Platforms for Assessment of Content Prioritization in C3I GIS Systems

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November 9, 2019

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Abstract. Military C3I (Command, Control, Communications and Intelligence) operations at the tactical level have come to rely upon Geographic Information Systems (GIS) to access geotagged units of information such as imaging feeds and personnel reports. Management of Information Objects within military GIS applications presents a number of known research challenges tied both to selection of mission-appropriate information and management of Soldier attention. Towards supporting content filtering and prioritization within tactical networks, methods based on the estimated Value of Information specific to mission and environmental context have demonstrated prior benefit (e.g., in conservation of bandwidth). By contrast, limited research has been conducted to-date on Soldier interaction with VoI-based content filtering in GIS applications, including assessment of its impact on Situational Awareness. This paper presents foundational work being applied towards studying Soldier interaction with VoI-enhanced GIS applications, covering the design of a supporting experimental platform based on the Android Tactical Assault Kit (ATAK).

Keywords: C3I, GIS, Value of Information

1 Introduction

Military C3I (Command, Control, Communications and Intelligence) operations have come to rely upon Geographic Information Systems (GIS) to support both Situational Awareness and completion of mission tasks. Similar to commercial applications (e.g., Google Maps), military GIS platforms offer functionality to access geotagged information (e.g., data feeds from IoT sensors). These units of geotagged information, termed *Information Objects*, can provide users (e.g., Soldiers, military analysts) with expanded knowledge over areas of operation. In the context of tactical networking systems, challenges with Information Object management include [1]: (1) Content dissemination with limited networking resources and infrastructure; (2) Methods to account for Soldier cognitive load under varying mission conditions.

In prior research (e.g., [1-3]), challenges in network management for C3I operations have been addressed through adoption of policy-based dissemination, centered on assessment of Value of Information (VoI) specific to the needs of consumers. These efforts have focused on identifying methods for assessment of VoI specific to mission tasking and environmental context [4, 5], as well as development of systems to support policy-based content dissemination [6]. Within tactical networking research, VoI enhancements have demonstrated support for conservation of resources such as bandwidth [6]. By contrast, limited HCI research has been conducted to assess the impact of VoI on Soldier interactions with GIS software and any corresponding effects on Situational Awareness [7]. As such, new research becomes desirable to investigate: (1) The utility of VoI for supporting Soldier Situational Awareness over areas of operation; (2) Methods for conveying VoI of Information Objects to Soldiers in a readily understandable manner.

This paper presents foundational work being applied towards studying Soldier interaction with VoI-enhanced GIS applications, covering the design of a supporting experimental platform based on the Android Tactical Assault Kit (ATAK).

2 Background

2.1 Value of Information

In prior research, Value of Information has been defined along the notion of intrinsic vs. extrinsic attributes of Information Objects. Intrinsic attributes can be viewed as measuring the inherent quality of an Information Object, and will vary based on the type of content considered. Here, intrinsic attributes can be viewed as establishing the Quality of Information (QoI) for a particular Information Object. By contrast, extrinsic attributes measure the utility of an Information Object to meet a specific consumer's needs. Within the context of tactical operations, examples of extrinsic attributes could include temporal relevance (*will I need this information soon for my mission tasks?*), geographic relevance (*is this information from a mission-relevant location?*), and source reliability (*did the information come from a sufficiently trustworthy source for mission needs?*). Additionally, extrinsic attributes could measure presence of relevant information (*does this image contain mission-relevant features?*). Prior work has viewed VoI as inherently building upon QoI [1], while emphasizing the inherent difference between these assessment classes (i.e., an Information Object with high image quality may not have mission-relevant information, thereby having low VoI).

Within tactical networking systems (e.g., [1, 3]), quantitative VoI assessment has previously been applied to prioritize Information Object delivery to Soldiers, through weighted averages of *evaluation metrics* each corresponding to particular Information Object attributes. An example of a weighted metric average for VoI assessment [4] takes the following form:

$$VoI = (GR * w_{GR}) + (TR * w_{TR}) + (E * w_E) + (I * w_I) + (IC * w_{IC}) + (SR * w_{SR})$$

For each evaluation metric, a *quantitative value* is calculated along with a corresponding *weighting of importance*. In turn, the metrics listed in this equation can be defined as follows:

- **GR (Geographic Relevance):** Based a consumer's mission location(s). For example, the distance between where an image was taken and a Soldier's location.

