A Collaborative Ontology Development Tool for Information Security Managers

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ABSTRACT

This paper explores the need for a collaborative development tool to allow information security experts to capture their interrelated knowledge in an ontology. Such a tool would enable organisations to make more informed security policy decisions around shared security issues. However, population of ontologies can be time-consuming and error-prone, and current collaborative ontology editing tools require a familiarity with ontology concepts. We present a Web-oriented tool which simplifies ontology population for information security experts, allowing them to develop ontology content without the need to understand ontology concepts. To understand how organisations manage information security knowledge within policies, we consulted two information security managers in large organisations. The Web-Protégé collaborative ontology editor was then modified to create a tool with an appropriate knowledge ontology structure that meets their requirements. The same information security managers then evaluated the tool, judging it to be accessible and potentially useful in policy decision-making.

Categories and Subject Descriptors

K.4.3 **[Computers and Society]**: Organisational Impacts – *computer-supported collaborative work*

General Terms

Human Factors, Management, Security.

Keywords

Information Security Ontology, Ontology Editor.

1. INTRODUCTION

Organisations need to manage the security of their information assets to limit potential abuse or damage within business activities. Information security policies are typically formulated which stipulate at an operational level how these assets should be secured across the entire organisation.

Currently, information security policies are generally informed by a mix of "professional opinion", staff experience, technology manufacturer advice and external security standards or regulations (e.g. ISO27001 [3]). However there are a potentially vast number of disparate information sources; the successful management of which can be complex and time-consuming. Although such knowledge may be consolidated by individual organisations, it is typically kept "in-house".

This knowledge can be aligned in the form of a communal ontology. An ontology can represent both structured and unstructured information security management knowledge within a single body of reference. This would help policy makers to make more informed security policy decisions. Information within the ontology is formalised as a set of concepts, creating an agreed-upon vocabulary of IT-security knowledge. The interdependencies between fragments of such knowledge will be exposed, facilitating navigation across related information concepts.

Information security managers and practitioners within different organisations often have to resolve the same or similar IT-security issues (e.g. authentication, remote access, etc.) and explore large amounts of information when doing so. Dissemination of this information throughout the IT security practitioner community in the form of an ontology has not as yet been explored as a specific issue. However, by making collaboration between domain experts an integral part of the knowledge management process, practitioners could share their expertise in an effective manner, deriving increasingly robust solutions to shared security problems.

The Web is a natural platform to host collaborative information security ontology development and facilitate distribution of ontology content. However, current editing tools tend to be complex, generic in nature and aimed at those with experience in ontology creation, and not necessarily those domain experts whose knowledge requires capture. It cannot be assumed that CISOs have the appropriate skills in ontology development, as they may be unable to acquire such skills due to a lack of time, inclination, or technical ability. As a result the process of populating an ontology could prove time-consuming and prone to errors during knowledge capture.

Here we consider a collaborative ontology editor tool for use by CISOs. We consider how an ontology should be presented to

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CISOs to ensure that it is both approachable and useful. We also explore how CISOs might use the features of a collaborative ontology editor to derive knowledge to help improve information security policy decision-making within organisations.

Through consultations with two CISOs within large organizations we build a picture of the process of formulating information security policies within organizations, as well as identifying influential factors that arise within this process. Within these consultations we also explore the potential to share the knowledge inherent in these policies with the IT-security practitioner community.

Insights from the CISO consultations inform development of a collaborative Web-based ontology development tool intended to serve CISOs or individuals in similar positions in charge of information security policies for organisations. The tool allows direct capture of knowledge – both from disparate sources and created as professional "know-how" – and integration of this knowledge into a centralised ontology-based knowledge repository. The tool limits the need for users to be familiar with ontology construction.

The CISOs consulted earlier within the research participated in a structured evaluation of the ontology editor tool, providing feedback on tool design and functionality. Evaluation sessions also provided the participants with a tangible software tool around which to discuss the preferences they have for a potential knowledge-sharing environment.

The paper is arranged as follows: Section 2 discusses the need for a collaborative ontology effort and current construction approaches. Section 3 discusses related work in ontology tools and construction; and Section 4 captures the requirements for our tool through consultations with real CISOs. Section 5 details the implementation of the tool while evaluation findings from follow-up consultations with CISOs are discussed in Section 6. Concluding remarks are presented in Section 7.

2. BACKGROUND

2.1 Communicating Information Security Policy Decisions

CISOs are the primary decision makers on information security policy within an organisation. The CISO must make decisions on their organisation's security policy that consider not only the security of the organisation's information assets, but also the needs of the business and its employees (be this regulatory expectations or budgetary limitations). By formalising knowledge of various IT-security concerns and exposing their interdependencies, the content of an information security knowledge base would serve to inform and communicate those decisions.

CISOs are part of a wider community of IT-security practitioners and experts tasked with understanding and addressing information security concerns. Teams of information security experts may work within organisations, or may be acting in isolation in different organisations to address similar IT-security concerns.

These experts potentially share information security knowledge within informal or closed groups. The sharing of expertise within relatively small groups exerts limited impact – sharing of this expertise to the wider community exposes it to greater rigour (improving the quality), but also helps global efforts to resolve what are often global information security threats.

2.2 Current Ontology Development

Currently the construction and/or modification of an information security knowledge base or ontology would involve an ontology development tool. These typically come in two forms, either graphical or text-based. Both types of editor allow content to be converted to a file encoded in an ontology language.

