and exploiting the site. Potential intelligence collected from a typical site takes a variety of forms. Collectively, SE literature refers to all sources of intelligence as information, material, and personnel (IMP) to include documents, weapons, equipment, supplies, and biometrics (FM 3-90.15, 2010). Raven Eye provides SE assistance with respect to searching, collecting, and analysis of information. Searching is the systematic procedure of identifying potentially valuable IMP, while collecting is the process of gathering and preserving IMP. Analyzing IMP on-site determines the actual value and relevance of the information in relation to ongoing operations and gets the intelligence into the decision loop more quickly.

The early inspiration for this research comes from two prior Department of Defense (DoD) projects: the Nett Warrior (NW) and Android Tactical Application Kit (ATAK) systems. The objectives of both projects were to integrate new capabilities into military units in order to increase the capabilities of dismounted soldiers (Rosen & Walsh, 2011). A main issue for many Army systems is the balance between providing soldiers with the necessary equipment for their specific job without burdening them with excess weight or clutter. This was a main issue that NW encountered throughout the development and integration of their system (Rosen & Walsh, 2011). ATAK relieved soldiers of overburdening but still enhanced their battlefield functionalities by incorporating a mobile-handheld Android platform capable of multiple functionalities through an open Application Programming Interface (API) (Gillen, Usbeck, Scally, & Kohler, 2012). The capability gap encountered in the research of NW and ATAK was a lack of time and incompleteness in data collection during SE operations. Merging this gap was a driving force behind our inspiration to pursue the development of Raven Eye.

This paper is organized into four parts: related work, approach, implementation, and conclusions. The approach, discusses the design process, the system design, the development of an SE ontology, the design of the application interface, and the data management. The implementation section details the ongoing implementation and testing of Raven Eye.

2. Related Work

The intelligence gained from conducting SE is extremely valuable. Today, conducting SE has become the standard procedure for U.S law enforcement and military. The FBI was the first pioneer of this practice; where in 1980, the US Attorney General mandated that the FBI revamp their system in order to address the record high 23,000 homicides committed that year. Special Agent R.L Depue (1986), in his book, "An American Response to an Era of Violence," comments on his experience as an FBI agent in 1980 where the agency was undergoing change. As a result, the FBI created the Center for the Analysis of Violent Crime (NCAVC). From this center they created a practice they coined forensic science which is a broad form of SE. This practice proposed imaginative strategies, resulting in earlier arrest, and more certain convictions (1986).

These principals of conducting an investigation transcended into the military, where in 2002, the U.S. military used this practice but called it SE during operations in the War on Terror. Lofty (2002) wrote about his experiences in his mission to hunt for weapons of mass destruction, "managing sensitive site exploitation is a new and complicated process. This process can be simplified, however, when it is nested in the already-existing system of the military targeting process. This established method makes the task more manageable…and gives the unit actionable tasks. Correct and efficient management of this process will ensure minimum strain on unit combat power because of sensitive site security missions" (2002). A particular problem in SE is having detailed feedback about the exploitation after its completion. A successful and completed SE mission requires soldiers to gather complete and accurate information; otherwise, the target must be re-serviced.

Site exploitation is similar to crime scene analysis and related forensic activities requiring search, inventory and analysis of items within a discrete area. There have been several techniques and tools developed to support these tasks. In one notable example, the Department of Justice sends law enforcement personnel to the National Forensic Science Technology Center (NFSTC) where students receive training on applied forensic techniques for intelligence gathering (2015). The NFSTC prescribes a twelve piece SE Kit as its training platform. In another prominent example, the Department of Defense sends selected Special Operations personnel to the Technical Exploitation Course (TEC) (2015, March 11).

Our design is most similar to a system developed by Sergeant First Class Christopher Linnel (Stewart, March 2013). Linnel developed an application called *Lighthouse Sensitive Site Exploitation* which "utilize[d] the Lighthouse intelligence analysis methodology developed in the DA department's CORE Lab." Lighthouse Sensitive SE was created to simplify the process of SE by capturing mission context along with pictures, faces, documents, and reports. The application is operated on an Android OS-based mobile device and connected to a tactical network. Linnel conducted an exercise and concluded that special operations forces were able to complete SE tasks more accurately and efficiently Linnel's application. (Stewart, July 2013). Several key aspects of the Raven Eye design make it distinct from Linnel's work. First, Raven Eye utilizes Google Tango, a platform that constructs 3D maps and provides an elaborate marking feature to annotate the site. Secondly, the Raven Eye annotation feature helps identify the exact location of evidence in a room as compared to the Lighthouse application's consolidation of all evidence found during SE operations into a single bin. Lastly, at the end of a mission, the operator will be able to generate a SOF-SE report with all pertinent mission information that was collected. Linnel built his application primarily with the operator's point-of-view in mind.

