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The Role of Software Engineering Ontology Model & Design for Multi-Site Software Development

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ABSTRACT: Ontology is important concept for software engineering to formally represent knowledge in a way software can process the knowledge and reason about it. The software engineering ontology assists in defining information for the exchange of semantic project information framework. This paper gives an analysis of what software engineering ontology model is, what it consists of and what it is used for in the form of usage example scenarios. The usage scenarios presented in the paper highlight characteristics of the software engineering ontology model and design in UML. The software engineering ontology assists in defining information for the exchange of semantic project information and is used as a communication framework. Its end users are software engineers sharing domain knowledge as well as instance knowledge of software engineering.

Keywords:- Software Engineering, Ontology Development, Multi-site Software Development Knowledge Sharing and Knowledge Engineering.

1. INTRODUCTIONS.

Having realized the advantages of multi-site software development, major corporations have moved their software development to countries where employees are on comparatively lower wages. It is this imperative of financial gain that drives people and businesses to multi-site development and the Internet which facilitates it. Software development has increasingly focused on the Internet which enables a multi-site environment that allows multiple teams residing across cities, regions, or countries to work together in a networked distributed fashion to develop the software.

The development of the software in various fields, have become more cushy and comfortable. Realizing the pros of multisite software development, major MNC's and the corporate sectors have moved their business to the countries where the employees work for curtail and pare salaries. Software development has increasingly focused on the Internet, which enables a multisite environment that allows multiple teams residing across cities, regions, or to countries to work together in network distributed fashion to develop the software. However, the effective communication and coordination across multiple sites is extremely important for the global software development. Team members, team leaders and the managers who carry out, control, manage different tasks and activities respectively may not be located at the same site in a multisite environment.

Consider a scenario of a software development process where the team members work in a particular site and the person who manage them, their team leader is at different site who controls them and collects, integrates the completed modules for further enhancement of the software project.

As the team completes their respective module and send the same to the team leader. They draft in their own form of representations for conclusions on the completed module with

respect to their culture, customs and tradition which they follow in their day to day life. It is obvious that they might have not come face to face and never met as they work online. So, strict software engineering principles should be followed, to have a better communication among the teams and the team members.

The incongruity in analysis, design, documentation, presentation, and diagrams could prevent proper access by other stake holders in a particular software project. Seldom issues of this kind are kept enigmatic. In reference to the above discussed problems, the software engineering has a commonly understood body of knowledge and is an easily learnt subject that includes some of the latest technology and methodology that is easily adopted. As the teams at different sites refer to various texts in the same software engineering domain, each individual have a personal guide and when they communicate with each other their terminology could be quite startling and unusual. This leads to inconsistency and equivocation among the teams. Communication is the real challenge that everyone face in their daily life and the affective communication is an important part of a successful business. Ontology is an important part of developing a shared understanding across a project to lessen the problems.

1. ONTOLOGY IN SOFTWARE ENGINEERING

The term 'Ontology' is derived from its usage in philosophy where it means the study of being or existence as well as the basic categories [1]. Therefore, in this field, it is used to refer to what exists in a system model. An ontology, in the area of computer science, represents the effort to formulate an exhaustive and rigorous conceptual schema within a given domain, typically a hierarchical data structure containing all the relevant elements and their relationships and rules (regulations) within the domain [2].

An ontology, in the artificial intelligence field, is an explicit specification of a conceptualisation [3, 4]. In such an ontology, definitions associate the names of concepts in the universe of discourse (e.g. classes, relations, functions) with a description of what the concepts mean, and formal axioms that constrain the interpretation and well-formed use of these terms [5]. For example, by default, all computer programmes have a fundamental ontology consisting of a standard library in a programming language, or files in accessible file systems or some other list of 'what exists'.