These different forms of ontology editor place similar demands on the user. The tool user must construct a suitable ontology structure in the tool before knowledge capture can begin. Due to its complex nature this process assumes familiarity with ontology technologies. As such, to create and/or modify an information security ontology, knowledge is required of: ontology creation, including the use of ontology development tools; ontology structure and language; and the ontology content itself. An information security domain expert may be unable to develop ontology content themselves, and would require either the assistance of an ontology expert or a dedicated ontology editing tool that hides ontology complexity.

2.3 Collaborative Ontology Development

The creation of an information security ontology is far too large a task for any one individual or small team to carry out effectively. Derivation of knowledge within small teams also limits the applicability and verifiability of knowledge base content.

Collaboration must be an integral part of ontology development, allowing multiple experts within the information security domain to capture, integrate, publish and share their knowledge with peers and colleagues. Through collaboration these domain experts can potentially submit, comment on, and peer-review submitted knowledge, with the ultimate aim of reaching consensus on a robust body of knowledge. For an ontology of information security knowledge to be useful the knowledge it contains must be accepted and trusted by both its providers and its users. Through the involvement of multiple experts, a larger and more applicable knowledge base can be created.

Technology can allow information security domain experts to successfully share in the creation of a knowledge base. The Web is a natural platform for collaboration and knowledge-sharing, by distributing the development process and disseminating the resulting knowledge across the information security community.

3. RELATED WORK

A number of works have been conducted to develop information security ontologies, complimented by an array of collaborative tools resulting from a growing interest in the Semantic Web.

Donner [7] discusses the need for an ontology to describe the most important security concepts and their interrelationships. Such an ontology is needed to provide explicit meaning to the current, vaguely defined terminology and allow clear and effective communication between colleagues and their clients. The discussion ends with the proposal that the ontology should be developed in a collaborative manner.

Formalising information security knowledge for the purpose of auditing and aiding with policy making has been shown to be viable through a number of studies (e.g. [8], [9], [12], [22]). Fenz et al [9] integrate the ISO/IEC 27001 guidelines [3] with their own security ontology which considers the physical aspects of information security. Organisations can use the ontology and accompanying the "OntoWorks" toolset to automatically review and examine IT security policies for ISO 27001 compliance and/or certification.

The ontology by Parkin et al [22] that is used here has also been used by Mace et al [18] as the foundation for an existing information security ontology editing tool tailored for domain experts. Experts are able to intuitively capture and formalise their knowledge while the ontology construction itself is abstracted away. This tool concentrates on single-site deployment, and so is not Web-oriented and lacks collaborative features.

The main features identified for successful collaborative ontology development are discussed in [2] and [19]. These include synchronous/asynchronous communication; proposed content agreement policy; annotation of content and changes; content provenance; concurrency and version control; and personalized views of ontology content.

A host of generic Web-oriented collaborative ontology tools are available aiming themselves at users with varying degrees of experience in ontology construction and offering various techniques in knowledge capture and representation, e.g. [17, 21, 24]. A survey of selected tools is carried out in [5]. OntoWiki [1] serves to decrease the entrance barrier for domain experts to capture their knowledge and collaboratively develop ontologies. OntoWiki combines existing Wiki systems and Semantic Web knowledge representation models. The simplification of knowledge acquisition and presentation is brought about by considering ontologies as "information maps". Each node or concept in the map is represented visually in its own page and allows intuitive viewing, editing and linking to other concepts and resources. COE (Collaborative Ontology Environment) [11] builds on the rapid construction techniques of CmapTools [6] and its concept mapping system to represent domain knowledge. An ontology viewing area and collaborative editing environment are combined within COE which then displays ontologies as concept maps. The tool converts these human readable maps into a machine readable ontology language. Concepts from other Web-based ontologies may be incorporated into an ontology, allowing the capture of knowledge from a wide variety of sources.

These tools are aimed towards the domain expert and primarily attempt to make collaborative ontology development and knowledge sharing more accessible. They do however remain relatively complex, are generic in nature and require a substantial amount of initial training and configuration before knowledge owners can begin the knowledge capture process.

4. REQUIREMENTS CAPTURE

A CISO uses their knowledge and expertise to compose information security policies, which then inform the IT-security stance of their organisation. We examine the process of information security policy-making through semi-structured discussions with information security managers, through a mixture of surveys and phone interviews. For this we consulted two information security managers: (*CISO1*) has a wealth of experience as a former Chief Information Security Officer (CISO) of a large multi-national financial organisation, and; (*CISO2*) is an information security manager at a leading UK University with previous experience at UK regional councils.

These discussions help us to understand and identify the requirements of policy makers when using information security knowledge. The consultations also build a picture of how policy makers across the community choose to interact with external bodies and other knowledge holders, identifying barriers to the sharing of knowledge and with this the potential uptake of a collaborative ontology editing tool.

4.1 Consultations

The results of our CISO consultations are organised and presented here.

4.1.1 Policy Review Timing

Within the organizations of both *CISO1* and *CISO2* information security policies are reviewed at regular intervals, typically annually. *CISO1* points out that although this is normally the case, reviews may be forced by the emergence of a new threat or with the introduction of a new security technology. With this we may assume that CISOs require access to relevant material for guiding policy decisions regarding new threats and security technologies.