3. Approach

3.1 Design Methodology

According to the USMA Department of Systems Engineering, "the Systems Design Process (SDP) is a collaborative, iterative, and value based decision process that can be applied in any system life cycle state" (Parnell, 2011). Initially, the SDP was used to design Raven Eye until our candidate solutions converged on a software application. Once determined that a software solution was required, the team adopted the Scrum methodology–a leading design process for software application design (Michael, , 2014). Scrum emphasizes the idea of "empirical process control" that uses real world progress of a project, instead of baseline estimates, to plan and schedule sprints—groupings of tasks spanning 2-3 weeks in durations. The capstone project was divided into a total of six sprints which ranged from problem definition and stakeholder analysis to Android application design and prototype testing. The team used *Trello* (2015), an online Scrum project management tool to coordinate design deliverables, track progress, and make design resource decisions. Overall, the Scrum methodology proved to be a successful project management tool.

3.2 Design

Design of the Raven Eye application consists of four major activities: 1) conceptual design 2) the SE ontology 3) design of the graphical-user interface (GUI) and 4) collection, storage, and export of SE data.

3.2.1 Conceptual Design

Our conceptual design for Raven Eye began with a review of the system's requirements and proposed functionality. Our requirements analysis started with a review of the necessary functions that are listed in the SE manual for an operator to conduct SE. Raven Eye addresses three major operational requirements: collect information, store information, and produce/send a SOF-SE. The SOF-SE is the standard output we selected due to our clients' specifications that our solution will primarily be used by SOF Teams. The SOF-SE format is most commonly utilized by the Army SOF community (2007). Within the collect feature, our application allows the user to input and update mission information, create or capture a 3-D map of all the rooms in a building/compound, record video, or take pictures while the user records the video. Additionally, the user can insert and attach annotations to the videos and/or photos, via voice-to-command text or manual input. The annotations can later be viewed and/or updated. According to Sergeant First Class Rothrock, Special Forces NCO, the annotation feature is an incredible asset for SE because it benefits both the operators and analysts (Rothrock, personal communication, January 18, 2015). This feature is critical because it allows the operator to create mapable, evidence-based data that is capable of "larger picture" analysis. Specifically, the tagging feature allows for evidence specific notation that an analyst can review later with perspective closer to what the operator had while gathering evidence. As a result of the improved perspective, the analyst is able to develop suspect profiles and understand the terrorist network (Rothrock, 2015). The final capability in our collect feature is Manage Biometrics, where the user is able to match, share, collect, and store biometrics. Again, this capability is crucial because biometrics provide a high level of certitude about the identity of individuals (Wiggins, *DOD Biometrics Architecture Briefing to Industry*). Our application has an extremely large database in which any operator is able to revisit any logged mission in the application. In the Store feature of the application, the user can review all previous mission's videos, photos, and annotations in the "Gallery" section. Additionally, the user is able to modify any changes, by adding or deleting. The last feature of our application is Produce/Send Data. This feature focuses on finalizing mission information, transmitting the mission information from the SE to a SOF-SE report, ensuring all areas of the SOF-SE report are complete, and finally, generating a SOF-SE report. The SOF-SE report is produced as a Microsoft Word or PDF document and can be emailed or printed.

After completing the requirements analysis, a functional analysis of the Raven Eye System was conducted. The functional analysis activity represents all the operational function of Raven Eye in a hierarchal and flow form. The functional flow allowed us to visualize the flow and link among all the operational functions. Figure 2 illustrates the most important portion of Raven Eye's functional flow, the collection phase. Reading the figure from left to right, Raven Eye records a video or takes photos (functions 1.2.2 and 1.2.3). Next, it will display the photos taken in the gallery for the user to view, annotate, and tag with drop down menus (functions 2.2.4 - 1.4.3). Afterwards, the user can either store and save the data or erase it (functions 2.1.1 and 2.1.2).