- **TR (Temporal Relevance)**: Based on when an Information Object will be needed by a consumer for their mission tasks.
- **E (Expiration)**: Estimates when the content of an Information Object will become too stale for mission needs.
- **I (Importance)**: A value provided by a Subject Matter Expert (SME) or automated process, denoting an individual Information Object's importance specific to particular consumers and mission tasks.
- **IC (Information Content)**: An assessment of the intrinsic significance of an Information Object's content for particular mission needs, as defined by an SME or automated process.
- **SR (Source Reliability)**: An assessment of the reliability / trustworthiness of an Information Object's source or provider, as defined by an SME or automated process.

VoI assessment systems are seen as having a particularly rich set of research challenges, which include development of effective models for both Soldier context (e.g., concerning environmental/physiological factors) as well as mission state. Towards representing mission state, including mission tasks and events, recent efforts tied to semantic models of mission planning and execution (e.g., [8]) are of particular relevance.

In supporting Information Object management for tactical software systems, uses for VoI have previously included the following [1]:

- **Information Object Filtering,** where VoI acts as a filter over a set of available Information Objects (i.e., reducing the number of Information Objects displayed on a map).
- **Information Object Prioritization**, where VoI acts as a mechanism to support ranking or binning of Information Objects by their estimated value.

Within tactical networking research, VoI enhancements in both of these areas have demonstrated support for conservation of resources such as bandwidth [6]. However, limited HCI research has been conducted to assess the impact of VoI on Soldier interactions with GIS software and any corresponding effects on Situational Awareness [7].

2.2 Tactical GIS Platforms

Growth in availability of mobile computing platforms has prompted their increased usage in military operations [9]. Under these conditions, a number of C3I-oriented GIS systems have been developed for Android-based devices, which include: (1) Android Tactical Assault Kit (ATAK) [10]; (2) Kinetic Integrated Low-cost Software Integrated Tactical Combat Handheld (KILSWITCH) [11]; and (3) Tactical Ground Reporting System (TIGR) [12]. Common features of these platforms include:

- Presentation of map-based information using interfaces similar to available commercial software (e.g., Google Maps). An example screenshot from the ATAK platform is given in Fig. 1.
- Support for communication amongst Soldier teams.
- Support for downloading / uploading information corresponding to geographic areas of operation.

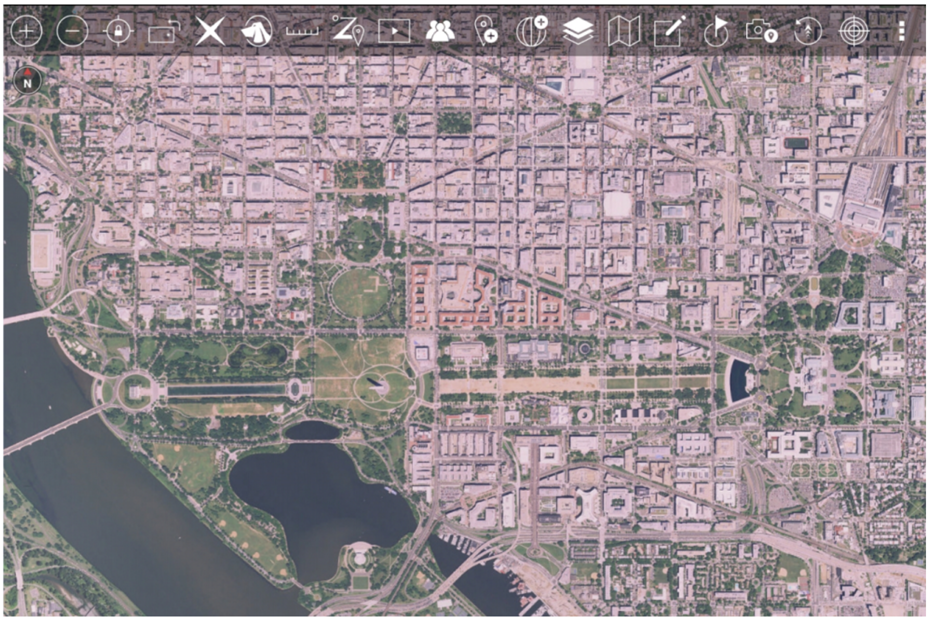

Fig. 1. Map display interface within Android Tactical Assault Kit.