However, the representations are sometimes poor for certain problem domains, so more specialised schema must be created to make the information useful and for this we utilise ontology. An abstract view of representing the software engineering knowledge is shown in Fig. 1. The whole set of software engineering concepts representing software engineering domain knowledge is captured in ontology. Based on a particular problem domain, a project or a particular software development probably uses only part of the whole set of software engineering concepts. The specific software engineering concepts used for the particular software development project representing software engineering sub-domain knowledge are captured in ontology. The generic software engineering knowledge represents all software engineering concepts, while specific software engineering knowledge represents some concepts of software engineering for the particular problem domain.

The actual content and the domain are represented in the fig 2 with Semantic and the Pragmatic representations respectively. The content in the semantics (Actual meanings) area can be Stuff, Things, and Relationships. The Domains in the pragmatic (Dealing or concerned with facts or actual occurrences) area can be Knowledge domain, Applications domain, and Functional domain. Combining both the Content and the Domain knowledge forms the basis for the Ontology. A simple and very regular ontological representation can be a standard library in a programming language environment which has all the methods, attributes, classes and packages that gives the answer for the preliminary question of "What Exists" in a programming language..However, some Representations may be poor due lack quality in design, implementation.

For example, if a project uses purely object-oriented methodology, then the concept of a data flow diagram may not necessarily be included in specific concepts. Instead, it includes concepts like class diagram, activity diagram and so on. For each project in the developmental domain, there exists project information or actual data including project agreements and project understanding.

The project information especially meets a particular project need and is needed with the software engineering knowledge to define instance knowledge in ontology. Note that the domain knowledge is separate from instance knowledge. The instance knowledge varies depending on its use for a particular project. The domain knowledge is quite definite, while the instance knowledge is particular to the problem domain and developmental domain in a project. Once all domain knowledge, sub-domain knowledge and instance knowledge are captured in ontology, it is available for sharing among software engineers through the Internet.

All team members, regardless of their location, can query the semantically linked project information and use it as the common communication and knowledge basis for raising discussion matters, questions, analysing problems, proposing revisions or designing solutions and the like.

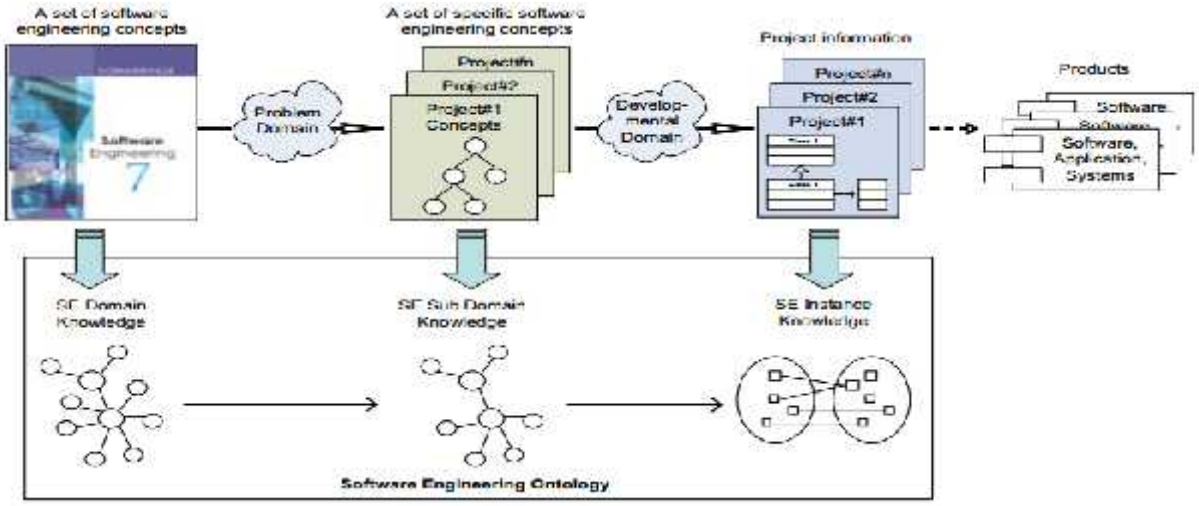


Fig.1 Schematic overview of software engineering knowledge representation.

