A Decision-making Format for the Semantic Web

[Position Paper]

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ABSTRACT

This paper describes the work of the W3C Decisions and Decision-making Incubator[1], with the goal to identify requirements for a standard decision format, through a set of use cases, and to develop a first version of a potential standard format for representing decisions, fulfilling the requirements of the use cases and exploiting semantic web standards. Ongoing efforts include the identification and modelling of 'decision patterns' and development of proof-of-concept applications to validate assumptions and patterns.

Keywords

Decision Making, Decision Format, Ontology Pattern

1. INTRODUCTION

The time and effort we spend converting our decisions into work products, such as briefs, proposals, and communication of decisions in meetings, conversations, and emails, could be reduced if we had a standard format for representing and sharing decisions. Our tools could be instrumented to generate our decisions in a format that could be shared and also track the state of decisions within the decision-making process. Instrumentation could support the development of a metric of information flow and help us optimize our decision processes across our organization or enterprise [7]. Visibility of the decisions in their formation and evolution would enable proactive management and assistance from others [8].

1.1 Usage Scenarios

Sharing decisions across a broad and diverse set of users and systems is an important aspect of situational awareness in many domains, for instance, in emergency management[2]. During an emergency, decisions must be shared among emergency managers and first responders from multiple organizations, jurisdictions, and functional capabilities. For example, decisions to route patients must be shared among first responders in the field who are sending the patients, those who are doing the transport, the medical facilities receiving the patients, and the patient's families and relatives.

First responders and emergency managers work under difficult conditions using current mechanisms for information sharing; they need improved solutions. For example, paper-based Incident Command forms provide an initial standardization of emergency information[3]. An Incident Command Structure (ICS) can organize responders into a hierarchical structure of sections (e.g. Operations, Planning, Logistics, Finance) and roles (e.g. Incident Commander, Public Information Officer, Safety Officer)[4]. XML-based standards are being developed to improve sharing of emergency information. The Organization for the Advancement of Structured Information Systems (OASIS) has a family of standards known as the Emergency Data Exchange Language (EDXL)[5]. The Emergency Data Exchange Language Common Alerting Protocol (EDXL-CAP) exemplifies simple, useful, and understandable information-exchange formats. What EDXL-CAP did for alerts, a Common Decision Exchange Protocol (CDEP) could do for decisions [6].

An important next step is to utilize the semantic web standards, including RDF, SPARQL, OWL and GRDDL to integrate information for dynamic queries across datasets, and for inferencing using the underlying ontologies (e.g. indicating that the emergency equipment named X in one jurisdiction is the same as the type named Y in another jurisdiction). Initial steps in this direction are already being taken, e.g., through the OASIS Distribution Element (DE) supporting packaging and addressing of emergency management information for purposes such as routing. The standard has links to externally-managed 'lists' representing concepts such as 'senderRole', 'receiverRole' and 'keywords'. Ontologies should encapsulate, in a machine-understandable manner, such information sharing policies. Implicitly present is the underlying decision-making process, continuing at all levels through an emergency. The decision format advocated in this paper will support the move toward the use of linked data [1], and the recognition of the significance of information sharing policies utilizing semantic standards.

The need for representing, sharing and managing decisions in a machine-understandable format is not exclusive to emergency management. One example of another critical

[1]For more information, or to participate in the Decisions Incubator, please review the charter at http://www.w3.org/2005/Incubator/decision/charter and visit the wiki at http://www.w3.org /2005/Incubator/decision/wiki/Main_Page.

[2]For more information on emergency and incident management, see for example the National Incident Management System, December 2008, published by the U.S. Department of Homeland Security at http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf.

[3]For examples of incident command forms, see http://training.fema.gov/EMIWeb/IS/ICSResource/ICSResCntr_Forms.htm.

[4]For more information on ICS, see the online training provided by the U.S. Federal Emergency Management Agency, Lesson 3, at http://emilms.fema.gov/IS100A/indexMenu.htm.

[5]For a good overview of EDXL, see http://en.wikipedia.org /wiki/EDXL. The EDXL family of standards is available at the OASIS website: http://www.oasis-open.org/home/index.php.

domain of interest is organizational innovation. Each person is a 'decision-maker' at some level in the organization. The decisions a person makes are critical to the success of an organization, so aspects of decision-making and objective measures of the decision-making process become significant. Decisions involve weighing reasonable options based on metrics in order to take an action. If we granulize the decision-making process by considering each member of our organization as a decision-maker, then we can support the representation and sharing of individual innovative actions. Most organizations attempt to solve this problem through direct or indirect person-to-person communication (e.g., meetings, telecons) or unstructured collaborative tools (email, chat, wiki). XML formats can support notice-type publishing of activities, e.g, RSS or ATOM feeds; however, there remains an opportunity to showcase semantic standards to capture decision-making to improve the querying, inferencing, and integration with underlying ontology support.

