

An Idea Ontology for Innovation Management*

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Author Note

This research was funded by the German Federal Ministry of Economics and Technology under the promotional reference 01MQ07012, 01MQ07017, 01MQ07019, and 01MQ07024 and the German Federal Ministry of Education and Research under grant number 01IA08001A. The responsibility for this publication lies with the authors.

This paper has been published in the *International Journal on Semantic Web and Information Systems (IJSWIS)*.

Please cite as: Riedl, C.; May, N.; Finzen, J.; Stathel, S.; Kaufman, V. & Krcmar, H. An Idea Ontology for Innovation Management. *International Journal on Semantic Web and Information Systems*, 2009, 5(4), 1-18.

Abstract

Exchanging and analyzing ideas across different software tools and repositories is needed to implement the concepts of open innovation and holistic innovation management. However, a precise and formal definition for the concept of an idea is hard to obtain. In this paper, we introduce an ontology to represent ideas. This ontology provides a common language to foster interoperability between tools and to support the idea life cycle. Through the use of an ontology additional benefits like semantic reasoning and automatic analysis become available. Our proposed ontology captures both a core idea concept that covers the ‘heart of the idea’ and further concepts to support collaborative idea development, including rating, discussing, tagging, and grouping ideas. This modular approach allows the idea ontology to be complemented by additional concepts like customized evaluation methods. We present a case study that demonstrates how the ontology can be used to achieve interoperability between innovation tools and to answer questions relevant for innovation managers that demonstrate the advantages of semantic reasoning.

Keywords: Innovation management, ontology, semantic web, open innovation, integration, creativity

Introduction

What is an idea? How does it relate to an innovation? While people may have an intuitive understanding of what these terms mean, there is no accepted precise and formal definition for the concept of an idea. As holistic innovation management and, in particular, the concept of open innovation gains traction, it becomes increasingly important to close this gap: a commonly agreed concept of an idea would support exchanging and analyzing ideas across different idea platforms and innovation tools, and hence be the basis to realize the vision of open innovation (Chesbrough, 2006; Gassmann & Enkel, 2004; Ogawa & Piller, 2006; Riedl, Böhm, Leimeister, & Krömer, 2009).

In this paper, we provide our own definition of the concept of an “idea” and introduce an ontology to represent ideas. Our research was motivated by the observation that various innovation management systems implement the concept of an idea based on similar core concepts but also distinct features. The goal is to capture the common core of different approaches to facilitate reuse and better integration. We also want to allow modular extensions required for the needs of specific innovation tools. Hence, we present a core idea concept that is enriched by concepts required to deal with ideas, e.g., rating, collaboration, tagging, or grouping of ideas. Thereby, we also illustrate how the Idea Ontology can be complemented by further concepts like customized evaluation methods.

The remainder of this paper is structured as follows: first, we study the challenges that arise as a result of recent trends in innovation management. We suggest meeting these challenges by following an ontology approach and analyzing related work. Then we describe our idea ontology in detail followed by an evaluation section. Using a case study, we demonstrate how technical

integration between innovation tools has been achieved and how the ontology can be used to answer questions relevant for innovation managers in order to demonstrate the advantages of semantic reasoning. Finally, we discuss the results of the case application and identify opportunities for future work.

Innovation Management

The Oxford English Dictionary defines an *idea* as: “1 a thought or suggestion about a possible course of action. 2 a mental impression. 3 a belief.” An *innovation* is defined as: “1 the action or process of innovating. 2 a new method, idea, product, etc.” Rogers defines an innovation as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003). This definition indicates that an innovation is more than an idea. To become an innovation, an idea has to be adopted. This concept is further developed by linking an idea or invention not only to adoption but to the concept of commercialization. Thus, Porter defines innovation as “a new way of doing things (termed invention by some authors) that is *commercialized*” (Porter, 1990). A precise definition of the meaning of the term “innovation” has been contentious and problematical and terms are often used loosely and interchangeably (Storey, 2000). However, there seems to be agreement on a general distinction between “invention” and “innovation” (Storey, 2000). Bullinger (2008) defines an innovative idea as “the more or less vague perception of a combination of purpose and means, qualitatively different from existing forms.” She thus claims it to mark the starting point of an innovation activity. As innovative ideas form the basis of innovation, idea collection and development is considered one of the first steps in most innovation process models (e.g., Cooper, 1990; Tidd, Bessant, & Pavitt, 2005; Wheelwright & Clark, 1992).

In the context of providing a tool to support the management of innovation processes, these definitions are not adequate because they do not specify (1) what information should be conveyed in an idea and (2) which methods or operations are applied to ideas. Hence, for the purpose of developing a semantic representation of the concept of an idea in innovation management applications, we informally define an *idea* as:

An explicit description of an invention or problem solution with the intention of implementation as a new or improved product, service, or process within an organization.

This central concept of an idea which we term *Core Idea* can be supplemented with various concepts that relate to feasibility and marketability, i.e., commercialization. Many of these concepts are used in the selection of tools that have been developed to support the different phases of idea generation and idea evaluation (van Gundy, 1988; see also Ardilio, Auernhammer, & Kohn, 2004 for an overview). A recent trend in innovation management is the implementation of openly accessible idea Web portals as one form of user innovation toolkits (von Hippel, 2005). We investigated 25 publicly available idea portals with between 146 ideas (ErfinderProfi, an inventor community in Germany) and over 75.000 (Starbucks) ideas¹ and analyzed how they describe and manage ideas (see Table 1 for a selection of the results).