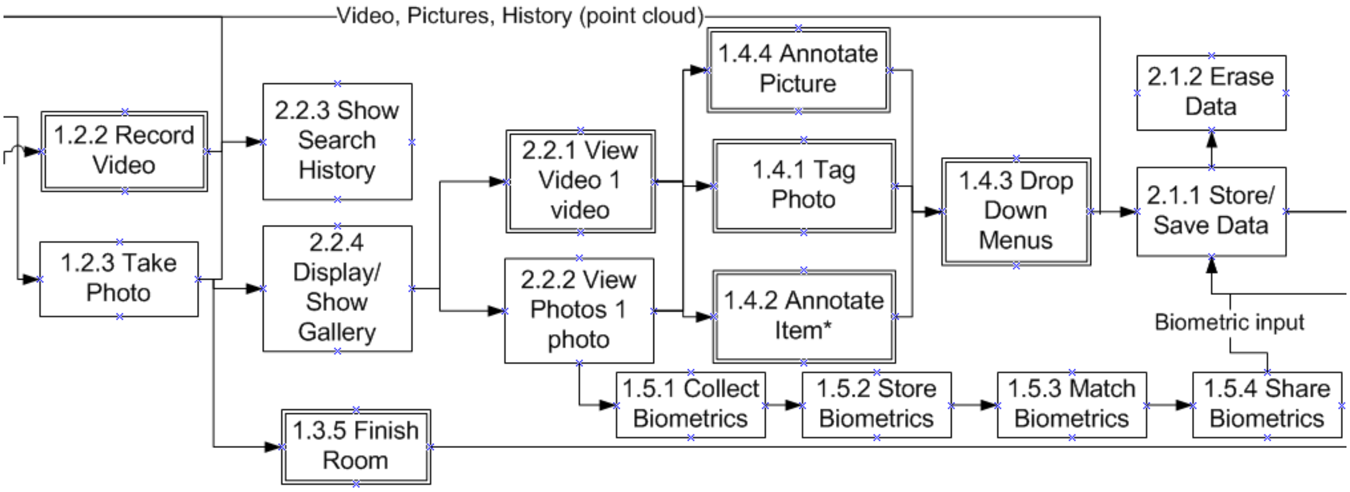

Figure 2. Functional Flow Extract

3.2.2 Ontology Development

The conceptual design process identified the importance of creating an SE ontology to fulfill the needs, wants, and desires of our stakeholders. This ontology guides how SE information is entered by the user and stored in the Raven Eye system. The ontology is a database schema that was derived from the SOF-SE report and other intelligence processes from SE missions. The ontology organizes information categorically and within natural language constraints to facilitate follow-on queries and analysis. For example, assume a soldier finds a building or compound full of IED precursors. At this site, perhaps the soldier notices a trend in the national origin of the IED source material. Without an ontology, the trend would be noted as free-form text, unable to be easily mined for key-words or other terms common to strategic intelligence analysts. The trend noted by the solider might be missed. However, through use of a common ontology, the soldier can note the IED source materials using standardized terms that are shared with the upstream analyst. This facilitates higher-quality reports and decision making. In the future, this common ontology could even facilitate automated analysis provided by machine-learning algorithms.

The following data sources are merged into the implementation of the Raven Eye ontology: the SOF-SE Report, the SE Manual, the Weapons Technical Intelligence IED Lexicon of the Joint Improvised Explosive Device Defeat Organization (Dennard, 2014), and the Counterterrorism Analytical Lexicon of the Federal Bureau of Investigation (2012). The Raven Eye ontology is specified as nine objects in the data schema. These objects span a wide range of SE concepts, including weapons, threat finance, electronics, explosives, and the psychological disposition of a detainee. Furthermore, all objects have at least one degree of further specification. For example, within the ontological Java code, explosives are categorized as `explosiveType = {high explosive, military explosives, munitions}`; and munitions further specified as `munitions = { missiles, grenades,…, mortars}.`

3.2.3 GUI Design

We determined that Raven Eye should not deviate from existing general user interface GUI norms with the intent of retaining familiarity with common applications in the Android platform. Raven Eye is programmed to leverage as many ergonomic and intuitive hand motions as possible. Using the Low Fidelity (Lo-Fi) methodology in the solution design of the Research and Development phase, a preliminary design of the Raven Eye GUI was created (see Figure 3, left). Lo-Fi is the use of tangible raw materials such as cardboard, paper, and other basic crafts in order to construct a virtual version of the intended product. In the software and programming industries, this method is extremely valuable due to its ability to flush out and highlight major design flaws prior to the introduction of code which can be difficult and cumbersome to alter. Nested in the concept of usability testing, the overall benefits of Lo-Fi are 1) increased understanding of user operability, 2) increased visualization of the design, and 3) less time spent on actual development. Thus, designers use Lo-Fi to create a physical, rough sketch of the intended product that is able to identify the second and third order intricacies of the projects functionality. The Lo-Fi was utilized to determine the placement and all executable pathways for actions accessible by the user on the screen. Paper virtualizations of Raven Eye were created to simulate the flow of a SE mission. The early construction of the Lo-Fi design was extremely useful in working with SE Subject Matter Experts (Figure 3, right) highlighting user interface requirements for Raven Eye such as audio/video capture modes, data review, and the storage of captured information. Raven Eye must be intuitive and easy-to-use in order to allow the user to efficiently and effectively conduct SE missions.

