# Know-Ont: A Knowledge Ontology for an Enterprise in an Industrial Domain[1]

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***Abstract***

*Research in the field of knowledge representation system is usually focused on methods for providing high-level descriptions of the world that can be effectively used to build intelligent applications. This paper shares the development process of an ontology which involves preparing questionnaires, design decisions, and interviewing key persons. This is an ongoing work resulting in the development of ontology for knowledge management in an enterprise. The final result is a knowledge ontology, coined as Know-Ont, is a collection of concepts and their related properties from maintenance and new product design domain that fit together to process and store knowledge thus making it available for later reuse.*

***Keywords:*** *Knowledge Management, Ontology, Semantic Web, AI.*

## 1. Introduction

Knowledge representation [11] developed as a branch of artificial intelligence is defined as the science of designing computer systems to perform tasks that would normally require human intelligence. Knock et al. [6] states that *the single most important factor that ultimately defines the competitiveness of an organization is its ability to acquire, evaluate, store, use and discard knowledge and information*. Bradley et al. [1] estimate that, knowledge is currently doubling every 18 months; therefore knowledge should be managed efficiently and effectively so that it can be put to re-use.

Our hypothesis is based on the following: if a system can somehow understand the user requirements and be aware of the situation a user is working on, it might probably be able to put the knowledge management system to use: adapt itself to meet different user's requirements, automatically monitor the knowledge process and extract reusable knowledge, proactively provide right knowledge at the right time, and so on. But how to achieve such a system still remains at large. Using ontologies is one of the ways; the first step in this direction is to develop knowledge ontology for industrial domain. The principal contribution of this paper is to present and discuss the various steps followed during the process of ontology development; we studied business cases provided by our industrial partners (name withheld due to privacy issues), prepared questionnaires, conducted interviews, which resulted in the definition of concepts and its related properties. Knowledge ontology, Know-Ont is envisioned as a final result. To the best of our knowledge, this work is one-of-its kind, and no ontology exists for modeling knowledge management in industrial scenarios. Though there are few works that appear similar to ours [8], however our approach and methodology

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serves a different purpose. A working prototype of the system is implemented and queried using SPARQL[2].

Section 2 introduces ontology in an industrial domain and also explains how our work is different from other existing ontologies. Section 3 presents the business cases and requirement analysis, which is followed by the discussion about the resulting knowledge ontology Know-Ont, and a case study to evaluate its consistency and effectiveness in Section 4. The final section, section 5, comprises future work and conclusion.

## 2. Ontologies in Industrial Domain

Ontology is an explicit specification of conceptualization [4] i.e. ontology is a description of concepts and relationships that can exist between them. Construction of ontology seem a natural process to a naive user, however, it is an art or design which has to be crafted carefully. The concepts can be determined manually or through an experimental process. In this paper, we use software engineering principle to determine concepts and their associated relationship. Some of the concepts are borrowed from existing ontologies like GEO[3], FOAF[4] etc. It is normal to borrow concepts from other ontologies, this puts ontologies to re-use.

There are numerous ontologies available on the web but very few of them provide explicit details about the process followed that lead to its development. Also, a very few ontologies exist for industrial domain. These ontologies model process flow in industrial scenarios, for example there is a manufacturing system engineering ontology [9], ontology for virtual enterprise integration [3], ontology for supply chain [10], and so on. We on the other hand advocate use of ontologies for knowledge management in a different context. Our objective is to provide reusability of stored information in an efficient and effective way, so that right information is available to the right person at the right time. We are not trying to model industrial scenarios, but providing an ontology for knowledge management in industrial scenarios.

Mason [8] is a popular ontology for industrial scenarios that models manufacturing domain. One of the applications of this ontology is automatic cost estimation; If someone tries to envision an application for Know-Ont, it would be search for persons who can do a particular job, time duration required to finish a job, searching relevant documents similar to a job in hand, and search for similar activities etc.