Based on this analysis, we identified the following aspects to be included in an ontology for innovation management:

- *Comments and discussions* help to identify shortcomings within the original idea and develop it towards the users' needs (Franke & Shah, 2003; Piller & Walcher, 2006). Thus, open and interactive forums are key requirements within company-internal innovation management, e.g., employee suggestion systems, as well as in idea development Web portals (Fairbank & Williams 2001; Fairbank, Spangler, & Williams, 2003).

- *Ratings* are widely used to estimate user acceptance of ideas and are a key metric for idea selection (van Gundy, 1988). Within innovation management, many different rating mechanisms are generally applied. The methods differ substantially in (a) the rating subject (who is allowed to rate), (b) the rating object (what aspects are rated), and (c) the rating scale. Note that Table 1 names six similar websites applying four different rating scales.
- *Grouping and clustering* methods help to keep track of idea submissions, especially within large idea portfolios. The two main approaches to group ideas are hierarchical classification systems and tagging mechanisms. Our findings show that the two methods are frequently used in parallel. The categorization schemes are usually highly domain-specific and differ in aspects including granularity, depth, and multi-selectability.
- *Status*: In addition to content-related classification, organizational aspects are often applied to arrange the idea portfolio. Many idea portals assign an explicit development state to each idea, e.g., “ongoing”, “evaluated”, “rejected”, etc. Furthermore, patents and trademarks are widely used to protect innovations or to exploit them commercially (e.g., via licensing contracts). Thus, patent and copyright information are highly important within idea management.

Motivation for an Idea Ontology

Several benefits can be expected from the use of an ontology, including a shared and common understanding, providing structure to poorly structured or unstructured information, realizing management support and interdisciplinary communication as a result of structuring information, and allowing the analysis and comparison of the information represented beyond operational data (Noy & McGuinness, 2001; Fensel et al., 2002; Hüsemann & Vossen, 2005; Bullinger, 2008). In addition to these generic benefits of representing information with defined

ontologies, other benefits particularly important in the area of representing ideas and innovation management can be expected. There is a growing need for integration of Information Systems to interoperate in a seamless manner (Sheth, Ramakrishnan, & Thomas, 2005). This is particularly so in the area of innovation management where a single tool cannot support the whole innovation process. As more and more idea and innovation platforms appear on the Web, it becomes desirable to exchange information between platforms and adopt tools to prevent ideas from being restricted to silos. At the same time, enterprises are starting to understand the potential benefit from open innovation systems, and feel the need to open up their internal innovation processes and to integrate innovation management tools (Gassmann, 2006). The semantics of an organization's specific working context are captured by its local or private ontology, which serves the purposes of the particular organization (Ning, O'Sullivan, Zhu, & Decker, 2006). Thus, there is a need for a common language, i.e., a common idea data interchange format or a shared ontology to support the interoperability and to improve cross-enterprise collaboration.

Today, many idea portals on the Web are restricted to capabilities like tagging and ordinal ratings as the basis for idea analysis. However, we believe that more powerful tools and methods in idea portals cannot reveal their full potential until agreement is reached on the basic concepts of an idea. The use of semantic techniques brings with it the possibility to improve end-user efficiency by means of automated processing, and to cope with advanced analytical processing of idea metadata through reasoning. Thus innovation managers could profit from better structured information, integration and data exchange across tools and platforms, and additional semantic reasoning that allows them to analyze ideas based on related concepts.

In summary, the main benefits of using an ontology approach for idea management are the ability to achieve interoperability and technical integration between tools resulting in a better

support of the idea life cycle from idea generation, idea evaluation, through to idea implementation.

Related Projects and Research

In addition to the requirements that resulted from the study of existing innovation portals, we base our design of the Idea Ontology on the experience we observed in three different innovation management projects:

Stathel, Finzen, Riedl, and May (2008) outlined an innovation process and innovation management architecture targeted to the needs of the TEXO project³. This project investigates how services can be made tradable and composable in a business value network.

The Laboranova project⁴ aims to create collaborative tools that support knowledge workers in sharing, improving, and evaluating ideas systematically across teams, companies, and networks. The tools investigated in this project have a broader scope, i.e., beyond services, and focus on collaborative work processes within idea management.

Finally, an SAP-internal prototype, called Technology Business Exchange (TBE), investigates the commercial exploitation of ideas that are collected and managed in a closed world. Innovators submit their ideas on a Web platform and promising ideas are evaluated by experts. Business plans are then developed for the commercial realization of the ideas selected.

Although several other research projects currently deal with aspects of idea and innovation management, to our knowledge none of them explicitly aims at creating a common idea ontology for the purpose of achieving interoperability across innovation tools. Ning et al. (2006) describe the system architecture of an innovation system that combines ontology, inference, and mediation technologies to facilitate the distributed collection and development of ideas. Their system is based on metadata harvesting and RDF access technologies. It relies on

semantic technologies to allow for integration of idea development tools. However, the article does not give details of the concepts used in the proposed ontology and the ontology is not publicly available

The innovation ontology developed by Bullinger (2008), called OntoGate, aims at modeling the idea assessment and selection on a company-specific level. The ontology is deduced from empirical research and offers a means to structure a company's understanding of the innovation process, in particular the inputs, outputs, participants, and assessment perspectives. For example, different inputs into the innovation process have been developed such as *internal input* and *external input* which can further be broken up in *continuous internal input* and *discontinuous internal input*, input by *employees* and input by *executives* and so on. Thus, it gives an organization a better understanding of how the overall innovation process can be structured and how ideas can be systematically developed. In contrast to the work presented in this article, it does not provide a data model for representing individual ideas. Regarding the assessment of ideas, the largest module of the OntoGate ontology, three perspectives along which an idea or concept can be evaluated are suggested and subsequently developed: market, strategy, and technology. The resulting ontology, OntoGate, is classified as a *domain ontology* (Bullinger, 2008) as it represents the terms used to describe idea assessment and selection during the early stages of the innovation process in companies.