The focus of this paper is on the information sharing aspects of a decision, which is fostered by a format which is concise, generic, i.e., domain independent, and tiered. The more concise the format, the more quickly it can be understood and accepted by developers and users alike.

1.2 Project Goals

The work performed by this incubator activity is designed to help organizations improve integration of human decisions into computer systems, to track and manage digitally the decision-making process, to enable improved information-flow metrics, to maintain an archive of the decisions and the decision-making process, to enable semi-automation of certain decision-making processes, to improve information sharing, and ultimately, to support better, rapid, and agile decision making [7]. The potential standard format should provide concise, generic, structured assessments and decisions that allow 'drill down', support pedigree and confidence, enable approvals and vetting, define options considered, including decision criteria with weighting, links to previous decisions and sub-decisions, and support flexible structuring of complex decisions [7]. However, to reach its full potential, the proposed decision format must be compatible with semantic web tools and standards, to provide semantic interoperability and to provide a basis for reasoning that can ease development of advanced applications.

In summary the main goals of the incubator are:

- To discover a set of requirements for a standard decision format, through a set of use cases.
- To develop a draft of a potential standard format for representing decisions, fulfilling the requirements of the use case and exploiting semantic web standards.

2. METHODOLOGY BACKGROUND

Creating a vocabulary for expressing decisions that exploits semantic web standards means, in practice, creating a set of ontology modules that can be linked in a network, to be used independently or together in different combinations. The main tools we use for this practical task is the eXtreme Design ontology engineering methodology and the notion of Ontology Design Patterns (ODPs), supported by the ontology development environment NeOn Toolkit[6].

[6]http://www.neon-toolkit.org

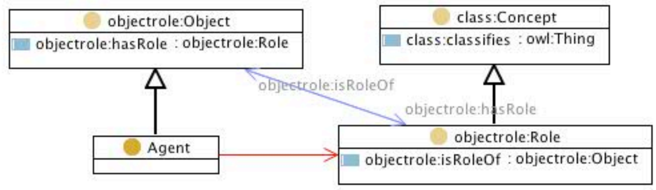

Figure 1: The AgentRole Content ODP's graphical representation in UML.

2.1 Ontology Design Patterns

Under the assumption that classes of problems in ontology design can be solved by applying common solutions (as experienced in software engineering), ODPs can support design reusability. ODPs can be of several types [3], e.g, focusing on logical language constructs, architectural issues, naming, or on the efficient provision of reasoning services. In this paper we focus on Content ODPs (CPs), which are small or cleverly modularized ontologies with explicit documentation of design rationales. CPs can be used as building blocks in ontology design [2]. As an example we describe a CP called AgentRole. It represents the relation between agents, e.g., people, and the roles they play, e.g., manager and meeting chair. Figure 1 shows the UML diagram[7] of the OWL[8] building block representing this CP.

CPs are collected in different catalogues, such as the *ODP portal*[9]. In addition to their diagrammatic representation, CPs are described using catalogue-entry fields (c.f. software pattern templates), such as *name*, *intent*, *covered requirements*, *consequences*, and *building block*, linking to an OWL realization of the pattern. The requirements an ODP covers are expressed using Competency Questions (CQs) [4], i.e., typical natural-language queries.

2.2 eXtreme Design

With the name 'eXtreme Design' (XD) we identify an agile approach to ontology engineering [5]. In this paper we focus on XD for CP reuse in ontology design. In XD a development project is characterized by two sets: (i) the problem space, composed of the actual modeling issues (local problems), e.g., to model steps in a decision making process; (ii) the solution space, made up of reusable modeling solutions, e.g., a piece of an ontology that models sequences of events (a CP). Each CP, as well as the local problem, is related to ontology requirements expressed as CQs or sentences. If a local problem can be described in terms of the CQs of a CP then that CP can be reused for building the solution. XD does not prescribe a specific method for matching the local problem to patterns, and at the moment the only tool support available are search functionalities utilizing the textual descriptions of the patterns.

XD is a test-driven and task-focused approach that results in highly modular ontologies. The main principles of XD include the intensive use of CPs, and extensive collaboration [5]. The iterative workflow of XD contains 12 steps. The project is initiated in the first four steps, which in-

[7]For notation details, see: http://www.topquadrant.com/products/TB_Composer.html

[8]http://www.w3.org/2004/OWL/

[9]http://www.ontologydesignpatterns.org

clude, scoping, and requirements engineering (e.g., deriving the CQs from user stories). In steps five through nine the CQs are divided into into small, coherent sets and ontology modules produced realize those sets of CQs. These steps include unit tests on each module before its release. The three final steps integrate modules into a coherent solution, focusing on collaboration and integration.