## 3. Business Case and Requirement Analysis

The most important step in engineering an ontology is to understand user requirements, much like in software engineering. This section details the steps to elicit information from the industrial partners. The framework of work is divided into two parts: the first part describes business cases and the second part is analysis. To get a better understanding about the problems encountered while using legacy systems in industrial domain, we did a business case and requirement analysis with 3 industrial partners, each from different domain viz. electrical engineering industry, aerospace industry, and engineering consultancy. The

[2] http://www.w3.org/TR/rdf-sparql-query/ - SPARQL is a query language for querying RDF repositories.
[3] http://www.w3.org/2003/01/geo/ - an ontology for spatial modeling like country, cities etc.
[4] http://xmlns.com/foaf/spec/ - an ontology for describing a person.

objective of this section is to understand the area or process where knowledge enhancement is needed and modeling of business case and use cases. Moreover, defining and analyzing the business case also contributes to better understanding of ontological concepts, and relations between them.

### 3.1. Business Cases

Each industrial partner was asked to identify target processes in their respective domains where knowledge enhancement is needed. A questionnaire was prepared and distributed among the industrial partners for their feedback. The ultimate result from this questionnaire was to identify a set of concepts for the ontology and define relationships between them.

Table 1. Target Processes recommended by Industrial Partners.

| Industrial Partner A | Industrial Partner B | Industrial Partner C |
|---|---|---|
| Design | Corrective Maintenance | Maintenance |
| Maintenance | Scheduled Maintenance | Project Development |

Each business case follows the following format: description, description of process, definition of quantifiable business objectives, expectation of improvement after the implementation, use case modeling of the process. Each industrial partner responded with 2 business cases. For the elaboration of both the business case description and requirements description, personal interviews were conducted. The personal interviews resulted in the following details: how the process will be initiated, what are the precursors, what are the expected results, people involved, work flow, activities, etc. Table 1, shows the target processes where the industrial partners seek improvement by applying knowledge management.

### 3.2. Analysis of Business Cases

In this section, we first present results from the analysis of business cases and questionnaire, i.e. identification of areas or processes to improve, definition of quantitative objectives to achieve. Further, we will lay down the basis for the proposed ontology.

Industrial Partner A identified two main processes: product design and maintenance service. Both processes involve manual search of documents which is a tedious process, for ex: product design activity (**Activity**[5]) generally involves improvising an existing product (**Artefact**) by introducing current market requirements. For improvising an existing product, its previous design methodology, sketches, drafts, (**Document**) etc. are needed to be readily available; moreover, searching for appropriate and available staff (**Person**) who can carry out the design job in stipulated time (**Time**) is also need to

[5] Text in bold reflects the concepts that were extracted from the business cases – Here we are only showing a partial list of concepts as an illustration.

be determined. Similar type of issues exists for the maintenance department also. The design process involves most of the departments (**Department**) of the company (Technical office, Quality Department, Marketing, etc) as well as external organizations (commercial organizations, labs, etc).

Industrial partner B identified maintenance process. This process can be of two types: corrective maintenance i.e. the process launches after a customer request arrives. Another type of maintenance is scheduled maintenance like AM (Annual Maintenance). They envisioned the following objectives from the proposed solution: improved network for co-operative networking, personalized solutions, and remote maintenance (**Location**) by providing information readily (semantic search) everywhere and anywhere.

The third industrial Partner C selected maintenance process and project development as two main processes. The actors involved in the maintenance process are distributed in several subsidiaries or locations (**Location**) across the country. Finding the right available person for the right task can be a daunting task taking into account different skills (**Role**), availability, and location. Developing a new project generally involves improvising an already existing project; similar requirements were posted by industrial partner A also.

