Value-of-Information Driven Content Presentation and Filtering in Military Geographic Information Systems

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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 information relevant to mission needs. 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 prioritized content delivery and filtering within tactical networks, methods based on the estimated Value of Information (VoI) specific to mission context have demonstrated prior performance benefits (e.g., conservation of network bandwidth). However, limited HCI-themed research has been conducted to-date on Soldier interaction with VoI-augmented GIS applications, including assessment of their impact on situational awareness over areas of operation. This paper presents foundational work for studying Soldier interaction with VoI-augmented 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.

Keywords: C3I · GIS · Value of Information

1 Introduction

Military C3I (Command, Control, Communications and Intelligence) operations at the tactical level have come to rely upon Geographic Information Systems (GIS) made accessible through a variety of Portable Electronic Devices (PEDs). Similar to commercial mapping applications, military GIS software commonly offers functionality to access geotagged information (e.g., imaging feeds, personnel reports) for areas of operation. These units of geotagged information, termed *Information Objects*, can provide Soldiers with expanded knowledge over areas of operation for routine decision support tasks. Management of Information Objects in military GIS software presents a number of research challenges, including [1]: (1) Content dissemination with limited networking resources and infrastructure; (2) Content selection strategies that 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 content dissemination,

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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, from an HCI perspective, limited research has been conducted to assess the impact of VoI functionality 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: (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.

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. For instance, an Information Object corresponding to audio data could have intrinsic quality attributes of bit rate and sample rate. 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:

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

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 on where the data for a particular Information Object was obtained, relative to a consumer's mission location(s). For example, the distance between where an image was taken and a location of mission relevance.
- **TR (Temporal Relevance):** Based on when an Information Object will be needed by a consumer for 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.

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: Android Tactical Assault Kit (ATAK) [10], Kinetic Integrated Low-cost Software Integrated Tactical Combat Handheld (KILSWITCH) [11], and the 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), as depicted in Fig. 1.
- Support for communication amongst Soldier teams.
- Support for downloading/uploading information corresponding to a geographic area of operations.

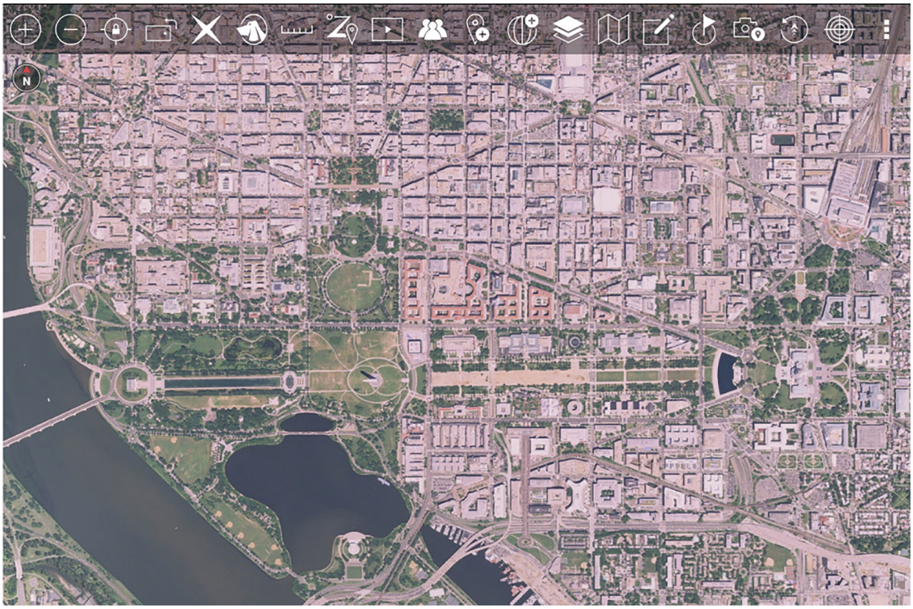

Fig. 1. ATAK user interface.

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 simulation 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 centered on two functional uses of VoI:

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

In both cases, supported experiments center on two phases: (1) experimental trials, in which participants review a set of Information Objects displayed over an area of operations; (2) recall tasks, in which participants receive a set of questions to test their acquired knowledge of the Information Objects.