3. ONGOING WORK

In this section we describe our ongoing efforts and how we apply the XD methodology to support these efforts. We proceed in a bottom-up fashion, starting from the use cases and deriving requirements for a representation format that can be realized as ontology modules based on ODPs. However, we have also encountered a number of cases where this leads to the development of general ODPs themselves.

3.1 Use Cases

Use cases are in our context general scenarios, horizontal with respect to application domains (i.e., they are represented in multiple domains), where the envisioned decision format can give some substantial benefit. So far, five use cases have been identified (the list is continuously extended). The use cases are intended to be general and not domain specific, in terms of industry domain. Their detailed description, including resulting requirements in the form of CQs can be found in the Incubator wiki[10]. Background and related work for two of the use cases are described more in depth in Sections 3.1.1 and 3.1.2.

- **Measuring Information Flow** - Where a decision process representation can help answering questions such as 'When did a certain process begin and end?', 'How much time was spent on a certain step in the process?', and 'What is the average time for making a certain type of decision?'.

- **Linked Data Supporting Decisions** - Where linked data [1] supports decision making, and a decision representation format could help answer questions such as 'What data support this decision?', 'What were the options and the criteria used for this decision?', and 'How were the options assessed?'

- **Automatic Assessment of Options** - Where a decision format is intended to support semi-automatic decision making by automatic assessment of options through some metric. In this case questions are for instance 'What are the metrics for this decision and to what options do they apply?', 'What are the relative weights of different metrics?', and 'How will the metrics be combined to generate an overall assessment?'

- **Interoperability** - For example, a shared decision representation can support interoperation between different command and control units and between decision makers and people implementing decisions.

- **Situational Awareness** - A representation of decisions and the decision-making process can support systems and/or organizations to be aware of the decision status, to identify situations, such as the situation when important information is missing, and to base new decisions on the collected knowledge in the recorded decisions of the organization.

[10]http://www.w3.org/2005/Incubator/decision/wiki/Final_Report_Use_Cases

3.1.1 *Measuring Information Flow*

Research shows that an analytical solution of information velocity is intractable but metrics that support the understanding of information flow can be useful [8]. An agent-based model for information flow can be used to characterize physical analogs to causal measures [6]. In this use case, interactions and exchanges can be modeled as physical properties. Information, its suppliers, and consumers are then treated as agents. The behavior of the agents and system as a whole can be discussed and infodynamic analogs of thermodynamic and other physical quantities associated with these processes could be explored [8]. The use of conceptual analogs from the physical domain implies the viability of future ontologies to characterize information flow.

3.1.2 *Automatic Assessment of Options*

Design considerations have been described and exemplified for implementing a decision-acquisition system based on a CDEP [7]. CDEP is an XML- and REST-based protocol for representing generic human decisions in a simple, interoperable format. The characteristics of decisions can be expressed using CDEP and its proposed XML format [7]. The CDEP concepts will be considered, and enhanced, within the currently envisioned decision format, and a conversion XSLT stylesheet will enable interoperability across these formats as needed. The use case ontology would allow for the consideration of multiple data sources, multiple decision options, and the tracking of decision confidence throughout the decision-making process.

3.2 Decision Patterns

The decision patterns include concrete decision format components, as well as generic patterns, hence, both:

- The ontology modules that we propose as a starting point for creating a standard in this field,

- and the more general ODPs that we discover and develop as a result of this effort.

The first module draft that was produced corresponds to the use case of 'Measuring Information Flow' listed above. This ontology module is a specialization of the Transition ODP[11]. In this case we found an ODP already available that we could specialize and create a specific decision-process pattern. In other cases, such as when viewing a decision as a past event, no 'event-pattern' was available in the ODP portal. Therefore, we are creating general ODPs to be specialized in the decision ontology modules. By treating general (rather than domain-specific) use cases of decision-making, we make sure that the developed modules are actually reusable patterns, rather than a solution tailored to one specific application. All decision patterns will be implemented in RDF/OWL. Eight patterns are identified so far, but need to be created. Four examples are described below:

- A 'Statement with variable'-pattern, to describe queries, such as the question underlying a decision.

- 'Filter' and 'Aggregation'-patterns, where a filter would represent criteria applicable to some data, e.g., a set

[11]http://ontologydesignpatterns.org/wiki/Submissions:Transition

of options, and an aggregation would represent a way to combine data, e.g., grouping options.

- A 'Normalization'-pattern that models transformations of values into a common scale, for comparing options.
- A 'Weighting'-pattern to express the relative importance of data, e.g., weighting of assessment criteria.