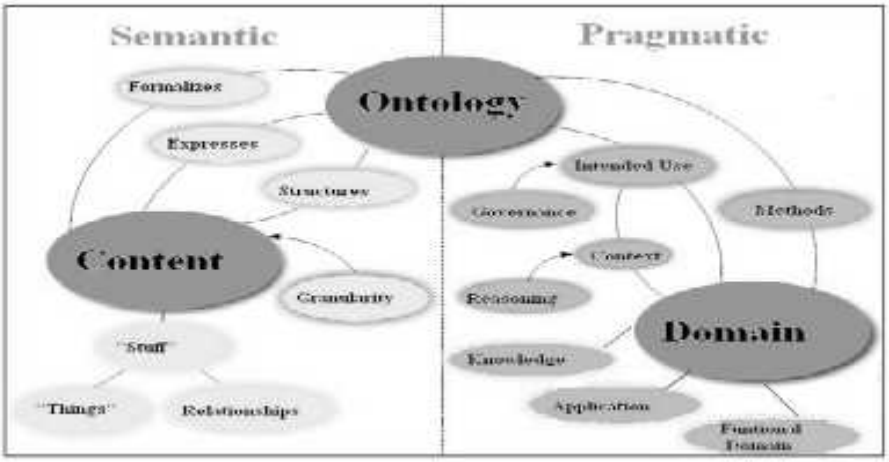


Fig.2 Ontology with its 'Content' and the 'Domain' Concepts

Software engineering domain knowledge constructs should be sought in ontology, a well-founded model of reality. Ontology is used to analyse the meaning of common conceptual modelling constructs [6] which accurately reflect the world. The notion of a concrete thing applies to what software engineers perceive based on software engineering domain knowledge. In this light, the notion of ontology is a solution for software engineering knowledge representation. When the knowledge of the software engineering domain is represented in a declarative formalism, the set of software engineering concepts, their relations and their constraints are reflected in the representation which represents knowledge. Thus, the software engineering ontology can be defined by using a set of software engineering representational terms. Then a conclusion from the knowledge of what is can be determined.

In order for the software engineering domain knowledge to be shared amongst software engineers or applications, agreement must exist on the topics about which information is being communicated. The issue of ontological commitment is described as the agreement about concepts and relationships between those concepts within ontology [4]. When the software engineering ontology is committed, it means agreement exists with respect to the semantics of the concepts and relationships represented.

The main purpose of the software engineering ontology is to enable communication between computer systems or software engineers in order to understand common software engineering knowledge and to perform certain types of computations. The key ingredients that make up the software engineering ontology are a vocabulary of basic software engineering terms and a precise specification of what those terms mean. For software engineers or computer systems, different interpretations in different contexts can make the meaning of terms confusing and ambiguous, but a coherent terminology adds clarity and facilitates a better understanding. Software engineering ontology has specific instances for the corresponding software engineering concepts. These instances contain the actual data being queried in the knowledge-based applications..

2. SOFTWARE ENGINEERING ONTOLOGY MODELLING

Various formalisms have been developed for modelling ontologies, notably the Knowledge Interchange Format (KIF) [7] and knowledge representation languages descended from KL-ONE [8]. However, these representations have had little success outside Artificial Intelligence (AI) research laboratories [9, 10] and require a steep learning curve. KIF provides a Lisp-like syntax to express sentences of first order predicate logic and descendants of KL-ONE include description logics or terminological logics that provide a formal characterisation of the representation [11]. Traditionally, AI knowledge representation has a linear syntax.

There have been recent efforts, documented in the literature [12-14], to use UML for ontology modelling. In UML, ontology information is modelled in class diagrams and Object Constraint Language (OCL) constraints [13]. However, there is controversy regarding whether or not ontology goes beyond the standard UML modelling, so that standard UML cannot express advanced ontology features such as constraints or restrictions, and [15] cannot totally conclude whether the same property was attached to more than one class, and does not support the creation of a hierarchy of properties.