3 Experimental GIS Platform for VoI Assessment

Towards investigating the utility of VoI in military GIS systems, a prototype experimental platform was defined and implemented for usage in mission scenario-based user studies. The platform implementation was based upon prior work with VoI extensions to the Android Tactical Assault Kit [3], and supports the presentation of mockup geotagged Information Objects across simulated areas of operation.

The purpose of this experimental platform is to support user studies involving two components: (1) Experimental Trials, in which participants review a set of Information Objects displayed on a map; (2) Recall Tasks, in which participants receive a set of questions to test their acquired knowledge of the Information Objects. At present, two varieties of experimental trials are being investigated for this platform:

- **User-driven Information Object Review:** Here, a set of Information Objects are displayed as icons on a map. Study participants can freely point-and-click on these icons, which in-turn displays details about the Information Object (e.g., details about an observed event or thing in the environment).
- **Simulation-driven Information Object Review:** Here, participants view a simulated patrol mission, in which a vehicle moves along a pre-defined route. As the vehicle moves along the route, Information Object icons are periodically displayed on the map, along with corresponding pop-ups containing observation details.

In both experiment varieties, different icons are assigned to Information Objects to represent different possible VoI scorings as assigned by the experiment setup. In the following sections, an overview of the experimental platform and its individual components will be provided.

3.1 Experimental Platform Design

Figure 2 depicts the system architecture for the experimental platform, which consists of the following components:

- **User Interface:** Based on the ATAK platform, this presents Information Objects during experimental trials, and sets of corresponding questions during recall tasks. Further details are provided in Sections 3.2 and 3.4.
- **Experiment Session Manager:** This manages content displayed on the user interface, and processes inputs received from study participants (e.g., interface interactions, question responses). Further details are provided in Sections 3.2 and 3.4.
- **Experiment Session KB:** This supports the generation of mockup Information Objects for experimental trials, as well as storage of vehicle routes to be used in simulation-driven Information Object review. Further details are provided in Section 3.3.
- **User Interaction Record KB:** This stores user responses to questions during the recall tasks, and additionally logs user interactions with the interface from the experimental trials (e.g., Information Objects clicked).

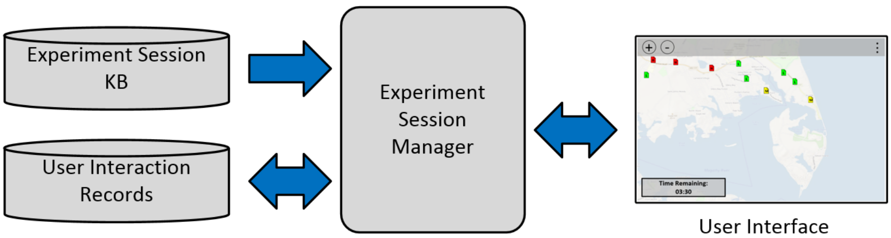

Fig. 2. System architecture for the experimental platform.

3.2 User Interface – Experimental Trials

The user interface for the experimental platform (as depicted in a session of the user-driven review mode in Fig. 3) consists of three components:

- **The Map Display**, in which an area of operations is presented along with icons depicting locations for Information Objects.
- **Information Object Popups (bottom right)**, which presents text-based details on an Information Object.
- **Timer (bottom left)**, indicating remaining time in the experimental trial. The timer may be enabled or disabled, depending on the type of experiment carried out.

Upon selection of an Information Object by the user (in the user-driven review mode) or a pre-determined simulation point being reached (in the simulation-driven review mode), an Information Object popup is displayed. Experimental trials are designed to stop under one of the following conditions: (1) non-timed: a participant indicates through the interface that they have completed their review; (2) timed: a participant runs out of time to continue reviewing.

Following completion of the Information Object review, study participants are given a set of questions corresponding to the Information Object content they reviewed. Types of questions supported by the experimentation platform are listed in Section 3.4.