4.1.2 Policy Review Resource Gathering

When reviewing and creating policies, *CISO1* refers to the following sources for guidance:

- Payment Card Industry (PCI) [23]
- ISO27001/27002 security standards [3, 4]
- Information Security Forum (ISF) [14]
- International Information Integrity Institute (I-4) [13]

CISO2 also examines a range of sources for guidance:

- Information Technology Infrastructure Library (ITIL) [15]
- ISO27001/27002 security standards [3, 4]
- The Law Society [25]
- TechRebublic [26]

Although both CISOs work in different sectors, they both refer to the ISO27K family of standards during their work.

Having to refer to a number of independent sources implies the need for this information to be cross-referenced in an appropriate manner.

Within *CISO1*'s organisation information gathered from different sources is entered into a software-based policy management tool, which provides facilities to create information security policy database(s). The tool also allows policy content to be separated according to applicable roles (e.g. system development, human resources, auditors, etc). The tool's databases are by no means complete as they provide only information about standards. There remains a lack of coverage of some other kinds of information, such as industry "best practices" and information for managing human factors within IT security management.

For *CISO2* the majority of gathered information is recorded within the organisation "as-is". Some financial and business information is stored as an information base within an Enterprise Resource Planning (ERP) system [20]. Less than 3% of all the gathered information is formalised and managed within a standardised knowledge repository. This contradicts the need to cross-reference various sources of information.

Where information is stored, it is managed within individual policy categories, This together with *CISO1*'s responses suggest that there are various ways to formalise the arrangement of knowledge content into policies.

4.1.3 Policy Creation

The policy databases in *CISO1*'s organisation are used to create and publish information security policies internally upon the organisation's intranet. During policy creation, the IS027001 standard acts as an underlying structure. Internal policies are then created according to this structure, and developed through methods including benchmarking, forums and use of informal networks. Internal policies (e.g. software configuration settings, machine build settings) are then quite distinct from external information security standards (e.g. ISO27001).

For *CISO2*, an internal information security policy is created by examining the organisation's trading environment (e.g. business, legal and common practices). *CISO2* uses these practices to facilitate the formation of action plans or strategies to achieve particular IT security-related goals. Policies are defined to help realise these strategies and are put into practice upon approval by senior management. When addressing an information security concern with the forming of a policy, the order of strategy, policy and practice is always followed, suggesting that policies must be seen to be achieving a goal for the organisation.

4.1.4 Policy Reviews

When reviewing information security policy within *CISO1*'s organisation, various parties must be consulted both internally and externally (e.g. human resources, legal counsel, etc). In a regulated industry, regulators must be consulted as they may have their own published guidelines (e.g. Financial Services Authority [10]). Also, the views of both internal and external auditors must be sought to assist in aligning policy initiatives with industry standards.

Once the policy has been decided upon, *CISO1* will talk with "technologists" to determine whether the proposed solution can be integrated into the organisation's applications and systems. The proposed policy is also discussed with "business people" to understand how it would be received within the organisation.

CISO2 also consults both internal and external parties during review of information security policies. These parties include the University Registrar, human resources, internal auditors and external legal counsel specialising in information security. Policies are verified by peers and external advisors (e.g. legal counsel) together with additional checks by JISC certificated legal services [16].

These responses imply a need to communicate knowledge meaningfully to peers and other disciplines.

4.1.5 Policy Justification

For both *CISO1* and *CISO2* it is the case that before a policy is enacted it must be justified to, and supported by, senior management. In *CISO1*'s case policies are discussed in terms of risk and what the effects could be to the organisation without such policies being in place. For *CISO2* debate around policies is framed in terms of impact and reach including legal requirements, financial considerations, personal data protection and intellectual policy. A further consideration noted by *CISO2* (but which is likely applicable for *CISO1*) is the commercial and reputational risks to the institute without such policies being in place. This implies a need to be able to objectively compare the advantages and disadvantages of particular approaches to IT-security. An ontology would serve to formalise knowledge of security solutions and expose their comparable qualities.

CISO1 noted that situations can arise where objective evidence relating to the impact of potential policy changes is lacking (e.g. effects on employee productivity). Here *CISO1* may rely upon his judgment and expertise to convey the reasons why a particular change in security procedure needs to take place. However *CISO1* notes that there would ideally be evidence at hand to support such an argument, implying a need to identify the objective evidence underpinning expert opinion within security policy decision-making.

4.1.6 Policy Evaluation

Within *CISO1*'s activities, information security policies are typically evaluated for correctness and effectiveness using metrics, but this is not always possible. When assessing technological solutions it is possible to obtain and analyse output from those systems (e.g. the number of e-mails rejected by anti-spam software). However where the behaviour of personnel is involved it is difficult to formulate and measure meaningful metrics. An alternative approach might be to obtain agreements from department managers declaring that security measures will be enacted. These agreements are then reviewed at least annually alongside computer-based employee training and forward-looking agreements, e.g. "I will comply with these measures for the next 12 months". Such "self-assessments" then transfer responsibility for security to individuals.

CISO2 notes yet another approach to evaluating IT security controls, where the security policy evaluation process entails physically observing individuals using human-facing security controls and identifying how those controls are dealt with or how they affect working practices.

Within *CISO2*'s organisation, business processes are also reviewed to see if current security controls are appropriate or whether they can be modified to effect improvement.

That there are various options for managing the assessment of information security controls within organisations, and that their place within business processes must also be accounted for, suggests a need to consider the merits of different methods for evaluating security solutions, and equally how appropriate a particular method might be for assessing a range of policy directives.