While our ontology, which can be classified as an *application ontology*, provides a technical means to represent complex idea evaluations along various concepts, OntoGate provides the necessary domain knowledge to decide which perspectives and criteria should actually be used for the assessment. Thus, OntoGate complements our ontology with additional

valuable domain knowledge to setup and customize a system based on the Idea Ontology to support and structure a given innovation scenario.

The specific contribution of our work compared to Bullinger's is the description of a technical architecture in which the ontology can be applied. The aim of our idea ontology is to offer a common language for idea storage and exchange for the purpose of achieving interoperability across innovation tools. Through reusing existing ontologies such as FOAF we hope to achieve interoperability not only among specialized innovation tools but general applications as well such as social networking. The innovation ontology developed by Bullinger (2008) aims at modeling the idea assessment and selection rather than providing technical integration.

Idea Ontology

We chose OWL for the development of our ontology and followed a generic ontology development approach (McGuinness & van Harmelen, 2005; Noy & McGuinness, 2001). Neither RDF nor RDFS is expressive enough to model complex structures like complex classes and relations carrying semantic expressions. As RDFS supports only classes and relations, it is capable of modeling sub-class concepts and relations, but only simple ones. In the evaluation section, this is illustrated with an example. We chose the approach by Noy and McGuinness (2001) as it focuses in particular on the reuse of existing ontologies which is a desirable attribute of ontologies (Lonsdale, Embley, Ding, Xu, & Hepp, 2009; Bullinger, 2008). Protégé has been used for modeling the Idea Ontology, and an OWL version and sample instances for testing and evaluation purposes are available on www.ideaontology.org. To further determine the scope of the ontology, a list of exemplary competency questions that a knowledge base developed using the ontology should be able to answer has been derived from Gruninger and Fox (1995). The

questions have been prepared from the perspective of an innovation manager working with a large pool of ideas. These questions served also as test cases in the evaluation section of our paper.

- Which ideas are in the repository?
- For which categories have ideas been submitted?
- Which tags have been used to classify ideas?
- Which ideas have already been implemented?
- Which ideas have at least three ratings?
- Which ideas have at least two or more ratings as well as at least one realization?
- Who are the most valuable community members by assessing at least three ideas?
- Which ideas already have a business plan attached (i.e., have an attached document with the topic 'business plan' to indicate feasibility)?

The namespaces used in the ontology are summarized in Table 2.

Ontology Design

This section introduces the Idea Ontology and gives a detailed explanation of the innovation and generic concepts it uses. Figure 1 depicts the ontology's main modules.

Modularity is a key requirement for large ontologies, as it facilitates reusability, maintainability, and evolution (Gómez-Pérez & Benjamins, 1999). Stuckenschmidt & Klein (2007) name the following reasons for modular design of ontologies: i) handling of ontologies in distributed environments like the semantic web, ii) management of large ontologies, and iii) efficient reasoning. Hence, a central design goal was to create a highly modular ontology. We achieved this by incorporating established ontology specifications to represent the more general metadata concepts that are associated with an idea. We therefore evaluated existing ontologies

with regard to their suitability to be reused in our Idea Ontology. In addition, we chose a hierarchical design that groups the three classes `im:CoreIdea`, `foaf:Document`, and `sio:Item` under a super class `rdf:Resource`. Thus, we are able to specify relations to various common meta-information which are then reused for all innovation-related resources. Specifically, every `rdf:Resource` has the following generic relations:

- `im:Origin`: the application from which the resource originates
- `r:Rating`: a rating mechanism that allows rating of the resource
- `foaf:Person`: the creator of the resource
- `tags:Tagging`: folksonomy tagging of the resource
- `skos:Concept`: definition of a subject matter of the resources that allows grouping of ideas
- `rdf:Resource`: through the `hasAttachment` relationship, innovation-related objects can be linked to each other.

However, it is important to note that an `im:CoreIdea` is the central object that defines an innovation project and for that purpose draws on other innovation resources such as documents and community discussions.

Innovation Concepts

Core Idea: To achieve a generic and versatile representation of ideas, we chose a hierarchical design with three layers of textual descriptions for an `im:CoreIdea`: `dc:title`, `im:abstract`, and `im:description`. All three represent a textual description of the idea but vary in length and detail. Thus, our ontology is able to support very simple tools such as electronic brainstorming, where an idea usually consists of no more than one sentence, up to more advanced tools that allow longer descriptions. It is also possible to extend the description

with resources such as images, screenshots, or process diagrams: they can be attached as `foaf:Documents` using the `hasAttachment` relationship. Furthermore, every `im:CoreIdea` has an associated creation date `dc:Date` and a version number to allow tracking of different instances of the same idea by means of the `isNewVersionOf` relationship. An idea can also have a relationship with `sIOC:Forum` (using `hasForum`) and `im:IdeaRealization` (using `hasRealization`) which we describe in the sections below. Figure 2 shows the complete `im:CoreIdea` class and its relationships.

When describing an idea, aspects related to the respective business context are relevant. They may be used to, e.g. assess the feasibility of an idea. Examples include a reference to the market, in which an idea can be commercialized, or potential customers and competitors. To model these descriptive attributes of an idea, we reuse the established Enterprise Ontology (Uchold, King, Moralee, & Zorgios, 1998). This ontology defines the semantic meaning of terms such as market, customer, competitor, supplier etc. Technically, we model these descriptive arguments as `sIOC:Items` that are attached to an idea and linked to a `skos:Concept` through the `hasTopic` relationship that defines the semantic meaning of the argument. As `sIOC:Items` are modeled as `rdf:Resources`, it is possible to assign a rating to them. This makes it possible, for example, to state that a certain `sIOC:Item` instance contains a text related to the “market” concept (through `hasTopic`) and then rate this specific attribute using a five star rating. Listing 1⁵ illustrates how the combination of `im:CoreIdea`, `sIOC:Item`, and `skos:Concept` can be used to represent detailed idea submission forms in a semantically enriched way. Furthermore, a `foaf:Document` linked to an idea using `hasAttachment` may contain a business plan, refer to a market analysis or a relevant patent. Together with expert ratings an innovation manager would be able to evaluate the quality of an

idea (cf. our last competency question). These artifacts can be of great help once the idea is realized.