The main aim is not only to create a graphical representation to make it easier to understand, but importantly, this model should be able to capture the semantic richness of the defined software engineering ontology. In the next sections, graphical notations are presented to facilitate the software engineering ontology modelling process. Some concepts or terms represented by the notations have multiple presentations.

3.1 Class Notations

The notation of the software engineering ontology class is represented as a rectangle with two compartments. The top compartment is for labelling the class and the second compartment is used for presenting properties, if there are any, related to the class or to an XML schema data type value. It is mandatory to specify the word '<<Concept>>' above the class label in the top compartment. The generalisation symbol appears as a line with one end empty and the other with a hollow triangle arrowhead. The empty

end is always connected to the class being subsumed, whereas the hollow arrowhead connects to the class that subsumes. Fig. 2 shows an example of a class ClassRelationshippresentation and its subclasses.

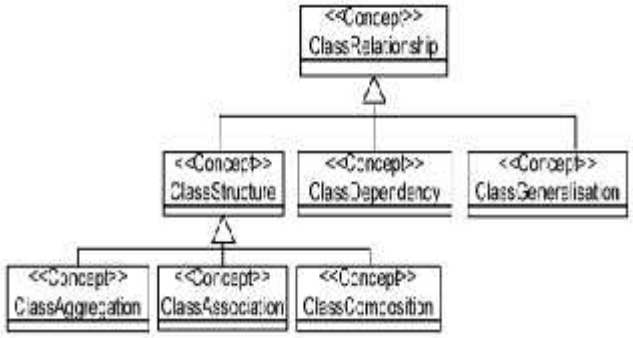


Fig.3. Class ClassRelationship presentation and its sub-classes

3.2 Property Relation, Characteristic and Restriction Notations

Notations for software engineering ontology properties include data type property, object property, its characteristics, its restrictions, and association class attached property. The data type property of the software engineering ontology class can be expressed in the bottom compartment of class notation. This is an alternative design for data type properties. That means the top compartment is called the 'domain'. In the bottom compartment, notation formats as in the order of data type property name, its characteristic, its type (e.g. String, Integer) and its restriction. The type of data type property is considered as a range. The characteristics of data type property can be either functional or non functional represented bythe words 'Single' or 'Multiple' respectively. An enumeration in software engineering ontology is represented in curly brackets ({}).

Fig. 4 expresses that class ClassOperationhas data type property Class_Operation_Namewhich is functional and its type is String. It also defines functional data type property Class_Operation_Visibilityto relate a set of data values of 'public', 'private' and 'protected'

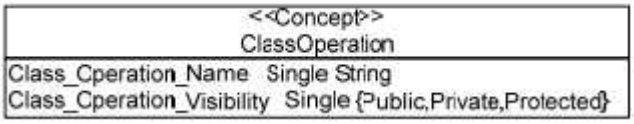


Fig.4. Class ClassOperation presentation and its data type properties

The object property of the software engineering ontology can be expressed in the bottom compartment of class notation like data type properties. This is an alternative design for object property. In this manner, the top compartment is still called its domain. Notation format in the bottom compartment is the same as the order of the object property's name, its characteristics, class name (its range), and its restriction. Class name expression as a range can assert the complex class description such as union (represented by symbol 'U'), intersection (represented by symbol '∩'). In addition, an object property can be expressed as an arrow with an open arrowhead and with a text label of the object property's name. This is an alternative design for object properties.

The arrow points from the domain of property to the range of property. Its restrictions can be expressed in the bracket after its name. Fig.5 shows class Classand its properties. Symbols ∀, ∃, and represent restrictions allValueFrom, someValueFrom, and hasValue respectively. For the cardinality restriction, symbols equal =, greater than and equal to >and less than and equal to <respectively represent cardinality specifying the exact number, minimum cardinality specifying the minimum number and maximum cardinality specifying the maximum number.