4.1.7 Sharing Policy Content

CISO1 states that formal and informal groups of CISOs regularly meet to discuss security issues and share expertise. With this approach, there is potential for organisations to converge on similar solutions, even to a low level (e.g. password composition rules, password reset intervals, etc). Sharing of information security management knowledge then occurs amongst known and trusted parties.

In the academic sector, institutions tend to reach consensus on approaches to information security through regular interaction and sharing of expertise. *CISO2* also corresponds regularly with other non-academic organisations (e.g. local government).

Both *CISO1* and *CISO2* would be hesitant to share policy content that exposes the security stance of their organisation. This suggests that if IT security practitioners across different organisations were to share knowledge, there would need to a consideration of how to hide the identity of contributors or otherwise maintain knowledge at an abstract level so as not to betray its source (although policies may tend to be framed at a high, operational level as a matter of course).

CISO1 would consider using policy-making knowledge from new and untrusted sources once consensus is established amongst peers. Consensus may potentially be reached through successive edits until the content is agreed (i.e. no-one feels it necessary to edit any further).

For *CISO2*, anonymously supplied information would be considered once it was proven successful elsewhere and recommended from a trusted source. If such proof was unavailable the anonymous content would still be considered if it could be tested in an environment of limited impact and in such a way that it could do no harm to the organisation. This suggests a need for details on how supplied knowledge can be enacted and tested.

4.2 Core Findings

From the discussions with CISOs a number of similarities are apparent, from which assumptions may be drawn regarding the management of knowledge contributing to IT-security policies:

- Information security policies are reviewed at regular intervals or when new security threats or technologies emerge, wherein security procedures are informed by guidance material gathered from a variety of disparate sources.
- Organisations across different sectors may form information security policies, and in turn security controls, according to the same guidelines (e.g. ISO27001/2). This implies that many organisations have similar IT-security requirements which could benefit from collaboration.
- Policy consensus is reached from correspondence and discussion amongst peers alongside the examination of guidelines and regulatory mandates.
- All material that informs policy decision-making (be it guidelines, regulatory mandates, technical documentation, etc.) is recorded "in house" and arranged within distinct, specialised policies, although this is not necessarily conducted in a centralised manner.
- Policy directives are reviewed in consultation with many internal and external parties, notably experts in legal, human resource and technical issues. These parties cannot be assumed to be proficient in the use of ontologies or IT-security.
- There is a need to compare different approaches to resolving information security issues and the evaluation of security controls, and to be able to provide justification for policy directives.

4.3 Tool Requirements

From both the examination of current policy-making approaches and discussions with CISOs, the following requirements of a collaborative ontology development tool for information security knowledge management have been identified:

1. *Knowledge Capture:* the ontology editor tool must allow capture and organisation of formalised knowledge relating to familiar information security concepts (e.g. assets, vulnerabilities, threats, procedural controls etc). Disparate knowledge fragments may also be interrelated, and users should be able to record these relationships, ideally within a single body of reference.
2. *Collaboration and Consensus:* an interface should allow collaborative capture of distributed knowledge between disparate parties. There should also be features to allow members of the user community to reach consensus (e.g. by discussing content).
3. *User Guidance:* users must be guided through all aspects of ontology development and exploration using "non-ontological" terms and concepts. There should also be appropriate mechanisms to minimise errors.
4. *Knowledge as Evidence:* it may be necessary to present ontology content to other stakeholders (such as senior management) whenever policy-related knowledge is used to justify the management of risks to the organisation.
5. *User Anonymity:* users must be able to preserve an appropriate level of anonymity. Users should not be expected to divulge specific organisation security practices.

5. IMPLEMENTATION

An prototype of the tool has been completed to help assess how members of the CISO community could capture and share their knowledge first-hand. The tool strives to allow these experts to construct and/or modify, share and analyse a security ontology at an abstract level without the need to familiarise themselves with ontology technologies.

The open-source ontology editor Web-Protégé [27] forms the foundation of the tool. Web-Protégé is a Web-accessible collaborative ontology editor built with a number of collaborative features that can be tailored to meet our requirements.

5.1 Overview of Tool Components

An overview of the components of the collaborative information security ontology editing tool is shown in Figure 1. The tool is composed of the client-side *Tool Interface* and the *Tool Server*.

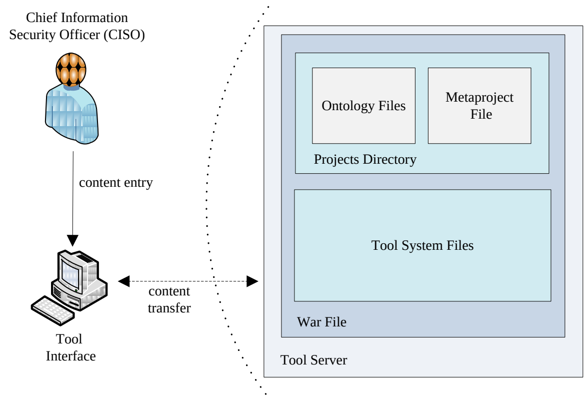


Figure 1. Overview of ontology development tool's components

5.1.1 Tool Interface

A browser-accessible Web application, through which ontology content is added, viewed and manipulated. The tool interface and its functionality are described in further detail in Section 5.3.