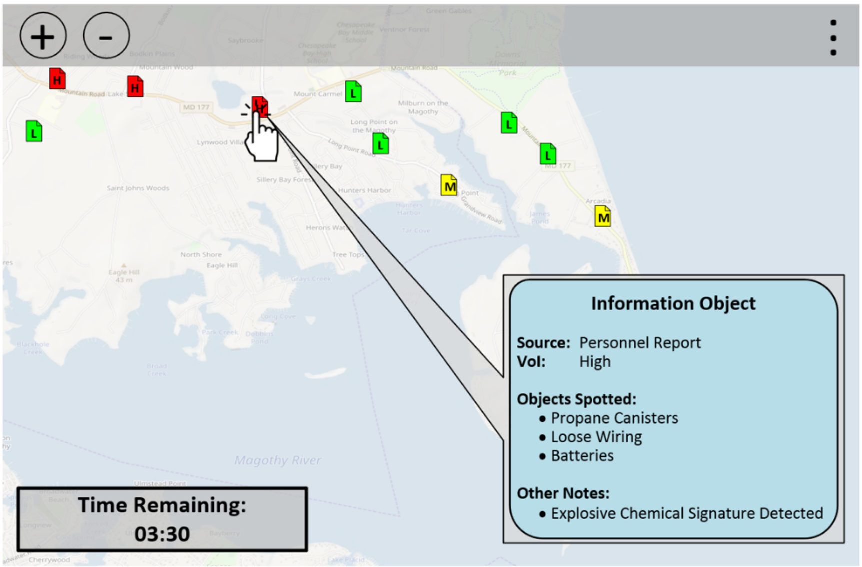

Fig. 3. User interface for the experimental platform, corresponding to the user-driven review mode. Here, clicking on Information Object icons produces a popup with corresponding details. Time remaining to review the Information Objects is provided in the bottom-left.

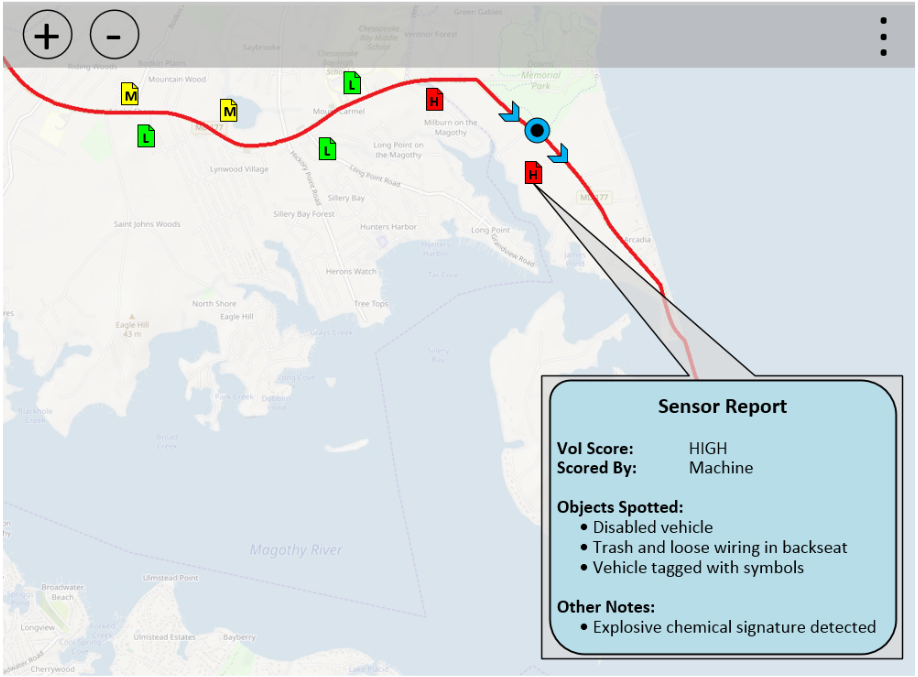

Fig. 4. User interface for the experimental platform, corresponding to the simulation-driven review mode. Clicking on Information Object icons produces a popup with corresponding details. Time remaining to review the Information Objects is provided in the bottom-left.

VoI Binning for Information Objects: Within the experimental platform, VoI for Information Objects can currently be binned into three scoring categories: *High VoI*, *Medium VoI*, and *Low VoI*. Fig. 5 depicts icons for each VoI binning category.

Fig. 5. VoI binnings implemented in the experimental platform, corresponding to High, Medium, and Low importance VoI categories.

3.3 Experiment Session Knowledge Base

The Experiment Session Knowledge Base supports the generation of mockup Information Objects for experimental trials, as well as storage of vehicle routes to be used in simulation-driven Information Object review.