Discussions and Collaboration using SIOC: Discussions and collaboration, both within and across organizations, are an important means for developing ideas (see, for example, Ahuja, 2000; Gemunden, Salomo, & Holzle, 2007). With increasing adoption of open innovation processes and the integration of users into the innovation process, the ability to systematically support discussions and collaboration becomes a key functionality (Chesbrough, 2006; West & Lakhani, 2008). Consequently, the ability to support comments has been added to our ontology.

Semantically-Interlinked Online Communities (SIOC) is an established ontology for integrating online community information (Bojārs & Breslin, 2007). SIOC can be used to represent community information such as blog, wiki, and forum posts. In the Idea Ontology, every `im:CoreIdea` can be linked to one or more `sio:Forums` using a `hasForum` relationship that provides a container for `sio:Items` related to the discussion of that idea. Furthermore, SIOC can be applied to model access rights to individual resources.

Status: In order to track an idea's progression throughout a submission, evaluation, and implementation process, it is necessary to track the status of an idea. The `im:Status` class offers this functionality: through a `dc:Title` a set of status individuals (i.e., instances) can be created depending on the innovation context. For example, status individuals could be "none", "under review", "in process", "implemented", "already offered" or others depending on the area of application and the innovation process in place. More formally, the output states proposed by Bullinger (2008) could be used: "stop", "hold" and "invest". These individuals are then associated with an idea via the `hasState` relationship. In this way, the ontology can easily be integrated into existing processes and evaluation structures.

Idea Realization: To support the full innovation life cycle and to allow for incremental innovations of existing products and services the link between ideas and their resulting realizations must be preserved. Moreover, the back-link from a realization to the original idea supports the application of various performance measures. For example, it would be possible to identify authors of highly successful ideas. To achieve this tracking across the life cycle our ontology contains an `im:IdeaRealization` class which is linked to an `im:CoreIdea` by means of the `hasRealization` object property. The `im:IdeaRealization` class is a placeholder for whatever is an appropriate means of representing an idea's realization. In a product environment, this may be a product number. In a software-as-a-service environment, the idea realization could link to a description of a Web service, for example, using WSDL⁶.

Generic Concepts

User: Friend of a Friend (FOAF) is an established RDF/OWL-based ontology for describing persons, their activities, and their relations to other people and objects (Brickley & Miller, 2007). Due to its de-facto standard for representing information about people and its simple design, we chose FOAF for representing all person-related information in the Idea Ontology. Specifically, links to a `foaf:Person` are maintained for all resources as `hasCreator`, and for `im:Rating` and `tag:Tagging` as `ratedBy` and `taggedBy`, respectively.

Tagging: Tags are keywords or terms associated with or assigned to a piece of information – in our case innovation resources. Due to their popularity in online communities and apparent benefits for information browsing (Mathes, 2004; Golder & Huberman, 2005), a tagging concept has been added to our ontology. Tag Ontology is an established and simple ontology for representing tagging information, which is also used by SIOC (Newman, 2005).

Tag Ontology represents tags as tuples of <tagger, tag, resource, date>. In the Idea Ontology, tags can be associated with all innovation resources by means of the `hasTagging` relationship.

Grouping: The Simple Knowledge Organization System (SKOS) is a W3C Recommendation of a common data model for sharing and linking knowledge organization systems such as thesauri, taxonomies, and classification schemes (Miles & Bechhofer, 2009). SKOS allows the definition of “concepts” that are identified using URIs and labeled with lexical strings in one or more natural languages. Furthermore, concepts can be linked to other concepts using semantic relations such as `skos:broader`, `skos:narrower`, and `skos:related`. This allows us to build taxonomies and semantic relationships between the various `rdf:Resources` that are associated with the concepts using the `hasTopic` relationship. This association with semantic concepts is used in two ways. First, a `im:CoreIdea` can thus be associated with a topic to indicate which subject area an idea belongs to (e.g., an idea related to the automotive sector). Second, it can be used in association with comments attached to an idea (`sioc:Items`) to support a structured idea assessment along predefined perspectives. For example, the perspectives *market*, *strategy*, and *technology* proposed in the ontology by Bullinger (2008) could be used for idea assessment. Additional semantic concepts can be added at runtime which thus allows the easy extension and customization of an ontology-based system.

Tracking the Origin of Contributions: As one of the main goals, the Idea Ontology fosters interoperability between various innovation management tools. Therefore, it is necessary to keep track of the application from which a given resource originates. The `im:Origin` class can be used for this purpose. An `im:Origin` contains a `dc:Source` and `dc:Title` attribute. In this way it can be stated that an idea originates, e.g., from a brainstorming tool, an idea portal on the Web, or another application.

Rating: A rating is used to associate values of appraisal for a resource. In the innovation domain, rating is of utmost importance as it is a necessary step for idea evaluation and selection (van Gundy, 1988). A great variety of idea evaluation and selection methods has been proposed (e.g., van Gundy, 1988) and new concepts like information markets are investigated for their suitability for idea evaluation (Stathel et al., 2008). Hence, the rating concept is required to be configurable with respect to the rating method and the range of values.