5.1.2 Tool Server

The tool is stored as a Web application archive file on a centralized Web application server. The server provides remote access to the latest version of the tool.

A *War file* contains both the tool system files and the ontology files. Having all the necessary files in a single archive allows for simple server deployment. *Tool system files* within the *War file* hold the tool's compiled source code, supporting images and html pages. All of the tool's current ontology files are stored in the *Projects directory*. The project directory also contains the tool's *Metaproject* ontology file, which describes access conditions for the tool's ontologies.

5.2 Foundation Ontology

An information security ontology should define the most important security issues and concepts and the relationships between them. For these purposes the tool uses a modified version of the ontology developed by Parkin et al [22] (Figure 2). This ontology is similar to others that represent information security knowledge (e.g. [9]), but informs policy decision-making further by representing the relationship between human-behavioural factors and other concerns within information security management (e.g. provision of password authentication policies that are both suitably secure and realistic for employees).

The ontology represents the security and usability weaknesses of an *Asset* that may promote or inhibit certain employee behaviours in relation to security mechanisms or processes. This is embodied in the *Vulnerability* concept.

A *Vulnerability* may be intentionally or accidentally *exploitedBy* a *Threat*, which then renders the *Asset* potentially insecure. A *Threat* represents activities that directly affect security mechanisms or elements of security-facing human behaviour. For each *Threat* the *Behavioural Foundation* serves to classify behaviours and indicate the concerns that they raise within an organisation (e.g., a person's memory capabilities or attitude towards security).

A *Vulnerability* may be *mitigatedBy* a *Behaviour Control*, which is considered to be a procedural control enacted by a CISO to manage the interactions between humans and the organisation's security mechanisms. A *Behaviour Control managesRiskOf* a specific *Threat* using a risk management approach indicated by the associated *Control Type*.

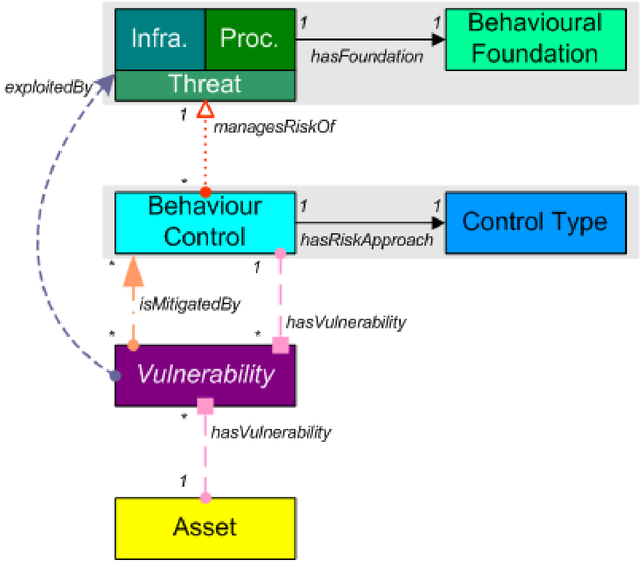


Figure 2. Overview of the information security and human factors ontology.

5.3 Tool Interface

The Tool Interface allows CISOs to access ontology content in a manner that abstracts away details of ontology construction. Users are then free to view, add, modify or relate fragments of IT-security knowledge to help them:

- View information security management knowledge and the interdependencies between knowledge fragments.
- Record (and share) knowledge of information security concerns (through use of editing controls).
- Collaboratively refine the knowledge stored within the underlying ontology, using the tool's collaboration features.

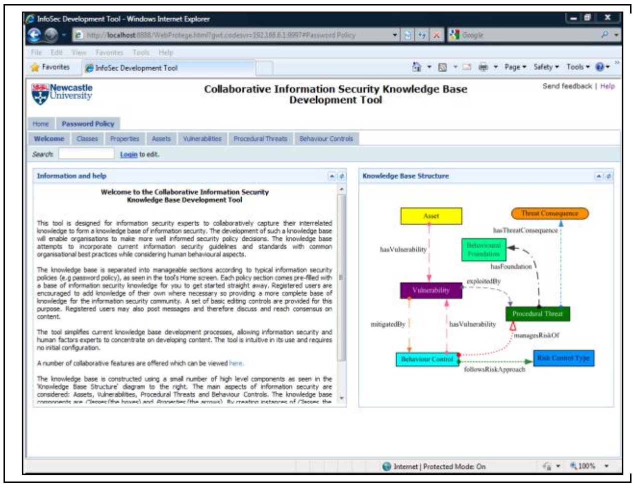
5.3.1 Accessing the Tool

Users are initially presented with a screen offering a list of available ontologies. For demonstration purposes distinct ontologies are provided to mirror an organisation's policies (e.g. USB stick policy, password policy, etc.). These ontologies employ the structure described in section 5.2, and can potentially be pre-populated with knowledge content that can be viewed and/or extended with user-supplied knowledge.

The main user interface consists of a number of tabbed pages providing users with ontology content, ontology editing controls, and features to advise users in how to interact with the tool. Only authorised users can access editing controls and make changes to the ontology, by providing a registered user ID and password.

5.3.2 Guidance for Users

A *Welcome* page (Figure 3) provides an overview of the tool, its functionality, and the base ontology structure. The *Class* and *Property* tab pages provide the user with descriptions of the ontology's structural components and how they interact with each other.