The Knowledge Base supports generation of Information Objects in the form of text-based bulleted lists, corresponding to pre-determined topics. From the Map Display, Information Objects can be accessed by clicking on a corresponding icon (as depicted in Fig. 3) or through reaching a pre-determined simulation point (as depicted in Fig. 4). Upon clicking, the following Information Object content is presented:

- A topic
- A VoI score (Low, Medium, High)
- A source for the VoI score (which could indicate where the scoring came from, as well as scoring metrics used).
- A bullet list of 3-5 corresponding properties, each described in one to ten words

To date, Information Object content has been generated corresponding to the following topics:

- **Potential IEDs:** Sightings of possible IEDs, along with their visual properties.
- **Infrastructure Damage:** Descriptions of damage to infrastructure including as buildings and roads.
- **Vehicles:** Descriptors (e.g., make, color) for a particular vehicle.
- **Persons:** Descriptors (e.g., appearance, objects carried) for a particular person.
- **Signage:** Visual descriptors for signage.
- **Potential Events:** Sightings of potential events such as demonstrations.

3.4 Supported Recall Task Types

At present, the following types of recall task modes are supported by the experimental platform:

Free Recall Questions: For this, participants are asked to recall as much detail as possible about the Information Objects they reviewed. Following from the Information Object topics discussed in Section 3.1, these questions can include:

- What IEDs were detected?
- What infrastructure damage was detected?
- What vehicles were detected?
- What persons were detected?
- What signage was detected?

Fig. 6 illustrates a portion of the free recall interface, in which text-based responses are obtained for the listed questions.

Map Markup: For this, participants are asked to mark locations on a map where Information Objects were located, and provide the following details: (1) the Information Object type; (2) the VoI score; (3) the source that provided the VoI scoring; (4) any remembered properties of the Information Object; (5) a measure on how confident they are in the information remembered. Fig. 7 illustrates the map markup interface.

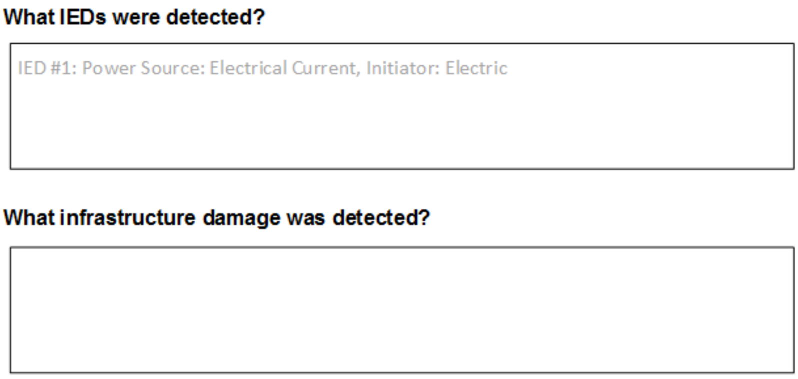

Fig. 6. A portion of the free recall interface, in which text-based responses are obtained for the listed questions.

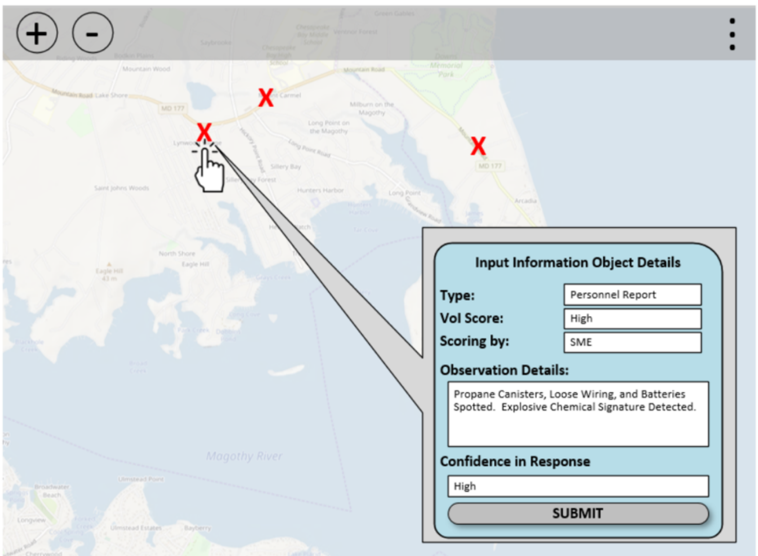

Fig. 4. The map markup interface.

Directed questions: For this, two types of questions are considered:

- Was any <*IO with Topic T*> with <*Properties X, Y, Z*> detected?
- In how many places were <*IO with Topic T*> with <*Properties X, Y, Z*> detected?