To accommodate these requirements, we extend the rating ontology proposed in Longo and Sciuto (2007) to support different kinds of ratings (see Figure 3). Based on this ontology, an `r:Rating` is a 4-ary relationship as follows: its rating value is expressed as some numerical `r:value`, the interpretation of which is application-dependent. The `r:Rating` refers to the resource that is rated. Notice that ratings are not restricted to ideas, but can refer also to documents or comments. A `foaf:Agent` refers to the person who expresses an appraisal for the rated resource. Note that we chose `foaf:Agent` instead of `foaf:Person` because ratings can also be expressed by software agents. The `r:RatingCollector` is a source that is used to collect ratings. The domain of values generated by this source is either defined as an enumeration of values or by an interval of numeric values (see Longo & Sciuto, 2007 for examples). The `r:RatingKind` is used to distinguish different aspects of the rated resource. Possible instances may be an `OverallRating` or a `UsabilityRating`.

While the tagging approach is rather generic, the opportunity of changing the ontology at runtime and thus allowing an adaptation of an ontology-based system to a given scenario's requirements, offsets the benefits of a more specific tagging approach.

Case Illustration of Ontology Application

The two major paradigms in Information Systems research are behavioral science and design science (Hevner et al., 2004). Our study clearly falls in the design science category and the question on how to evaluate the designed artifact, i.e. our innovation, arises. In general, there are numerous possibilities how to evaluate an artifact: analytical, case studies, controlled experiments, field studies, and simulations (Hevner et al., 2004). In this work, the argument for the utility, quality, and efficacy of our approach bases on four basic evaluation methods: scenario, prototypical implementation, informed argument, and architectural analysis (cf. Hevner et al., 2004).

Scenario The rationale behind using scenarios for evaluation of design artifacts in Information Systems is that scenarios can demonstrate the utility of an artifact. To this end, we apply the ontology developed above to a scenario derived from the TEXO project. This scenario points out clearly the necessity of a structured innovation process utilizing an innovation ontology,

Prototypical Implementation As a proof-of-concept, we prototypically implemented ontology instances for our application scenario. Artifact instantiation in general and a prototypical implementation in particular demonstrate the feasibility of the designed artifact. The construction of the prototype that fosters innovation management by using ontologies shows that an innovation management system can be assembled using already existing artifacts – it provides proof by construction (Nunamaker, Chen, & Purdin, 1991; Hevner et al., 2004).

Informed Argument The basic concept of informed arguments is to use information from relevant related research to build an argument for the artifact. To this end, we derived the requirements for the Idea Ontology in the motivation section, which contains an argumentation, why our approach is promising and useful.

Architectural Analysis In an architectural analysis one studies the fit of an artifact with the technical architecture of the overall information system. In the Section *Idea Ontology* we showed that the technical representation of our approach fits with the technical architecture of the prototype.

In the following, the application of our approach will be described using a case derived from the TEXO project context. The application demonstrates the effects of the ontology on a complex innovation management scenario. It further presents a sophisticated innovation process in which the ontology may be utilized to leverage the existing capabilities of the tools employed by resolving interoperability issues. This allows technical integration of various specialized tools that are designed to support the various idea generation and evaluation tasks.

The TEXO project investigates how services, in particular electronic services, can be made tradable and composable in a business value network. To harness the innovative capabilities present in the resulting business networks (Riedl et al., 2009), a cyclic innovation process consisting of several innovation steps is used in TEXO (Stathel et al., 2008). The resulting innovation framework methodologically and technically connects different tools and methods for systematic idea development. Figure 4 illustrates the innovation framework, aligning the innovation system architecture with the innovation process. After an idea has been created and developed using tools such as the Innovation Mining Cockpit⁷, workshops using electronic group support systems such as GroupSystem's ThinkTank⁸ software, or a Web-based community platform similar to the ones analyzed in Table 1, it is evaluated using an Information Market-based approach (Stathel et al., 2008; Stathel et al., 2009). Such an evaluation may be superior to evaluations by experts as they employ the wisdom of a great variety of people (Surowiecki, 2005). If the evaluation result is positive, the idea is implemented and used. Service

usage information improves existing services using the Service Feedback Controller. A central component within the framework is the Innovation Repository which, through the use of the Idea Ontology, provides means to store and retrieve ideas and systematically enhance them with additional information. All tools developed in the TEXO project implement the Idea Ontology and are supported by this repository in the back-end, which thus acts as a uniform idea data warehouse and aggregates the data generated in the respective components.

The tools in the example case can be used largely simultaneously by different teams or even organizations. The Idea Ontology explicitly enables collaboration by means of capturing the application (as `im:Origin`) that is the source of an idea. It also enables forum discussions as an example integration of established means for collaborative approaches to innovation. Reuse of the SKOS ontology provides for a simple way to structure the ideas. The link to involved collaborators is available as well through the reuse of FOAF. The semantic representation itself can be easily extended through reuse of extra ontologies so that additional requirements for idea development can be supported at low cost. The use of the Idea Ontology led to a successful integration of different TEXO tools.

For the case illustration at hand, some of the tools like GroupSystems' ThinkTank and the Web-based community platform can be configured to support functions for both idea generation and idea evaluation phases. To demonstrate the completeness of the integration Table 3 shows how the data fields of each of the tools can be mapped onto the Idea Ontology.

It is important to note that the Idea Ontology is an enabling technology. It cannot substitute proper innovation management processes in the organization or project at hand. Technical aspects such as particular repository management, content synchronization and tracking also represent complementary issues. With regards to existing innovation management

systems, the use of the Idea Ontology would translate to reengineering the systems for the purpose of more flexible and extensible exchange of ideas between applications, teams, projects and organizations. In the general context of so called extended enterprises (Browne, 1998), the time to realize synergy effects constantly gains importance. Our case illustrates that ideas development can happen more quickly and with less disruptions.