The asterisk * is used as part of the specification to indicate the unlimited upper bound. Fig. 6 (a) shows that at least two relations Relating_Activityrelate instance from class JoinTransitionto class Activity and the property Related_Activityrestricts instance from class JoinTransitionto exactly one instance of class Activity. In other words, in join transition (from activity diagram) there are at least two related activities transited into one related activity as shown in Fig. 6 (b).

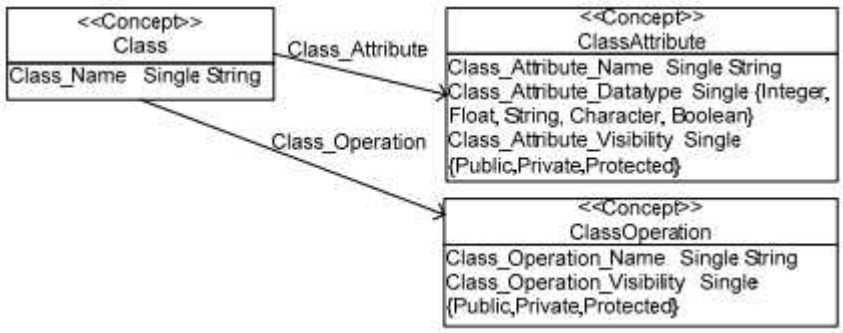


Fig.5 Class Class presentation and its properties

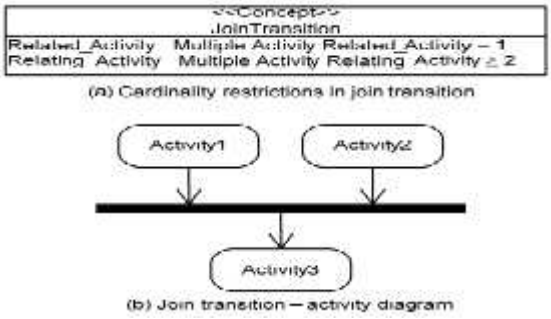


Fig. 6 Class JoinTransition presentation and its properties

3.3 Instance Notation

An instance notation is represented as an ellipse with a dotted line attached to its class or property. If it is an instance of property, then the ellipse contains the property name followed by a colon and then the instance name. Unlike an instance of class, in the ellipse there is only the instance name. To make it easy to read, a dotted line is attached to most of the class name or property name of its class instance or property instances. Fig. 7 shows populating the UML class diagram shown in Fig. 7 (a) into the ontology model shown in Fig. 7 (b) as instances.