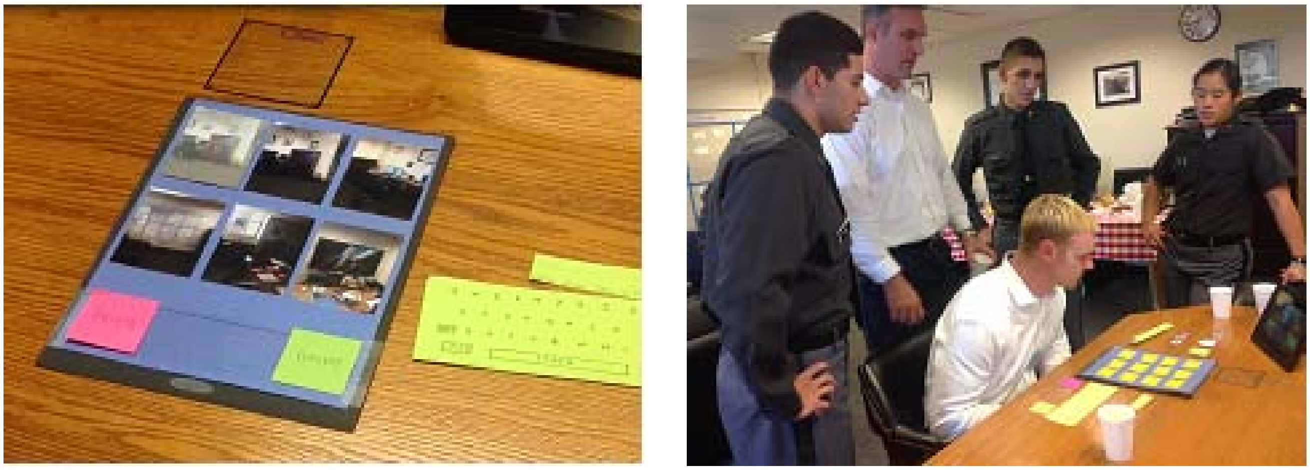

Figure 3. The Raven Eye Low Fi Prototype (left) being reviewed by Site Exploitation Subject Matter Experts (right)

3.2.4 Data Collection, Storage, and Output

Data collection includes the following media types: ontologically organized data tags, free text, still photos, videos with audio, hands free audio, and 3-D modeling. This information is entered by the soldier using forms provided by the Raven Eye software application, an example of which is shown in Figure 4 (left). Data tags using our standardized ontology will allow for analysis in a much more succinct and potentially real-time manner. The free text option is necessary for annotations not covered by the ontology. Given the necessity of concrete evidence in counter-insurgency, the ability to take photos and/or videos is crucial in documenting and providing evidence for SE. The audio feature allows for the added benefit of hands free annotations instead of onerous, manual documentation. Lastly, while the technology is still advancing, the incorporation of a 3-D scanner into the application allows for not only greater perspective in SE, but also the potential to determine the dimensions of a room and/or object.

Ultimately, these collected data receive a tag and position that are filed within a database. Data collection occurs with the pairing of an exploited item's characteristics to predefined event–oriented input tables. These secondary tables serve as the collection point for information that has already been tagged by the categories of the ontology and their respective levels of subjugation. The secondary data tables are stored in an SQLite database on the Android device. In total, there are 117 total event type branches available to the user. Furthermore, given the availability of a "miscellaneous" data category, the database is fully extendable. The output function of the Raven Eye design is accomplished via form fields that are similar to a standard mail merge. The SOF-SE report is parsed and coded with special mark-up tags that will substitute portions of the SOF-SE report with excerpts from the database. An extract of a marked-up SOF-SE is shown in Figure 4 (right).