Table 2. A partial list of concepts with their definitions for consideration to industrial partners. A complete list is not provided because of number of page issues, however, important concepts generated from the analysis of business cases are listed below.

| **Concept Name** | **Source** | **Definition** |
|---|---|---|
| Location | Geo | An abstract concept to describe any locatable entity |
| Resource | Self | A generic concept for any means that is used in an activity. |
| Document Resource | Self | Anything that can be regarded a document such as text files, spreadsheets, rtf documents, |
| Service | Self | Denotes anything described by a well-known, published interface. |
| Person | FOAF | A generic concept that describes people |
| Department | Self | Represents affiliation of a person |
| Profile | Self | Profession description of a person |
| Activity | Self | Describes everything a person/process has done, is doing, or will be doing (assigned tasks) in order to fulfill a goal. |
| Role | Self | Defines a role performed by the engineer |
| Task | Self | An activity is composed of several tasks |
| Artefact | Self | Final product |
| Time | Time[6] | To track the start, end and intermediate stages of a process |
| Process | Self | A process is composed of several activities |

[6] http://www.w3.org/TR/owl-time/ - an ontology for temporal concepts.

It is apparent from the above discussion; one common process that emerges out of business cases is Maintenance. On careful examination of processes "Product Design" and "Project Development", we found out that they reflect similar objective i.e. new product design. We therefore decided to provide proof of concept for Maintenance and Product Design business cases. Note that, the proposed ontology is a generic one which can be extended to other business cases also. Such ontology in the literature is referred as upper ontology[7]. Based on the evaluation of business cases, we define a set of concepts (refer Table 2), which were either borrowed from other ontologies developed by us or from ontologies developed by others like FOAF, Time, Geo etc.

## 4. Knowledge Ontology: Know-Ont

In this section, we lay the foundation of Know-Ont ontology; explain the various concepts and their associated properties. A very simple prototype of Know-Ont is developed using Protégé[8]. Protégé is an ontology editor that provides interface for inputting instances and querying them using SPARQL. Our basic objective is to model all the available information as instances in ontology and making it available for later re-use. Section 4.1 explains the specifications of Know-Ont followed by Section 4.3 that demonstrates how Know-Ont can be put to use for searching information based on an example use case in Section 4.2.

### 4.1. Know-Ont Specifications

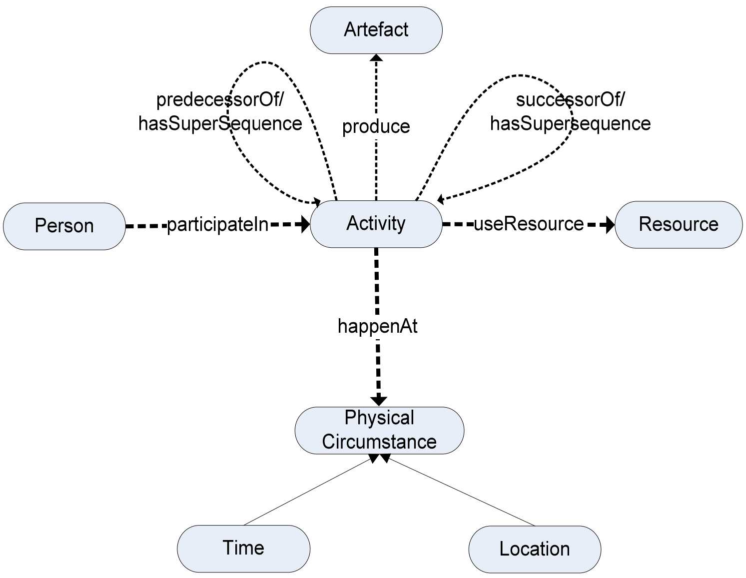


Figure 1. Overview of Knowledge Ontology: Know-Ont

Based on the feedback from industrial partners and meticulously going through the business cases, we arrived at the Know-Ont ontology shown in **Figure 1**.

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[7] http://en.wikipedia.org/wiki/Upper_ontology_(information_science) – definition of Upper Ontology
[8] Protégé - http://protege.stanford.edu/ - is an ontology editor.

