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Concepts and technologies for a knowledge environment supporting situation awareness

Topic: C2 architectures

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Abstract

Military commanders and staff operating in a net-centric command and control setting are overwhelmed by an increasing number of information sources that are made available to them. Significant research has been achieved for a few years to provide military decision makers and operators in command centers with knowledge management tools and services that help gain situation awareness, such as enterprise knowledge portals. Many challenges remain in order to improve knowledge management services and provide users with information that is relevant to their operational goals in order to enable a better comprehension and interpretation of ongoing situations in context. Semantic technologies and ontologies can play a role in supporting information integration, annotation of unstructured information sources, enhanced search and retrieval from heterogeneous sources, and intelligent notification that would highlight key information or events without overwhelming the users. The paper reports on research aimed at building a knowledge environment for enhanced situational awareness, leveraging from recent advances in Web technologies. We will review the requirements for knowledge management services, and we will highlight promising techniques, technologies and standards related to service-oriented architectures, Semantic Web, ontologies, and intelligent agents, that could be used in this context.

Keywords: knowledge portal, situational awareness, ontologies, semantic web.

1. Introduction

Military commanders and staff operating in a net-centric command and control setting are overwhelmed by an increasing number of information sources that are made available to them. The ability to adequately access, share and organize information is essential to develop effective situational awareness (SA) and decision-making. Systems supporting the development of a common operational picture for enhanced SA make use of various information or knowledge management (KM) techniques and technology. In particular, techniques can be used to automate tasks such as automatic document metadata tagging, information extraction from unstructured text, organization of document repositories according to predefined domain taxonomies or more dynamic structures. From the user side, services include advanced federated search engines, browsing information and drill-

down into details, notification and alerts based on user criteria, graphical visualization mixing maps and textual information, etc. In such environments, contextualization based on various dimensions (e.g. users' mission, role, domain of interest, information requirements), is key to facilitate the users' focus of attention on priorities. Adaptive intelligent interfaces are also important to design configurable environments that meet the users' informational needs.

Significant research work and results have been achieved for a few years to provide military commanders and their staff in command centers with tools and services that help gain situation awareness, such as enterprise knowledge portals. For example, within the Canadian military, the Joint Intelligence and Information Fusion Capability (JIIFC) aims at providing commanders and decision-makers with the timely, relevant and fused operational information that supports their shared situational awareness and the decision making crucial to their mission. They are developing a Command View portal that provides commanders with strategic situational awareness view of ongoing operations, events, incidents and high risk areas of the world, and include all available relevant information from all levels of command essential to effective command decisions.

However, many challenges remain in order to provide added-value to these information products. Advanced KM services could be integrated making use of recent techniques and technologies, for example:

- Information packaging according to users roles, tasks and interests, to enable a better comprehension and interpretation of ongoing situations in context while facilitating analysis and prediction;
- Semantic technologies and ontologies for the annotation of unstructured information sources, that could play a role in supporting information integration, and enhanced search and retrieval from heterogeneous sources;
- Intelligent notification in order to highlight key information or events without overwhelming the users;
- Collaboration functions for shared situational awareness.

The paper reports on research that aims at building a knowledge environment for enhanced situational awareness, leveraging from recent advances in Web technologies. We will review the requirements for KM services, and we will highlight promising techniques, technologies and standards related to service-oriented architectures, Semantic Web, ontologies, and intelligent agents, that could be used in this context.

2. Knowledge management through portals

With the ever increasing volume of information made available with network-centric warfare, it is more and more difficult for users to find, organize, access and maintain information that is relevant for their tasks. Consequently, good information and knowledge management is necessary. Enterprise portals are recognized as an enabling technology to meet the requirements of net-centric operations or warfare by facilitating

organizations to access, to share and to manage information and knowledge. In particular, enterprise knowledge portals offer a set of services as their core functionality including: personalized access, search, filtering of content, content management, notification, collaboration, and configurable user interfaces mixing maps/graphics and data with possibility to drill-down into data.

In a previous technology demonstration project conducted at DRDC Valcartier, the concept of a knowledge portal to support situational awareness and decision-making was proposed and implemented using Enterprise Portal technology [Gouin et al, 2005]. It reflected the vision of a user-centric, mission-oriented knowledge portal described in [Gauvin et al, 2004]. In particular, it provided capabilities such as: single point of access to multiple sources, integration of application services, filtering and packaging of information sources in portfolio views, dissemination of information using portfolios, contextual search services, and web-based geographical information services. The main capabilities of relevance are summarized below.