The Innovation Mining Cockpit, a Web-based community platform, a GroupSystems' ThinkTank-based brainstorming setup, an information market-based idea evaluation tool, and post-implementation service evaluation using the Feedback Controller, have successfully been integrated within the TEXO project, and interoperability has been achieved. Given the project context the ontology has proven to be expressive enough to cover all relevant data fields. Through the interoperability and technical integration between tools, a better support of the idea life cycle has been achieved as tools provide specialized support for different life cycle functions (e.g., sophisticated idea evaluation through an information market approach).

To determine whether the ontology contains enough information and to demonstrate advanced semantic reasoning functions, we evaluated our ontology against the set of competency questions proposed above. For that purpose, we designed test cases with sample data instances and modeled OWL DL query statements to answer the competency questions. In case of RDF and RDFS, queries are formulated with the SPARQL query language. For OWL-based ontologies as mentioned above, OWL DL queries are necessary. Thus, for example, to retrieve a list of all ideas stored in the ontology, the simple statement "CoreIdea" is sufficient. The reasoner will return all instances of the class `im:CoreIdea`. To answer more specific questions, more complex query statements are necessary. Table 4 presents a mapping of a set of competency questions to OWL DL queries.

Other questions that leverage the semantic abilities of an ontology include, for example, Which ideas are related to environmental topics? or What ideas have an economic market analysis attached to them? These questions span several namespaces imported in the Idea Ontology (`im`, `r`, `skos`). Instead of writing complicated SQL statements as would be necessary for a system based on relational databases, in ontologies a reasoner will work to identify the result set of these questions.

As shown in our examples, using ontologies for structured knowledge representation offers several advantages in expressing relations, sub-classes and dependencies between objects as well as “easy” querying. For our proposed ontology, these concepts are necessary to model the sophisticated interdependencies and links in related ontologies like SKOS or SIOC. Using sub-classes to describe concepts enables efficient inferencing and reasoning. Our short example showed that the ontology’s design is capable of returning a result set with adequate reasoning done by a reasoner like `pellet`⁹ or `racer`¹⁰. This is a valuable advantage that would be hard to realize with a traditional database-oriented system. By means of the imported ontologies, it becomes possible to add whole new concepts to an idea via already existing ontologies to enrich the idea and, at the same time, keep the ontology consistent.

Conclusion

A common language is a key component for information sharing and to foster interoperability between tools. This paper first presents our own definition of the concept of an “idea”. Second, based on the detailed analysis of the innovation management domain, the design of the OWL-based Idea Ontology is presented. Its primary goal is to facilitate interoperability between the various tools necessary to support the full life cycle of an idea in an open innovation environment. The ontology provides a consistent and semantically enriched method to represent

the information in the “fuzzy front-end” of innovation (Menor, Tatikonda, & Sampson, 2002).

Furthermore, the use of semantic techniques enables advanced management functions like semantic reasoning and automatic analysis. The design and development of our ontology follows principles promoted by design science research (Hevner, March, Park, & Ram, 2004; March & Smith 1995). For instance, problem relevance stems from the fact that the representation of ideas in innovation management is a problem domain with limited structure because ideas are, by their very nature, new and mostly not well understood. Furthermore, current development with an emerging interest in open innovation processes makes collaboration and information exchange between organizations important. The ontology has been developed by performing a thorough analysis of the requirements by common innovation-related tools such as Web communities and the experiences from three large research and development projects, one of which is used as the illustrative case study.

Particular emphasis has been given to the support for various community-related features such as commenting, tagging, and flexible rating mechanisms. The Idea Ontology can act as an enabler for open innovation processes as it provides a technical basis by means of which ideas can be generated systematically, refined, and evaluated across a wide set of tools and actors within or even across communities. The specific contribution of this work is the description of the technical architecture in which such an ontology-based approach is applied.

This research has certain limitations. Although information from three different projects as well as a survey of existing innovation communities and other innovation-related tools have been incorporated into the Idea Ontology, the scope might still be limited. The application of the Idea Ontology on an even broader scope, in other projects, and additional integration of innovation-relevant tools could further strengthen the confidence in the robustness of the

ontology. Certain innovation scenarios or idea-related concepts might not be adequately covered by our ontology. However, we believe that the modular design allows the easy extension of the ontology. A second limitation is that the evaluation is restricted to an analysis of only one scenario, Third, our exploration of reasoning capabilities presented covers only some exemplary innovation management tasks.

The limitations also serve as directions for future research and development. Our Idea Ontology provides a first systematic overview of the required key information for representing ideas in innovation management. In a broader sense the Idea Ontology proposed in this paper is a means of supporting collaborative working environments at the semantic infrastructure layer and a key to further explore innovation processes. Future research should also exploit additional reasoning capabilities of semantically related subjects.

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Footnotes

* An earlier version of this paper titled “Managing Service Innovations with an Idea Ontology” has been presented at the XIX RESER Conference, Budapest, Hungary, September 24th-26th 2009. This paper describes an extended ontology, contains additional technical details regarding the developed ontology, and a case study evaluating the system mapping and competency questions.

¹ Number of ideas as of October 2009

² <http://www.crowdspirit.com>, <http://www.dellideastorm.com>,
<http://www.erfinderprofi.de>, <http://www.incuby.com>, <http://mystarbucksidea.force.com>,
<https://www.atizo.com>, <http://ideajam.net/>, <https://mix.oracle.com/>; Dell and Starbucks are based on the same Salesforce Ideas software but use a different configuration.