3.1 Experimental Platform Design

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

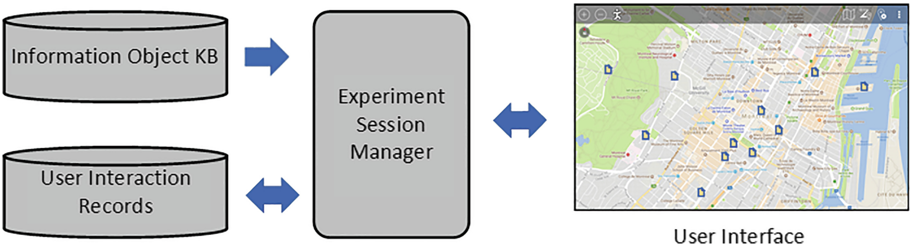

Fig. 2. System architecture for the experimental platform.

- **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 Sect. 3.2.
- **Experiment Session Manager:** This manages content displayed on the user interface, and processes inputs received from study participants (e.g., interface interactions, question responses).
- **Information Object KB:** This supports the generation of mockup Information Objects for experimental trials. Further details are provided in Sect. 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).

3.2 User Interface – Information Object Review

The user interface for the experimental platform (as depicted in Fig. 2) 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 to review information from the area of operations. The timer may be enabled or disabled, depending on the type of experiment carried out.

Similar to current usage of ATAK, user interaction is driven through point-and-click selection of Information Objects within the Map Display to review their content, as presented through Information Object Popups. 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 Sect. 3.2) (Fig. 3).

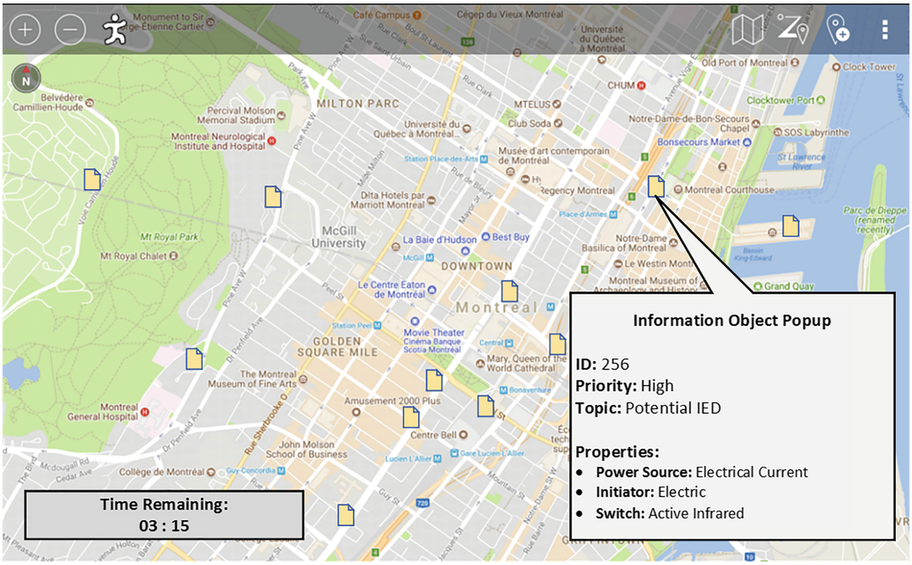

Fig. 3. User interface for the experimental platform, based on ATAK implementation.

VoI Binning for Information Objects: Within the user interface, VoI for Information Objects can be binned into three scoring categories: *High VoI*, *Medium VoI*, and *Low VoI*. Figure 4 depicts icons for each VoI binning category.

Fig. 4. VoI binnings implemented in the experimental platform, corresponding to Low, Medium, and High importance VoI categories.

3.3 Information Object Knowledge Base

To support generation of Information Objects for experimental trials, the Information Object Knowledge Base supports generation of Information Objects organized in the form of 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. 2). Upon clicking, the following Information Object content is presented:

- A Numeric ID
- A Priority Level (Low, Medium, High)
- A Topic
- A Bullet List of 3–5 corresponding properties, each described in one to ten words

At present, 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 Sect. 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?

Figure 5 illustrates a portion of the free recall interface, in which text-based responses are obtained for the listed questions.