Fig. 8 illustrates a portion of the directed question interface.

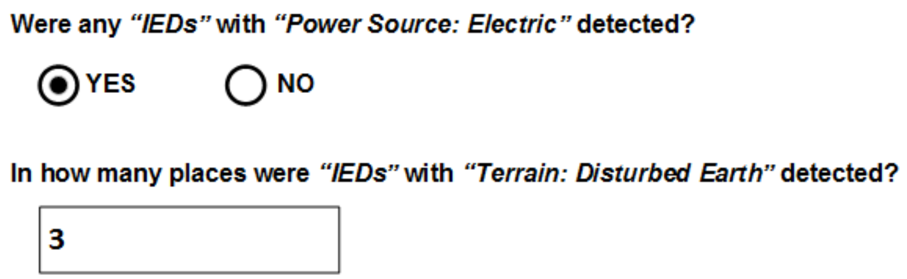

Fig. 8. A portion of the directed question interface.

4 Pilot Study

Towards testing the experimental platform for supporting VoI based studies, an initial pilot study was conducted with 44 Soldiers from the Canadian Royal 22nd regiment. For each participant, a sequence of two experimental trials in the user-driven Information Object review mode were conducted, each followed by a recall task. In the experimental trials, a series of Information Objects were depicted on the Map Display, where each could be clicked to produce an Information Object Popup. Experimental trials were timed, such that participants had 3 minutes per trial to review the Information Objects. Following each experimental trial, a recall task was given based on the free recall question mode. Following completion of both experimental trials and recall tasks, a post-experiment questionnaire was provided, which asked participants for general feedback on ways to potentially improve VoI presentation within the ATAK platform.

Analysis of the pilot study focused on review of: (1) Logs of Information Objects clicked by Soldiers during the simulated route review; (2) Responses provided during the recall task; and (3) Responses provided during the post-experiment feedback session. Findings from (1) and (2) indicate general inclination by participants to focus on review of higher-priority Information Objects, combined with a greater likelihood of recalling details about them.

5 Considerations for Future Studies

The pilot study discussed in Section 4 represented an initial attempt at assessing the impact of VoI on Soldier Situational Awareness. At present, several follow-on studies are envisioned, centering on the following themes:

VoI Presentation Mode: For the pilot study discussed in Section 4, the Information Object binning discussed in Section 3.2 was used, featuring three categories of importance (High, Medium, Low). Reflecting on previous implementation strategies for VoI systems (e.g., [1]), two alternative presentation approaches to compare against include: (1) Presentation of Information Objects labeled based on ranking of importance (e.g., 1st, 2nd, 3rd); (2) Presentation of Information Objects labeled with a raw VoI scoring (a numeric value calculated based on determined VoI factors).

Information Object Type: While the experimental platform has focused on supporting text-based Information Objects so far, other types of Information Objects are worth considering in future work. In particular, Information Objects based on images and other sensing data would reflect current usage scenarios for ATAK [3].

Explanation Interfaces for VoI: In real-world systems, scorings for Value of Information may be based upon a variety of separate factors (as indicated in Section 2.1), or on factors in which the scoring mechanism is not immediately intuitive (e.g., factors based on assessment of importance to mission tasks). Under such conditions, user trust in VoI scorings for Information Objects may be compromised. Therefore, investigation will be conducted into explanation interfaces for VoI calculations, and their impact on user trust of VoI scoring strategies.

6 Conclusion

Military C3I (Command, Control, Communications and Intelligence) operations at the tactical level have come to rely upon Geographic Information Systems (GIS), which commonly offer functionality to display geotagged units of information such as imaging feeds and personnel reports. Management of Information Objects within military GIS applications presents a number of known research challenges tied both to selection of mission-appropriate information and management of Soldier attention. Towards supporting content filtering and prioritization within tactical networks, methods based on the estimated Value of Information specific to mission and environmental context have demonstrated prior benefit (e.g., conservation of bandwidth). By contrast, limited research has been conducted to-date on Soldier interactions with VoI-based GIS applications. This paper presented foundational work being applied towards studying Soldier interaction with VoI-enhanced GIS applications, covering: (1) a supporting experimental platform based on the Android Tactical Assault Kit (ATAK); (2) a pilot study conducted with Soldiers, to assess the impact of VoI-based content prioritization on user experience and Information Object review.

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