³ <http://theseus-programm.de/scenarios/en/texo>

⁴ <http://laboranova.com/>

⁵ Code samples use N3 notation <http://www.w3.org/DesignIssues/Notation3>.

⁶ <http://www.w3.org/TR/wsdl>

⁷ A Web portal embracing several special search mechanisms for innovation professionals (Stathel et al., 2008; Finzen, Kintz, Koch, & Kett, 2009).

⁸ <http://www.groupsystems.com/>

⁹ <http://clarkparsia.com/pellet/>

¹⁰ <http://www.sts.tu-harburg.de/~r.f.moeller/racer/>

Table 1

Analysis of a sample of publicly available idea portals

Name	Comments	Rating	Classes	Tags	Status Model
Crowdsprit (FR) ²	Yes	Thumb Up/Down	Single	Yes	Incubator (Ongoing, Evaluated, Rejected), Elevator, Idea in Market
Dell (US) ²	Yes	Thumb Up/Down	Multiple	No	Already Offered, Implemented, In Progress, Partially Implemented, Reviewed, Under Review
ErfinderProfi (DE) ²	Yes	Scale 1 to 10	Single	Yes	n/a
Incuby (US) ²	Yes	5-Star	Single	Yes	With patent (Pending, Provisional, Full, Pat.-No.), Without Patent, Concept or Idea
Starbucks (US) ²	Yes	Thumb up/Down	Single	No	New, Under Review, Reviewed, Coming soon, Launched
Atizo (CH) ²	Yes	Thumb up	n/a	Yes	Open, In Evaluation
IdeaJam (US) ²	Yes	Thumb Up/Down	Single	Yes	Open, In Progress, Complete, Rejected, Withdrawn

Oracle Mix (US) ²	Yes	Thumb up	Multiple	Yes	n/a
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Table 2

Referenced Ontologies

Ontology	Prefix	Short Description
Idea Ontology	im	The ontology for innovation management introduced in this paper
RDF	rdf	Resource Description Framework
Dublin Core	dc	The Dublin Core for metadata about resources
FOAF	foaf	The Friend of a Friend ontology for describing agents and their relationships
Tagging Ontology	tags	A simple tagging ontology
SIOC	sioc	An ontology for (online) communities
Rating Ontology	r	A rating ontology
SKOS	skos	An ontology for knowledge representation

Figure 1

Overview of the Idea Ontology

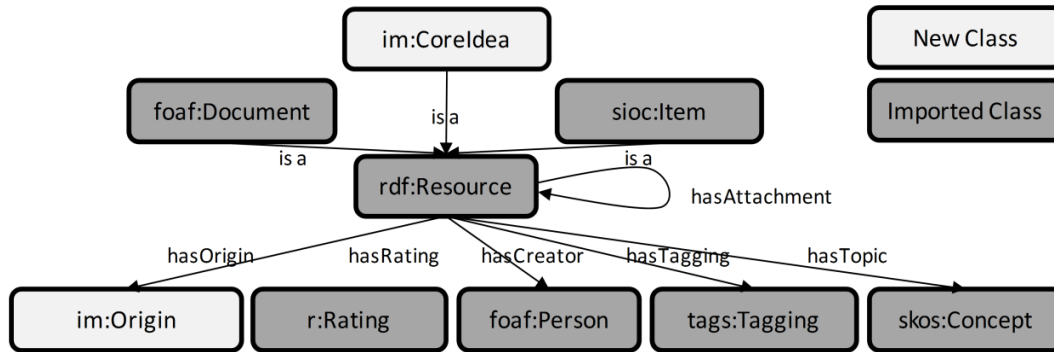
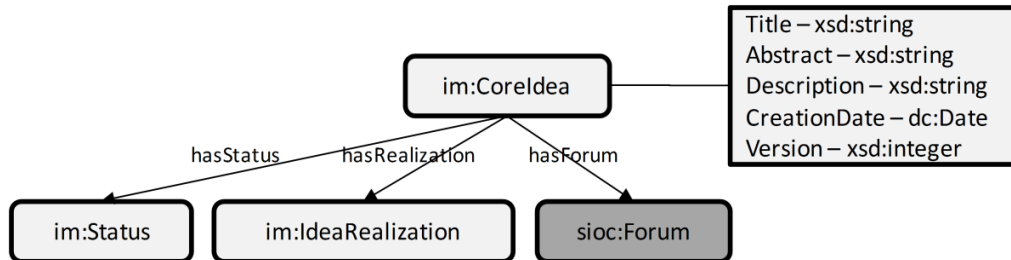


Figure 2

The Core Idea element



Listing 1

Representation of idea submission forms

```
<#ideal23> a im:CoreIdea ;  
    dc:title "Calculate environmental sustainability based on  
            bill of materials." ;  
    im:hasForum <#forum ideal23> .  
<#forum ideal23> a sioc:Forum .  
<http://en.wikipedia.org/wiki/Market> a skos:Concept ;  
    skos:prefLabel "Market"@en .  
<http://en.wikipedia.org/wiki/Customer> a skos:Concept ;  
    skos:prefLabel "Customer"@en .  
<#item101> a sioc:Item ;  
    sioc:has container <#forum ideal23> ;  
    im:hasTopic <http://en.wikipedia.org/wiki/Market> ;  
    sioc:content "Automotive industries" .  
<#item102> a sioc:Item ;  
    sioc:has container <#forum ideal23> ;  
    im:hasTopic <http://en.wikipedia.org/wiki/Customer> ;  
    sioc:content "Engineering departments of automobile  
                manufacturers" .
```