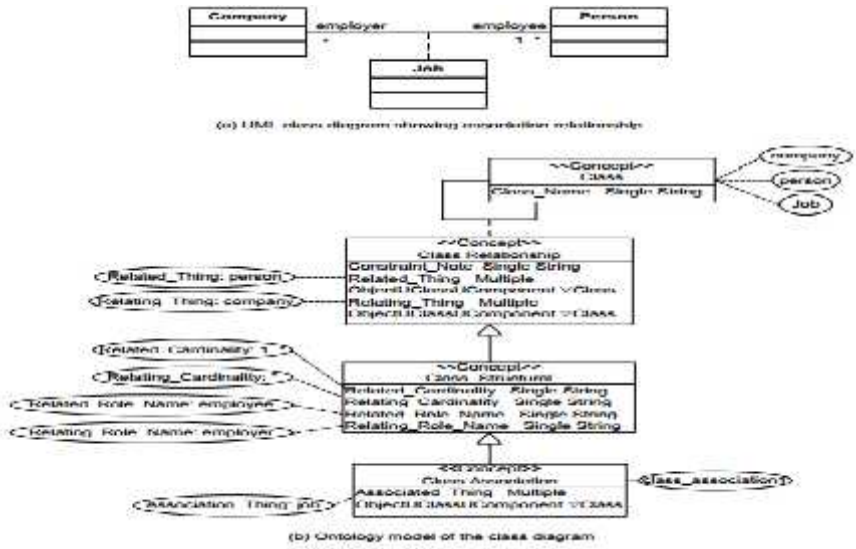


Fig. 7. Presentation of instances of classes and properties

3. IMPLEMENTATION OF SOFTWARE ENGINEERING ONTOLOGY AND DESIGN

A process of design in the software engineering ontology refers to the process of design concepts, concepts hierarchy, relations, and constraints in the software engineering domain. Sources of software engineering knowledge are from the software engineering textbook of Ian Sommerville [17] and the Software Engineering Body of Knowledge (SWEBOK) [18] upon which we base our design. The software engineering ontology contains 362 concepts and 303 relations. Due to limited space, in this section we will illustrate the design by choosing some specific examples of common, widely-used concepts such as UML class diagram, UML activity diagram, UML use case diagram, entity diagram.

4.1 Ontology Model for a UML Class Diagram

The first example is a UML class diagram ontology. A class diagram is a diagram that represents a set of classes and their interrelationships [16]. Commonly, the structural details of classes expand their attributes and their operations. The relationships within these five main classes are: dependencies, generalisations, aggregations, compositions, and associations.

The relationships of aggregations, composition and association are used to structure a class, so in the ontology model of class diagrams, they are grouped together. Fig. 8 shows the UML class diagram ontology.

4.2 Ontology Model for an Entity-Relationship Diagram

An entity-relationship diagram represents conceptual models of data stored in information systems [16]. Fig. 9 shows an ontology model of entity-relationship diagrams. There are three main basic components in the entity-relationship diagrams which are entities, attributes and relationships.

Entity attributes can be classified as being simple, composite or derived. A simple attribute is composed of a single component and a composite attribute is composed of multiple components. In the ontology model, cardinality restriction in relation has Subdivided Attribute defines attributes as being either simple or composite.

A derived attribute is based on another attribute(s) and refers to relation has Derived Attribute restricting at least one relation link to ontology classEntitiyAttribute. Key can be defined as attributes of super key, alternate key, primary key, or candidate key. This refers to relation Entity Attribute Key in the ontology model. An attribute can have a single or greater-than-one value. In the ontology model, cardinality restriction from relation Entity Attribute Value defines having a single or greater-than-one value. There are three main degrees of entity relationships: unary, binary and complex. The complex entity relationship can be further divided into quaternary and ternary.

In the ontology model, cardinality restriction constrains the number of entities that participate in a relationship. This means that in the ontology view there is only one entity i.e. relation Entity1. For a binary relationship, there are two entities in the relationship i.e. in relations Entity1and Entity2; while in a ternary relationship, there are three entities in the relationship i.e. in relation Entity1, Entity2, and Entity3. For a quaternary entity relationship, there are four entities in the relationship i.e. in relations Entity1, Entity2, Entity3, and Entity4.In an entity relationship, cardinality can be specified as a string which can be a string of 1..1 (one and only one), 0..* (zero or more), 1..* (one ormore), 0..1 (zero or one) as shown in the ontology model. Attributes can also be assigned to relationships referring to relation has Attribute on Relationships in the ontology model.

4.3 Ontology Model for a UML Activity Diagram

An activity diagram shows the control flow from activity to activity [27]. Mainly, activity diagrams contain activities, transitions, swimlane, and objects. A locus of activities is specified by a swimlane. This refers to relation in_Swimlanein the ontology model of activity diagrams in Figure 10. Every activity belongs to exactly one swimlane; however, transition may force it to cross lanes. This means maximum cardinality restriction in relation in_Swimlane. Objects may be involved in the flow of control associated with an activity diagram. This refers to relations set_Object_Flowand its inverse, get_Object_Flow.