Information packaging using portfolios

A key notion within the knowledge portal is the portfolio concept and associated context to organize and package information related to an activity. Portfolios act as virtual containers where the user can filter and categorize the information based on the interventions (e.g., peace support, crisis management) and his tasks (e.g. monitoring, planning). This way, it allows staff officers to easily assemble the information needed to carry out the tasks related to that portfolio. Portfolios can be assigned to a user or shared by a group of users. Some metadata are used to manage the portfolios and associated context.

Search

An integrated search tool allows users to submit searches based on metadata, so that results can be contextualized to the portfolio parameters. Moreover, persistent queries in the form of agents can be pre-configured to automatically find documents relating to a particular concept of interest. The search tool used within the project's knowledge portal was based on the commercial tool Autonomy, which relies on Bayesian probabilistic pattern-recognition algorithms.

Notification and dissemination

Notification and dissemination of critical information to users are performed through portfolios. As new information is added or updated in a portfolio, the information becomes available to all users registered to that portfolio. Users are automatically notified of new information or change in a portfolio through an event notification tool. It is also possible as a result of the Web Services based architecture for other applications or portals outside to the portal to access the portfolio services.

Beside the asynchronous collaboration in the form of notification and alert, synchronous collaboration such as chat or white boarding allows users to interact with each others and is useful to develop shared situational awareness.

Related work

Several research initiatives also aim at providing users with tailored situational awareness environments to better satisfy operators and decision-makers' information needs. An example is the user defined operational pictures (UDOP) capability whose purpose is to create, visualize and share decision-focused views of the battlespace to support situation awareness and decision-making [Mulgund et al, 2007]. It aims at building operational pictures in which users (or communities of users) can select the information they want to be included in the COP, based on various dimensions of operational information requirements. Another example, TIDS (Tailored Information Delivery and Service) [Corbin et al, 2007] provides information filtering mechanisms from multiple sources based on the accuracy of the sources and users' information needs within a multi-agent architecture.

Within such environments, both *pull* (search and discovery) and *push* (notification and alert) mechanisms are required to meet operators various information needs. In the first case, the user proactively seeks for relevant information in a particular situation context. In the second, agents monitor the sources to find information corresponding to users' operational critical information needs or significant events, in order to provide Valuable Information at the Right Time (VIRT) [Hayes-Roth, 2006]. With push, a key challenge is the identification of these conditions of interest to be monitored by agents. In any case, software monitoring or search agents have to be smart enough to match users' needs with available information sources. For this to happen, semantic mapping has to be applied between information producers and consumers.

In the next section, we present advances in web standards and technologies, and how they could contribute to the evolution of the portal concepts as described above.

3. Web technologies

There are two main approaches related to the evolution of the Web that are of interest for knowledge management, namely the Semantic Web and the Web 2.0. Synergies between these approaches could be leveraged so that knowledge management can benefit from them. In the next sections, we review the concepts underlying these approaches and give examples of how they could be applied within next-generation web-based C2 systems in support of situational awareness and sense-making activities.

The Semantic Web

According to [Berners-Lee et al, 2001], the idea of the Semantic Web is to extend the current human-readable web by encoding some of the semantics of resources in a machine-processable form. Moving beyond syntax opens the door to more advanced applications and functionality on the Web. Computers will be better able to search, process, integrate and present the content of these resources in a meaningful, intelligent manner. The core technological building blocks include ontology languages, flexible storage and querying facilities, reasoning engines, etc. that are being formulated under the auspice of the World Wide Web Consortium (W3C).

For a few years, the investigation of semantic web technologies and standards within research projects is increasing, and a growing number of international conferences (e.g. International Semantic Web Conference, Semantic Technologies conference, etc.) and journals (e.g. International Journal of Semantic Web and Information Systems) are devoted to the subject. Research areas focus on developing ontological engineering methods and tools, techniques for ontology mapping, merging or alignment, exploitation of ontologies for effective knowledge retrieval and sharing, or ontology-based information integration over heterogeneous sources. Semantic Web techniques are also exploited for the building of applications that integrate, combine and deduce information needed to assist users in performing tasks. In a net-centric setting, producers and consumers of information have to share a common vocabulary and semantics, either through a common ontology or by using mechanisms for solving semantic mismatches that may occur.

We present below some of the concepts and techniques in the Semantic Web area that may contribute to enhanced situational awareness in a net-centric command and control context.