Welcome to the Collaborative Information Security Knowledge Base Development Tool

This tool is designed for information security experts to collaboratively capture their interrelated knowledge to form a knowledge base of information security. The development of such a knowledge base will enable organisations to make more well informed security policy decisions. The knowledge base attempts to incorporate current information security guidelines and standards with common organisational best practices while considering human behavioural aspects.

The knowledge base is separated into manageable sections according to typical information security policies (e.g password policy), as seen in the tool's Home screen. Each policy section comes pre-filled with a base of information security knowledge for you to get started straight away. Registered users are encouraged to add knowledge of their own where necessary so providing a more complete base of knowledge for the information security community. A set of basic editing controls are provided for this purpose. Registered users may also post messages and therefore discuss and reach consensus on content.

The tool simplifies current knowledge base development processes, allowing information security and human factors experts to concentrate on developing content. The tool is intuitive in its use and requires no initial configuration.

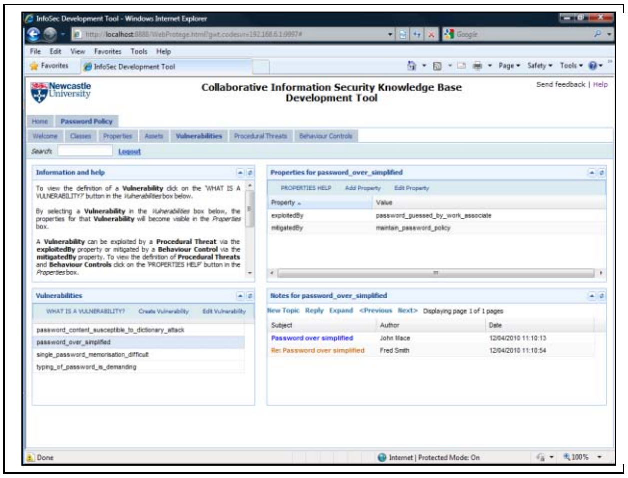
A number of collaborative features are offered which can be viewed here.

The knowledge base is constructed using a small number of high level components as seen in the 'Knowledge Base Structure' diagram to the right. The main aspects of information security are considered: Assets, Vulnerabilities, Procedural Threats and Behaviour Controls. The knowledge base components are Classes (the boxes) and Properties (the arrows). By creating instances of Classes the

Figure 3: Screenshot of tool's *Welcome* page

5.3.3 Editing Ontology Content

The *Content* pages (Figure 4) allow a user to view and edit ontology content. Any modifications made to an ontology are immediately visible to all those users currently accessing the tool, thereby making it useful in situations that require newly-available knowledge (e.g. when a new threat or technology emerges).



To view the definition of a **Vulnerability** click on the 'WHAT IS A VULNERABILITY?' button in the *Vulnerabilities* box below.

By selecting a **Vulnerability** in the *Vulnerabilities* box below, the properties for that **Vulnerability** will become visible in the *Properties* box.

A **Vulnerability** can be exploited by a **Procedural Threat** via the **exploitedBy** property or mitigated by a **Behaviour Control** via the **mitigatedBy** property. To view the definition of **Procedural Threats** and **Behaviour Controls** click on the 'PROPERTIES HELP' button in the *Properties* box.

password_content_susceptible_to_dictionary_attack
password_over_simplified
single_password_memorisation_difficult
typing_of_password_is_demanding

Property	Value
exploitedBy	password_guessed_by_work_associate
mitigatedBy	maintain_password_policy

Displaying page 1 of 1 pages

Subject	Author	Date
Password over simplified	John Mace	12/04/2010 11:10:13
Re: Password over simplified	Fred Smith	12/04/2010 11:10:54

Figure 4: Screenshot of a *Content* page

Four separate *Content* pages cover the main classes of the information security ontology structure; *Assets, Vulnerabilities, Threats* and *Behaviour Controls*. This allows a user to access ontology content from a range of perspectives rather than be restricted to a particular starting point.

Each of the *Content* pages contains a portlet listing the individual fragments of knowledge associated with the particular class. Selecting one of these individuals will display the properties associated with it (e.g. the *Vulnerabilities* of a selected *Asset*). A combination of editing controls and dialog boxes allow a user to add a new class individual or change the text of an existing entry. Warning mechanisms limit the potential for user error and ontology inconsistency (e.g. to prevent addition of an individual with the same text as an existing entry).

Users can also "connect" fragments of knowledge according to the relationships defined in the ontology structure. The tool restricts the user's choice of property connections accordingly by way of restrictive controls, for example a user may only connect an individual *Vulnerability* to a *Threat* or *Behaviour Control* via the *exploitedBy* and *mitigatedBy* properties respectively.

Each Content page has an information portal providing an overview of that page's content and relevant instructions on how ontology content may be extended and/or edited.

5.3.4 Collaborative Features

A *Notes* portal enables users to annotate, discuss and reach consensus on ontology content by "posting" messages, akin to a bulletin-board system. Posted messages are linked with specific content and are visible to all users when that content is selected. Authorised users may post new messages or reply to pre-existing messages via an e-mail style dialog box.

6. USER EVALUATION

For the purposes of this paper we conduct an evaluation of the functionality and usability of the tool's initial implementation by presenting it to the CISOs consulted during the Requirements Capture stage (see Section 4).

During evaluation the tool was demonstrated according to a structured demonstration plan, and the chance offered to participants to practice using the tool first-hand. This was immediately followed by a series of structured questions that serve to relate each participant's impression of the tool to the tool's requirements (as defined in Section 4.3).