The central concept is an *activity*, which represents a knowledge based activity and is very general to include any sort of processes in an industrial domain. Each activity is performed by a group of human beings, which is modeled as a *person* concept and can be imported from the FOAF ontology. Other concepts like department, skill, etc are also imported from FOAF. An *Activity* is related to itself as a predecessor/successor activity to represent hierarchy, as well as a hasSubsequence/hasSupersequence activity to represent time sequence.

The concept *Activity* can be made domain specific by extending into more specific concept which may vary from case to case. For example, we extend concept *Activity* into several specific sub classes viz. Product Design Activity, Maintenance Activity, etc. as shown in **Figure 2**.

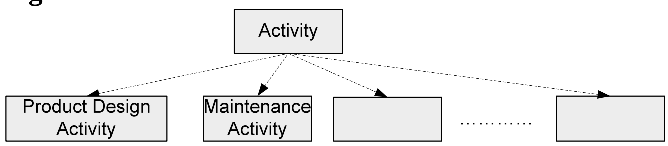


Figure 2. Extension of Activity concepts into domain specific concepts.

Every *Activity* has some physical circumstances associated with it, like, *Location* and *Time*. *Physical Circumstance* is a Concept. An *Activity* is related to *Physical Circumstance* through the object property happenAt. Result of an *activity* is ultimately an *Artefact* (or Product). Know-Ont has a layered architecture, so *Artefact* represents a part of core ontology and there is a further classification of *Artefact* which depends on the application domain. The object property particpateIn defines the relationship between the *Person* and *Activity*.

Each *Activity* uses some *Resource* (such as Document, Manuals, URLs, tools, etc) to produce an *Artefact*. Therefore, a concept *Resource* is defined, which is related to the *Activity* through the useResource object property. To make the ontology domain specific, the concept Resource can be further extended into *Document*, *Tool*, etc. as shown in

**Figure 3**.

Note the difference between concepts *Resource* and *Artefact*; Resource is something that is used by an activity for the production of a product (referred as *Artefact*). This means that in one industrial environment, scissor can be a resource and in other it can be an Artefact. We plan to re-use existing product ontology. There are numerous product ontologies [5, 7] available; work to identify which product ontology suits out requirement is in progress.

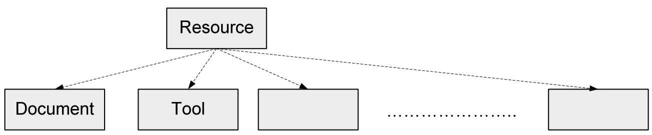


Figure 3. Domain specific ontology extension to core concept resource.

### 4.2 A use-case representation of Know-Ont Ontology

**Figure. 4**. presents a use case using Know-ont ontology, which shows two activities, persons involved in the activity, artefact produced and tools used to produce the artefact. It also shows relationship between two activities.

For simplicity, we have used OOPS model to represent class name and instance name. For ex: concept Activity is represented as a Class and the term "Know-Ont Concept development" is represented as an instance of Activity concept. It can be clearly seen that "Know-Ont Context Extraction" activity is successor of "Know-Ont Concept development" activity. Note the difference between precedence and subsequence object property; if an activity A is 'predecesorOf' activity 'B', it means, activity 'A' executes and terminates following which activity B starts. Whereas, if an activity A 'hasSubsequence' activity B, it means, activity A needs activity B to finish and use generated results to finish itself. Similar difference exists between 'successorOf' and 'hasSupperSequence' object property. Also note that, 'predecessorOf' is owl:inverseOf 'successorOf' object property.