Metadata and ontologies

Metadata and ontologies are the cornerstone of the Semantic Web. Ontologies provide a formal means for knowledge producers to structure, access and share their knowledge effectively. This vision has led to the development of languages to facilitate the representation and management of knowledge on the Web, in particular RDF (Resource Description Framework) and OWL (Web Ontology Language). The purpose of formal ontologies for the Semantic Web and the OWL proposal was to facilitate an understanding of web content to enable dynamic resource discovery, effective search and retrieval, composition of semantic services, etc. [Berners-Lee et al 2001]. For web resources to be automatically exploitable by machines, information must be enriched with metadata with precise semantics. RDF is a XML-based language that can be used for describing metadata of web resources. Metadata sets associated to information resources include domain-independent metadata elements (e.g. Dublin Core) and semantic metadata representing domain specific elements using the vocabulary of the domain. Traditionally, the annotation or metadata tagging process is done manually, but text mining techniques can be used to automate the metadata annotation process, with human validation exploiting ontology-based controlled vocabulary.

In order to represent domain knowledge with more expressive semantics (objects' properties, relationships, constraints), OWL-DL, the version of the OWL language based on Description Logic has become popular due to its expressiveness and tractability. It is thus the appropriate ontological language candidate when the reasoning capabilities it offers are to be exploited.

Ontologies have been considered as a key component for semantic information integration among heterogeneous sources, and this is a challenge within knowledge portals as well. However, different approaches are possible for semantic integration: annotate information sources according a standard common ontology, or having each data

information source producer use its own ontology. The second approach, while simplifying metadata tagging at the producer side in distributed context requires ontology mapping mechanisms.

Within a knowledge-based situational awareness portal environment, ontologies are used to represent domain knowledge and to support knowledge management services. The scope of ontologies in this context could cover various sub-domains, such as knowledge about military equipment, weapon, geography, and organizations (mission, responsibilities) to name a few. The notion of context presented in the previous section could also be modeled by using ontologies along different dimensions (user profile and preferences, working domain and processes, interaction requirements). It could then be exploited to provide users with contextualized services. In particular, as users want to be notified of critical events, an ontology describing the types of events that may occur could serve as a basis to specify alert conditions.

Search, inferencing and reasoning

According to T. Berners-Lee Semantic Web stack, the inferencing capability constitutes the logic layer of the Semantic Web. The semantics of the OWL language (in particular the DL variant) supports basic types of inference such as subsumption reasoning that can be used for knowledge classification. To support activities such as situation monitoring and sense-making tasks, more sophisticated reasoning schemes are needed. Various formalisms have been proposed to reason on top of Semantic Web standards, for example RuleML, or Semantic Web Rule Language (SWRL). As an example, S. Stoutenburg et al. [2006] exploit SWRL and ontologies to construct a dynamic web service for semantic web-based decision support in a military context. Based on an ontology represented in OWL, a set of rules in SWRL and instances, the reasoning service detects events and triggers rules to determine standard operating procedures based on visibility and threat conditions and provides alerts and recommendations. Such semantic rules and reasoning could be exploited in a portal environment to provide advanced “business intelligence” capability on top of the basic knowledge management services. However, the authors noticed that the semantics of rule languages such as SWRL does not provide support for reasoning capabilities that are required in the military context, in particular uncertain and non-monotonic reasoning. Consequently, these rules can be translated to a logic programming language to overcome some limitations and for efficient reasoning.

Inter-portlet communication

Applications in a portal are represented by portlets that are reusable software components. An important aspect is the integration of external applications to bridge structured and unstructured information through context-based portlet integration. T. Priebe proposed in the INWISS portal prototype [Priebe 2005] to use Semantic Web standards and technologies to represent and map the semantics of the context elements between portlets to enable semantic-aware inter-portlet communication. It uses RDF to represent the context (i.e. portlet content is annotated with RDF metadata). OWL concept mapping and an inference engine can be used to map the concepts used by the context provider to objects from an enterprise ontology. This way, portlets can be developed without taking into account with which other portlets they might be integrated.

Semantic web services

Web services in service-oriented architectures are traditionally exposed and invoked using discovery (UDDI), binding (WSDL), and messaging (SOAP) technologies.
To make use of a web service, software agents need a computer-interpretable description of the service and the means for access it. Semantic Web services combine Semantic Web and Web Service technologies to provide greater expressiveness for describing services in a way that software agents can reason about. Enhancing information source discovery is critical in dynamic environments. These technologies can be used to create more powerful tools and more fully automated approaches to Web service tasks such as service discovery, selection, interoperation, enactment, and composition. Languages and ontologies for semantic description of Web services and semantic annotation of content of services have been proposed to the W3C, for example: OWL-S (an ontology for describing Web Services based on OWL), WSMO (Web service Modeling Ontology), SWSL (Semantic Web Service Language), WSDL-S (Adding Semantics to WSDL), SAWSDL (Semantic Annotation for Web Service Description Language), to name a few.
Using these approaches, web services can be agent-discoverable, invocable and composable unambiguously. Although the domain is still evolving in terms of standards and technologies, some prototypes have been developed in the military domain or other contexts involving multiple organizations and dynamic business processes (e.g. search and rescue). Such concepts and technologies could also be exploited in several military application domains, in particular in the context of crisis management or emergency response.