As well as evaluating the requirements that were defined for the tool, the evaluation sessions provided the opportunity to centre discussion of collaboration and knowledge-sharing around a tangible tool, eliciting comments about how the tool may be practically applied (along with any issues that have the potential to limit application of this, or a similar, tool).

Each complete session was voice-recorded to allow us to capture feedback from the participants throughout the evaluation process.

6.1 Evaluation Sessions

6.1.1 Knowledge Capture

Overall, the tool was considered as being approachable and easy to navigate, with a clear ontology structure, thereby making progress towards accommodating the needs of target users. *CISO2* stated that "*regular IT security folk will be able to dig into [the tool] and use it*". The tool's user interface was not thought to be confusing but instead very clean, with a "*nice flow round the screen"* (*CISO1*). *CISO2* regarded the ontology structure, covering *Assets*, *Vulnerabilities*, *Procedural Threats* and *Behaviour Controls,* seemed "*very obvious*".

The notion of separating ontology content, thus making the ontology more manageable, was described by *CISO2* as a very complex area, but that *"splitting the content into policies makes sense"*. However *CISO1* argued that it might be preferable to *"slice and dice the content whatever way the user chooses"*, and that individual users might potentially not recognise policy content that they would otherwise think is relevant to them if it is not appropriately labelled. For example, a security manager might regard "identification and authentication" as separate technologies, whereas another manager would regard the same content as "sign-on" policy. This problem of potentially unexpected terminology *"makes it less accessible in some ways"*.

With the capturing of content, the tool was described by *CISO2* as generic and "*open enough to do just about anything in information security*", qualified with examples of issues within networking management, such as firewalls, denial of service attacks, and routing. The tool can potentially capture knowledge of sophisticated information security issues which can "*become horribly complex but you could end up with areas of specialisation*".

CISO2 suggested that ontology content could be 'tuned' according to the user's business sector, for example banking. However, each sector tends to have slight differences in information security needs, and so any content considered irrelevant to that sector would be omitted from the user interface. However, it would depend on "*who takes up the idea [of the tool] first, so making it a while before tailoring content becomes an issue*". Alternatively, *CISO1* suggested that one incentive to use the tool *"would be if you could tag items to make it specific to your organisation and then ... download an extract or have a version of it which is for your own organisation, so that you can ignore stuff which isn't relevant to you"*. *CISO2* made a similar comment that keeps content within the tool, suggesting that when users are creating an account they should declare their business sector so that the tool may tailor content to that sector once the user is logged in.

The mechanism which detects whether content is already added was described by *CISO2* as good, but the recognition of similar content is not addressed. Not having this feature was considered "*a bad thing*", as there was potential for multiple entries to describe the same concept. *CISO1* built upon this issue, speculating that duplicates might go beyond spelling (e.g. "pwd" instead of "password") to similar terms that use natural alternatives (e.g. "*user ID … logon ID ... username ... credential*").

Currently the tool relies on users to use the collaborative features to inform others when similar content is already expressed in the ontology. *CISO2* stated that this notion "*would probably work*" as the "*community will police itself to a certain extent but if too much policing is needed [the community] will get tired of it*". *CISO1* echoed this – *"what's the incentive ... to edit somebody else's content?"*, *"just because it's easy doesn't give me a carrot to want to do it"* – and suggested a solution of employing an administrator to *"collapse"* duplicates (which potentially defeats the purpose of the tool).

6.1.2 Collaboration and Consensus

CISO2 considered the collaborative features very useful in discussing knowledge with peers or other stakeholders within an organisation. The ability to add notes to content was described as "*a nice feature*" that "*added richness to the tool*". When discussing a threat a user could 'post' a message asking "*how real is this threat?*" while the reply could be "*we've actually had a breach on this*". The attachment of messages to specific content made "*perfect sense*".

Regarding the collaborative features, *CISO1* said that *"it's a time-save thing"* so that users are *"not having to reinvent the wheel"* at each organisation. However *CISO1* also speculated that *"within the organisation, that time-saving doesn't mean anything"* unless it is with auditors.

For *CISO2* the idea suggested of providing additional mechanisms for reaching consensus, such as a voting or rating system, could be seen as being useful. This would be akin to "*Ebay where the voting on how good a vendor and supplier are is a big deal*". Such a mechanism promotes sensible levels of discussion while ensuring that content stays appropriate: "*You end up with the community vetting itself which is what you want to do*". *CISO1* speculated however that users might inevitably just "grab" meaningful content, returning to the issue of how to *"incentivise people to comment and use"* the tool.

According to *CISO2* encouragement for users to record and share their knowledge may be brought about by stressing, "*this is your community and your tool to help you. The richer you make it the more powerful it becomes*". A suggestion was to implement a system where users are asked to review recently added content, perhaps through an e-mail style inbox that highlights content added since their last login.

It appears from the evaluation responses that the need for users to be able to discuss content and be aided in reaching consensus has been achieved, at least in part, via the notes feature. Realistic suggestions for further mechanisms include a voting/rating system enhancement to facilitate content selection. Users might also welcome a pre-prepared "expert" base of knowledge from which they could create an organisation-specific version.