3.3 Proof-of-concept Application

To verify the requirements and the ontology modules, and to demonstrate the usefulness of such a format, a demonstration system is being developed at the Space and Naval Warfare Systems Center Pacific. Initially, the system will focus on enabling decision making using open linked data sets [1]. The user has four modules, or screens. In the Topic screen, the user enters the key question of the decision, keywords, and where the decision result will appear. The keywords will drive a search for relevant open-linked data sets. Next, the user selects a data set from which the entries provide a named set of options. From the Options screen, the user selects the properties to use as metrics. On the Metrics screen, the user selects filtering criteria to reduce the options. The user can additionally assign weights to the metrics. When a similar decision is encountered, users can efficiently select a named set of Options or Metrics to aid reuse of decision components. A semi-automatic learning process will be considered for future releases, proposing named sets of options or metrics found useful to other users, based on similarity of questions and keywords. On the Assessment screen, the filtered options appear in an ordered list based on the weighted metrics. The user selects one or more options as the answer to the decision question. The user is returned to the Topic screen where the answer(s) is/are recorded and visible. Throughout the process, the time spent in the various stages is tracked to assess information flow. Future versions of this system will support manual entry of decisions, a more robust set of filtering criteria, integration of multiple datasets, and mobile applications for efficiency in the field. The decision format discussed here will be used to manage the decision as a whole, and its modular components.

3.4 Experiences

An important outcome, apart from the requirements and a proposed decision representation, will be experiences related to the XD methodology and ODPs. XD has been used in the project both as a framework for the modelling but also as a means for teaching ontology engineering to participants less familiar with semantic technologies. So far we found that the level of detail of the XD methodology is highly beneficial for teaching ontology engineering to novice modelers. It introduces an intuitive way of scoping the problem, through modularization, and it allows the modeler to draw on previous experiences of others through ODPs. We envision that the project will benefit the further development of XD, and XD will be validated through valuable experiences.

4. OUTLOOK

In September 2010, the project reached its half-way point and should be completed by the end of March 2011. By that time the project will have a set of requirements for a potential decision-representation standard, i.e., the use cases (initial set in Section 3.1), and a first draft of such a representation, i.e., the decision patterns (initial ideas in Section 3.2). We intend to submit any patterns developed (both general and specific to decision-making) to the ODP portal. We expect to present a set of proof-of-concept applications (see Section 3.3). These applications will show the potential of our draft patterns. The applications will be used to validate our results against current practices in different domains, e.g., to validate the hypothesis that linked data are suitable to support decision making and that automatic assessment of options is possible in certain use cases. During the project, we will make the problems and possible solutions visible in different communities, e.g., the semantic web community, domain specific interest groups, and standards organizations. We envision that at the end of the project we can propose a standardization effort in the context of W3C. We can pursue several use cases and application ideas as separate research projects.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] C. Bizer, T. Heath, and T. Berners-Lee. Linked Data - The Story So Far. *International Journal on Semantic Web and Information Systems*, 5(3):1–22, 2009.

[2] E. Blomqvist. OntoCase-Automatic Ontology Enrichment Based on Ontology Design Patterns. In *ISWC 2009, 8th International Semantic Web Conference*, volume 5823 of *LNCS*, pages 65–80, Washington, DC, November 2009. Springer.

[3] A. Gangemi and V. Presutti. Ontology Design Patterns. In *Handbook on Ontologies, 2nd Ed.*, International Handbooks on Information Systems. Springer, 2009.

[4] M. Gruninger and M. S. Fox. The role of competency questions in enterprise engineering. In *Proceedings of the IFIP WG5.7 Workshop on Benchmarking - Theory and Practice*, 1994.

[5] V. Presutti, E. Daga, A. Gangemi, and E. Blomqvist. eXtreme Design with Content Ontology Design Patterns. In *Proc. of WOP 2009, collocated with ISWC-2009*, volume 516. CEUR Workshop Proceedings, November 2009.

[6] J. Waters and M. Ceruti. Modeling and simulation of information flow: A study of infodynamic quantities. In *Proc. of the 15th International Command and Control Research and Technology Symposium (ICCRTS 2010)*, Santa Monica, CA, June 2010.

[7] J. Waters, M. Ceruti, R. Patel, and J. Eitelberg. Decision-acquisition system based on a common decision-exchange protocol. In *Proc. of the 15th International Command and Control Research and Technology Symposium (ICCRTS 2010)*, Santa Monica, CA, June 2010.

[8] J. Waters, R. Patel, J. Eitelberg, and M. Ceruti. Information velocity metric for the flow of information through an organization: Application to decision support. In *Proc. of the 14th ICCRTS (ICCRTS 2009)*, Washington, DC, June 2009.