Web 2.0

The Web 2.0 corresponds to the current state in web engineering, but evolves from classical web technologies in its social networking aspect [Reilly, 2005]. It focuses on distributed collaboration between people, in particular in communities of interest. The so-called social web aims at facilitating interaction between people so that they collaboratively contribute to the construction of some domain knowledge content by sharing their experiences, information, knowledge, or views on a domain. The social web concepts and technologies can be exploited to provide web-based knowledge management systems, by exploiting their underlying flexibility. In some cases, they could benefit from the Semantic Web concepts and technologies, to benefit from both worlds.

Wikis

The most popular example of Web 2.0 product is the large online source of encyclopedic knowledge Wikipedia, where content is continually enriched by contributors that produce web pages in their domain of expertise. This large-scale repository is composed of structured knowledge whose content elements are interrelated using hyperlinks and flexible categories.

Wikis are web sites whose content can be collaboratively enriched by anyone who wants to provide new elements, updates, or add comments related to the knowledge content. Wikis provide a flexible means to acquire expertise incrementally and build structured

content. In the command and control context, wiki technologies can be exploited by enabling military operators to contribute to the common operating picture by collaboratively updating elements of the evolving situation in the environment. In particular, wikis could be associated to knowledge objects to collaboratively build, maintain and update content for the COP (post information, add comments, start discussion, etc.). Some research investigations are being conducted in this area to demonstrate the benefits and the flexibility of this technology. SmartCOP [Whitt, 2005] provides a software environment that integrates shared workspaces and organizes constructs based on Wikis with the Common Operational Picture (COP). A smartPage is a wiki page associated with a tactical object (e.g. a track) on a map, or a mission object. Users can contribute information on tracks of interest (resp. mission) by publishing directly to the track's SmartPage (resp. mission page). Users can cooperatively view, revise, comment the published information, and subscribe to updates/changes to the information. As part of another initiative, [Brannstrom et al, 2006] have implemented the MilWiki knowledge base using wiki technology. This knowledge base is enriched incrementally with background and operational information. One particular feature of their proposal is the capability to link a wiki page to geo-reference coordinates using specialized geo-tags.

This technology seems suitable to dynamically and collaboratively collect and share the situation picture. However, as mentioned in [Brannstrom et al, 2006], for security and trustability reasons, editing should be restricted to authorized users, and the reliability of information could be controlled using quality markers, in order to highlight the quality of content.

Moreover, additional efforts are required to add explicit semantics in wikis, in particular by typing the links relating knowledge structures (e.g. actions, arguments). By enriching wiki contents with semantic metadata based on W3C standards, such as RDF and OWL, semantic wikis can be exploited by semantic tools (e.g. semantic queries using the SPARQL query language). For example, in a situational awareness knowledge environment, relations between events and/or incidents could be represented explicitly using semantic links. The knowledge base can then be queried accordingly.

4. Conclusions

In the age of information and network-centric warfare, advanced knowledge management tools have to be provided to commanders and their staff in support of shared situational awareness development. The ability to adequately access, share and organize information is essential to develop effective situational awareness and decision-making. Web-based enterprise knowledge portals provide environments that offer core functionalities to access, share and manage information and knowledge. However, enhanced knowledge management techniques and tools are required to ensure that information of contextual relevance is provided to users. Mechanisms are required both at the producers' side to support knowledge authoring enriched with semantics, and at the consumers' side for personalized knowledge organization and exploitation.

While semantic technologies are key to provide such services, the building and exploitation of domain ontologies that cover a large scope is a challenging task. Standard ontology languages with sufficiently expressive power (such as OWL-DL) require expertise in knowledge representation and engineering, and usually the contribution of subject matter experts. Consequently, knowledge management requirements have to be analyzed to determine if it is critical to have a formal ontology language and inference capabilities for advanced reasoning over heterogeneous sources, or if ontologies are to be exploited mainly to support annotation of unstructured documents with ontology-based vocabulary for enhanced information access, search and retrieval. In this latter case, lightweight ontology formalisms (OWL light, RDF) may be sufficient.

With the ever growing amount of unstructured information sources, some challenges remain to automatically add semantic metadata, extract relevant knowledge from texts using techniques such as text mining, or link analysis. These techniques should highlight relationships among the set of information made available in net-centric context, coming from heterogeneous information/knowledge sources, either from individual sources or from information products built collaboratively (e.g. wikis, chat).
Finally, software agents could be exploited not only as search agents or for monitoring purposes, but also to add learning mechanisms in knowledge management environments, to dynamically manage users' situational context, models, actions (and results) and exploit these knowledge for further reuse.

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