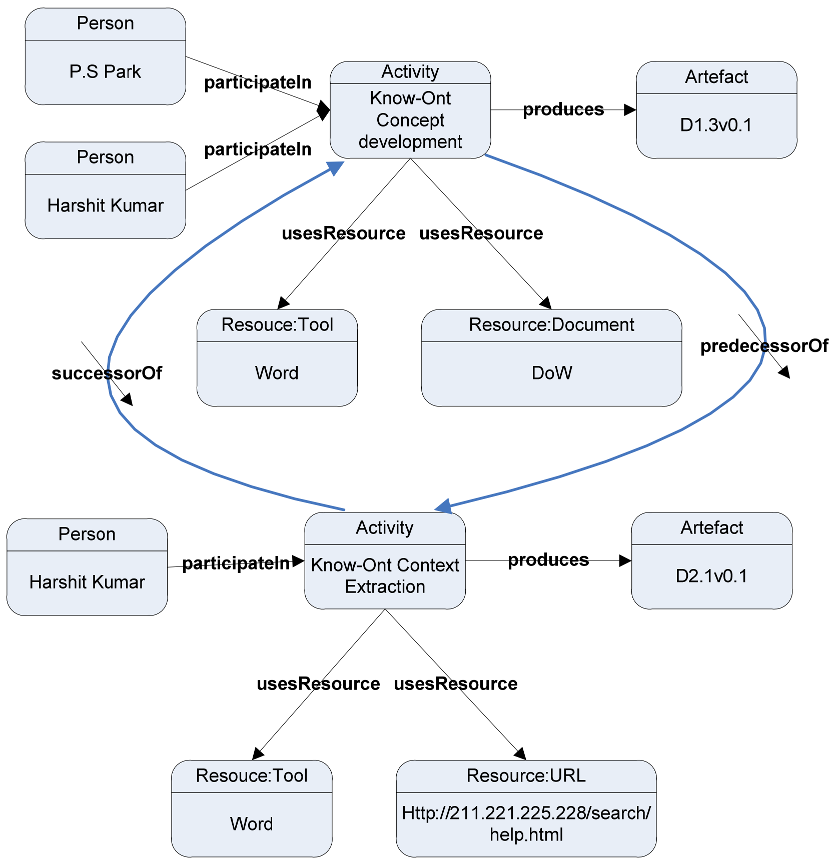


Figure 4. A use case of Know-Ont ontology represented using OOPS model.

### 4.3 Querying Know-Ont Using SPARQL

The Know-Ont ontology is available to address the following questions: *Is there any similar product exists?* If answer to above question is yes, then,

*List the similar products and the degree of similarity,*

*List the classification of existing product,*

*List the actors involved,*

*List the sketches,*

*List the technical specs,*

For ex: Find all the artefacts produced by user "Harshit Kumar". The query is as follows

SELECT ?person ?activity ?artefact WHERE {?person rdf:typeOf foaf:Person. ?person foaf:name "Harshit Kumar". ?person ko:participateIn ?activity. ?activity ko:produces ?artefact. }

The above query will search for tuples that have foaf:name "Harshit Kumar", who has participated in some activity that results in some artefacts, output is shown in Table 3.

Table 3. SPARQL query output, find all the artefacts produced by user "Harshit Kumar"

| ?person | ?activity | ?artefact |
|---|---|---|
| Harshit Kumar | Know-Ont Concept Development | D1.3v0.1 |
| Harshit Kumar | Know-Ont Context Extraction | D2.1v0.1 |

## 5. Conclusion and Future Work

The work presented in this paper deals with engineering a knowledge ontology which can be further re-used for knowledge provisioning. The process to engineer knowledge ontology involves interviewing, meeting with the key persons who execute or deal with the target business process. Knowledge ontology Know-Ont is based on two business cases selected by industrial partners, which are derived from different domains viz. maintenance and product design domain. A very simple prototype has been realized using Protégé and a use case is presented to show the results from the system on which a SPARQL query executes for finding all the artefacts produced by a particular user.

Certainly many works still need to be done, for instance, an interface for users to input data and query. Query results will probably return more than one match; all the matches need to be ranked. For ranking, we must define a similarity measure that can return tangible numbers so that we can differentiate which match is closer to the current context and which one is farther.

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