6.1.3 User Anonymity

CISO2 noted that the user interface did not raise any privacy or security concerns as the user's organisation is not being identified during content entry. The notion of anonymity is achieved by users logging into the tool through a 'username' alias. *CISO2* suggested the tool should "*stress the fact that content can be entered anonymously and content cannot be traced back to an organisation*". *CISO1* echoed this concern: *"the only drawback would be the level of comfort ... over the ... secrecy around the specificity to my organisation ... how would I know that other people can't see that?"*.

The mechanism for users to create an account, once implemented, must "*vet people and make sure not just anyone can gain access*" (*CISO2*).

The suggestions by both CISOs for personaling ontology content bring with them similar issues of guaranteeing that personal identifiers remain protected.

It appears from the evaluation responses that the need for users to submit information while not divulging specific organisation security practices can be achieved within the tool, although there are understandably many concerns surrounding the issue of user anonymity.

6.1.4 User Guidance

CISO1 thought that the tool was helped by a *"very nice layout"* that was *"not confusing"*. According to *CISO2* the user interface was not thought to be confusing but seemed "*fairly simplistic*" suggesting an appropriate level of detail for 'non-ontology' experts building an ontology of information security knowledge.

CISO1 suggested that users *"might ... want to follow something all the way through"* to *"produce another view"*, such that the interface changes dynamically depending on selected content (e.g. moving automatically to another screen).

CISO2 noted that "*two or three different learning styles are catered for*" by the help features, for example the 'Welcome' screen provides an overview of the ontology structure in both graphical and textual form. "*Some people will read the prose while others will use the picture. For me the [diagram of] the knowledge base structure was very useful*".

The tool has the capacity to guide users through aspects of ontology development and exploration, using a variety of help features.

6.1.5 Knowledge as Evidence

In relation to the potential for ontology content to be used in communicating and supporting policy decisions, *CISO1* speculated that *"you'd want to use this ... because it takes you through a structured way of doing a risk assessment ... but the only way that you'd want to do it is if you can make it specific to your organisation"*, reiterating the idea of "tagging" organisation-specific content. *CISO2* similarly *"would use [the tool] and happily add content but would need to see the outputs"* before using it within their organisation (*"Would it allow me to make a business case? ... Something that would support that would be really useful"*) before going on to speculate that if the tool was being used to assess threats etc. in a particular business sector then *"it would be good enough as it is"*. *CISO1* echoes similar thoughts: *"what makes it information is the specificity for your situation"*.

CISO2 noted that an information security manager *"cannot simply say we need to implement this because we are insecure"*. The manager must be able to present a business case to justify changes in IT security policy to senior management from a range of possible solutions, and *"the tool allows you to do that"*. The business case will state *"we can do this, this and this to get us there and then do calculations to work out the costs"*. A scenario could be imagined where departmental managers (e.g. finance or IT helpdesk) are consulted when making security policies and who use the tool's content to help work out costs: *"at the very least [the tool] helps to identify stakeholders to communicate with"*.

6.1.6 Further Comments

Some extensions to the tool's underlying ontology structure were suggested during the evaluation sessions. Such extensions could include – according to *CISO1* –, details of *"technical controls"* and their threat management approach (e.g. *"detective"*, *"defending"*). *CISO2* suggested that policy implementation costs, methods of policy enforcement and measurements of policy success would be useful ("*Cost is a big deal. Quantifying cost, cost of implementation, cost of risk etc. [is important] but it will be hard to categorise the financial [costs]*").

6.2 Summary

The tool satisfies the requirements outlined in Section 4.3. A summary of other key points that emerged from the evaluation sessions is as follows:

- The tool is approachable and easy to use.
- Care must be taken if dividing the underlying ontology according to distinct policies, as this may cause confusion.
- Concentrating the tool towards particular sector- or organisation-specific concerns may distort content that is essentially shared. Solutions include providing facilities to "tag" relevant content.
- Content duplication could cause problems that might only be resolved through concerted efforts by community members.
- Collaborative features can help users to reach consensus, but must provide proper incentives to maintain a collective community effort.
- Users would be able to preserve their anonymity with the tool, but would need reassurances that it does not disclose the organisation's security posture.
- The tool can support communication of policy decisions to stakeholders, however to fully exploit this capability ontology content would need to include or be enriched with relevant sector- or organisation-specific content.

7. CONCLUSION

We have shown that the capture and sharing of knowledge between information security experts (namely CISOs or similar) can be enhanced through a collaborative ontology development tool.

Here we have taken the needs of CISOs into consideration through CISO consultations, and developed a collaborative, Web-hosted ontology editor tool as a deployable application, allowing community users to record and share their knowledge within the structure of a pre-defined information security ontology.

When formulating information security policies, CISOs typically use numerous disparate information sources whose management can be complex and time consuming. Our tool has the potential to improve the IT policy making process by providing the information security management community with a single, shared, comprehensive reference for information security knowledge.

The tool's prototype has been evaluated by two CISOs from varying backgrounds, meeting with general praise for both its appearance and functionality. With further development work we look to address concerns raised about the control and quality of content through enhancement of the tool's collaborative features. This may include provision of a voting system or content-rating scheme.

Future work also hopes to consider the suggestions from participating CISOs for extensions to the underlying ontology structure, alongside incentives to motivate members of the information security management community to contribute knowledge to a tool as described here. This may include the provision of user anonymity guarantees, together with appropriate authentication and verification controls.

We also aim to engage with further CISOs or similar, and deploy our tool within their organisations to help us validate our assumptions relating to how security experts would participate in the collaborative development of information security knowledge.

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