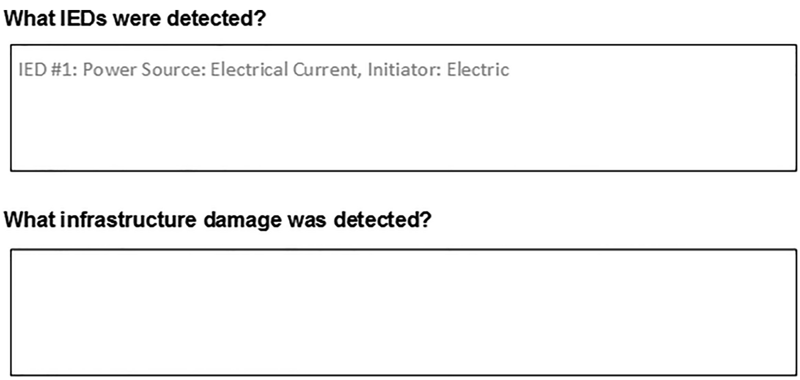

Fig. 5. A portion of the free recall interface, in which text-based responses are obtained for the listed questions.

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 topic; (2) priority level; (3) any remembered properties of the Information Object. Figures 5 and 6 illustrates the map markup interface.

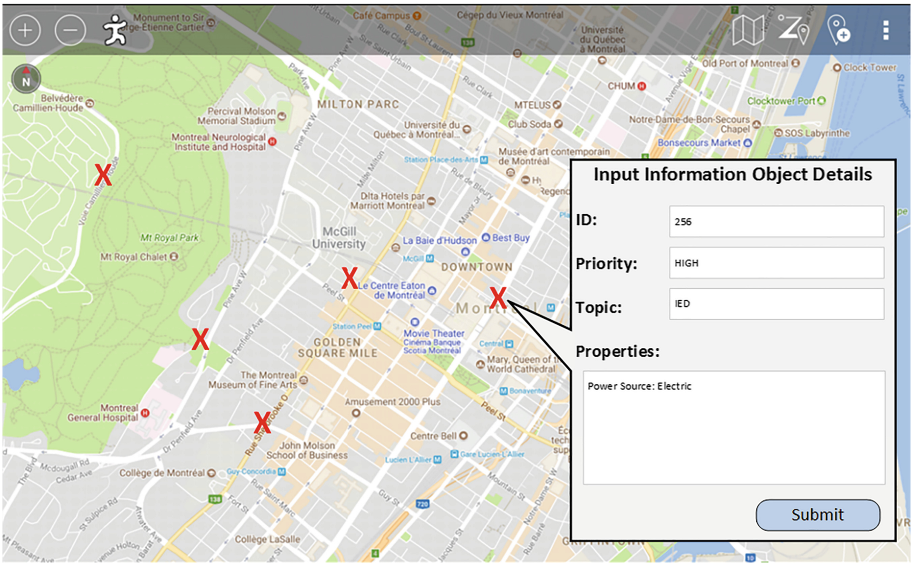

Fig. 6. The map markup interface.

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?

Figure 7 illustrates a portion of the directed question interface.

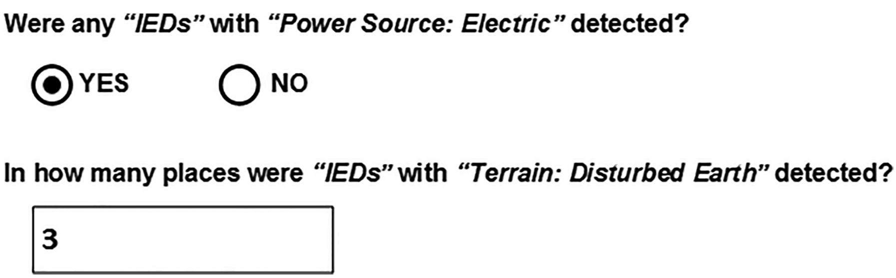

Fig. 7. A portion of the directed question interface.

4 Pilot Study

Towards testing the experimental platform for supporting VoI based studies, an initial pilot study was conducted with 44 participants from the Canadian Royal 22nd regiment. For each participant, a sequence of two experimental trials for a simulated mission 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 min 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 questionnaire. 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 represented an initial attempt at assessing the impact of VoI on Soldier Situational Awareness, in addition to testing the experimental platform. At present, several follow-on studies are envisioned, each involving separate extensions to the experimental platform and centering on the following themes:

VoI Presentation Mode: For the pilot study discussed in Sect. 4, the Information Object binning discussed in Sect. 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].

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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