Figure 3

Rating module

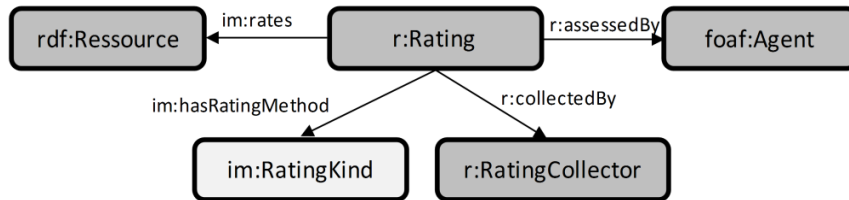


Figure 4

Innovation framework and system architecture of the TEXO project

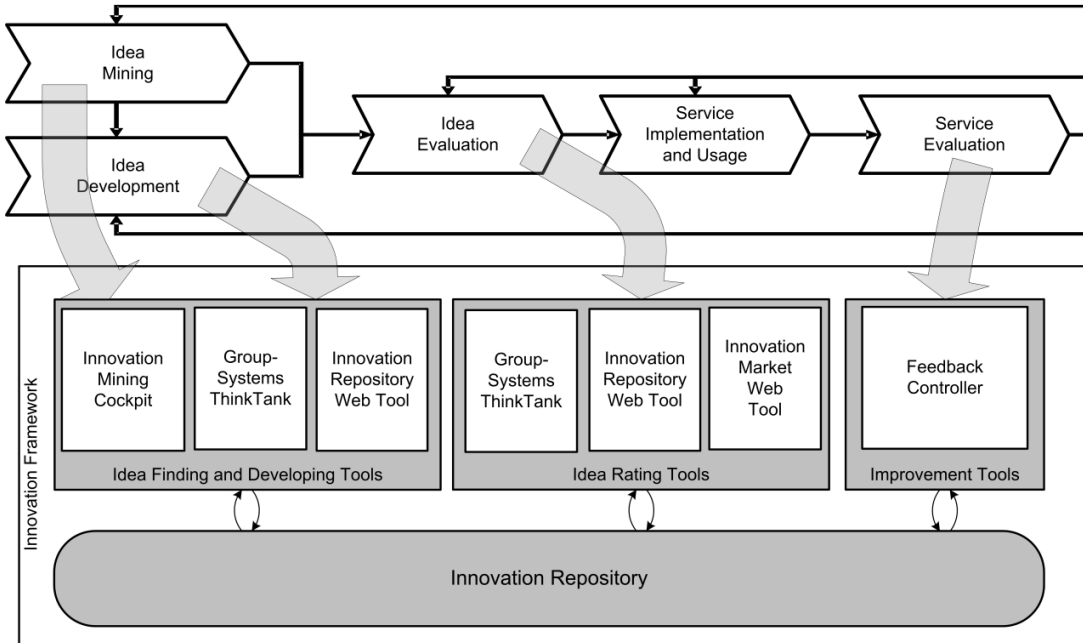


Table 3

Mapping between tool data and Idea Ontology concepts

Tool (Innovation Phase)	Field	Mapping in Idea Ontology
Innovation Mining	Title	im:CoreIdea/title
Cockpit (innovation impulse and idea development)	Search report	foaf:Document linked to an im:coreIdea through hasAttachment
	Search space configuration / saved search	foaf:Document linked to an im:coreIdea through hasAttachment
Web-Tool (idea generation and idea evaluation)	Title	im:CoreIdea/title
	Description	im:CoreIdea/description
	Author	im:CoreIdea/hasAuthor linking to foaf:person
	Status	im:Status
	Tags	im:CoreIdea/hasTagging links to Tags:Tagging with additional fields: taggedBy a foaf:Person taggedOn a date
Comments	sioc:Item linked to a sioc:Forum via hasContainer sioc:Forum linked to an idea via hasForum sioc:Item is also linked to skos:Concepts via hasTopic	
GroupSystems	Brainstormin	im:CoreIdea/title

ThinkTank (idea generation and idea evaluation)	g idea	
	Rating	r:Rating r:value (e.g., “1=bad”) r:assessedBy (e.g., “brainstorming session”) r:rates (i.e., the im:CoreIdea being rated) r:hasRatingKind (e.g., “usability rating”)
	Comment	as above
Information Market (idea evaluation)	Title	im:CoreIdea/title
	Description	im:CoreIdea/description
	Trade-based idea ranking	r:Rating r:value (e.g., ”99 ”) r:assessedBy (i.e., an instance of the information market) r:rates (i.e., the coreIdea being rated) r:collectedBy (i.e., the information market tool) r:hasRatingKind (e.g., an “OverallRating”)
Feedback Controller (service evaluation => idea generation or idea refinement)	Title	im:CoreIdea/title
	Implemented service	hasRealization linking to a service description in WSDL accessible under a URI
	Community	sioc:Forum attached to an im:CoreIdea sioc:Item for individual community posts

Table 4

Sample questions and matching OWL DL queries based on the Idea Ontology

Competency Question	OWL DL Query
Which ideas are in the repository?	CoreIdea
For which categories have ideas been submitted?	isSubjectOf some CoreIdea
Which tags have been used to classify ideas?	Tagging and inv(hasTagging) min 1
Which ideas have already been implemented?	CoreIdea and hasRealization min 1
Which ideas have at least three ratings?	CoreIdea and hasRating min 3
Which ideas have at least two or more ratings as well as at least one realization?	CoreIdea and hasRating min 2 and hasRealization min 1
Who are the most valuable community members by assessing at least three ideas?	Person and inv(assessedBy) min 3
Which ideas already have a business plan attached (i.e., have an attached document with the topic 'business plan' to indicate feasibility)?	CoreIdea and hasAttachment some (Document and hasTopic value http://en.wikipedia.org/wiki/Business_p lan)