4. Implementation

The Raven Eye system is implemented as an Android software system using Android API version 19. The system consists of two major activity classes–searching, and annotation /data management. The search activity class displays a video see-through interface where a user can view the SE environment using the android devices back-facing camera. The view includes overlaid graphics indicating mission information and prior annotations. When desired, the user can use the interface to take a picture of an item in the SE environment and begin annotation. At this point, the application transfers program control to the data management activity. This activity displays a series of forms that allow the user to quickly annotate objects (Figure 4, left). These forms are based on our Lo-Fi GUI design and include drop-down menus and other accelerators rendered using hyper text markdown language HTML5 and Javascript. A background class handles persistence of the HTML form and supports data management. Figures 1 and 4 (left) show an example of our current implementation.

The application is implemented on a 7 inch Google Tango tablet. The Google Tango tablet includes a 3D depth camera that allows for precise motion capture (within 1 cm) of the tablet as the user navigates around a site. This provides the ability to include the relative position of photographed objects within a detailed map of the SE scene. The Google Tango also provides a 3D scanning capability that will allow for collection of geometric point clouds for portion of the SE room and objects collected. This 3D scanning data can be stored and archived as part of the system. However, a problem was encountered in which the Google Tango was unable to conduct depth sensing and capture pictures simultaneously. This was a problem because the Tango's color camera is primarily used for depth sensing. If a picture was taken with the color camera, all 3-D aspects of the Tango would be interrupted. To solve this problem, another iteration of the SDP was conducted. It was decided to incorporate a second camera, a GoPro 4, into our design. Whenever the Tango drops tags during depth sensing, it sends a signal to the GoPro to capture a photo of where the tag was dropped and stores that photo.

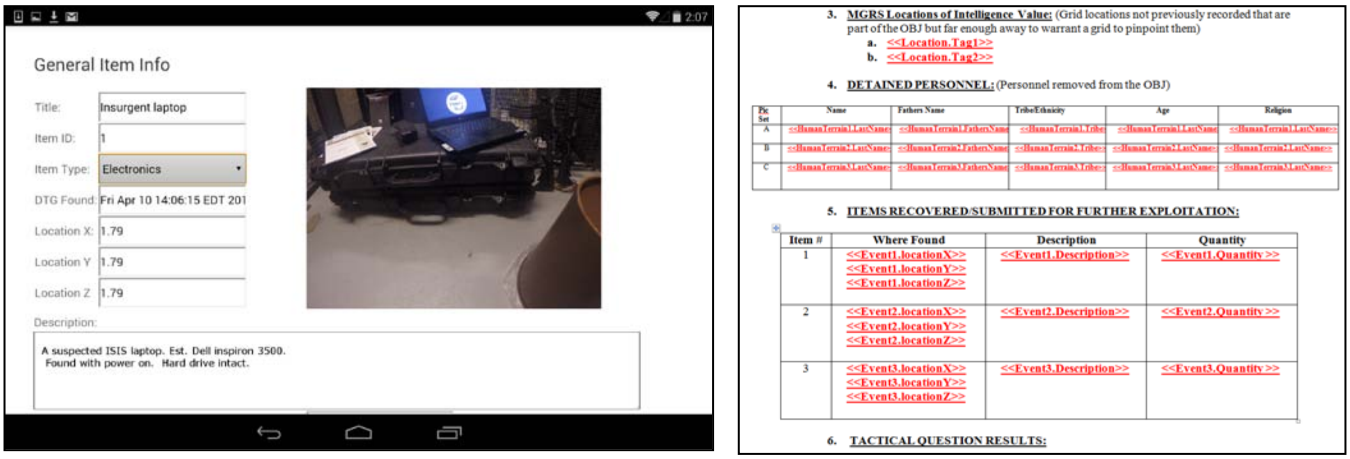

Figure 4. The information from the Annote Item [Function 1.4.2] form (left) helps populate the SOF-SE Markup (right)

5. Conclusion/Future Work

We are pleased with our current design of Raven Eye and look forward to the completion of the final product. The principal contribution of Raven Eye is a tool that adds value to SE missions. This tool supports in-depth analysis for SE management and will allow operators to take videos, photos, and annotations when fully developed. The collected information will be relayed to the analyst, and a SOF-SE report with the newly captured mission data provided. The immediate plans for future work include a final Scrum sprint to include finalizing data capture, completing the GUI, and conducting a pilot test of Raven Eye. Other opportunities for future research include placing Raven Eye in a rigorous testing environment with SOF soldiers to gain user feedback.

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