Transitions of activities are classified into four main transitions. Firstly, normaltransition shows the path from one activity to the next activity. This means that, ontology class NormalTransitionthat has a cardinality restriction, restricts only the one activity in the relations Related_Activityand Relating_Activity. Secondly, special transition is further divided into an initial and a stop transition. The initial transition is where the activity diagrams start. This means that, ontology class Startwhich has a cardinality restriction, restricts at least one activity in relation Related_Special_Activitybut no activity in relation Relating_Special_Activity.

4.4 Ontology Model for a UML Use Case Diagram

A use case diagram shows a set of use cases and actors and their relationships. Commonly, use case diagrams contain actors, use cases, and relationships. Figure 11 shows an ontology model of use case diagrams. Actors and use cases refer respectively to ontology classes Actor and UseCase. System boundary referring to ontology class SystemBoundary defines use cases limits.

Relationships between use cases, referring to ontology class UseCaseRelationship are categorised into four types of, firstly, generalisation relationship – referring to ontology class GeneralisationRelationship secondly, association relationship – referring to ontology class AssociationRelationship; thirdly, include relationship – referring to ontology class IncludeRelationship; and lastly, extend relationship – referring to ontology class ExtendRelationship. Only the association relationship defines the relationship between actors and use cases, and only the generalisation relationship defines the relationship between actors. Based on the design of software engineering ontology as shown by the above examples, software engineering ontology was implemented.

5. SOFTWARE ENGINEERING ONTOLOGY EVALUATION

The software engineering ontology has been implemented in the OWL and deployed on a platform. It can be accessed at www.seontology.org. This section is devoted to evaluating the software engineering ontology through the deployed ontology on the platform. Software engineering knowledge, formed into software engineering ontology, helps communications among team members and provides consistent understanding of the domain knowledge.

Software engineering ontology, together with its instance knowledge, is used as a communication framework within a project,

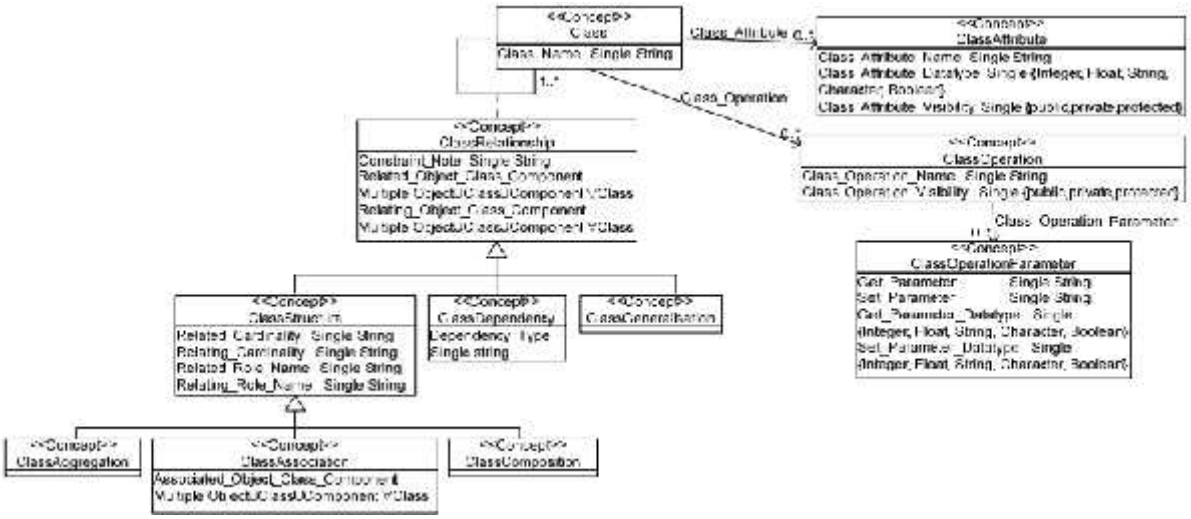


Fig. 8 UML class diagram ontology

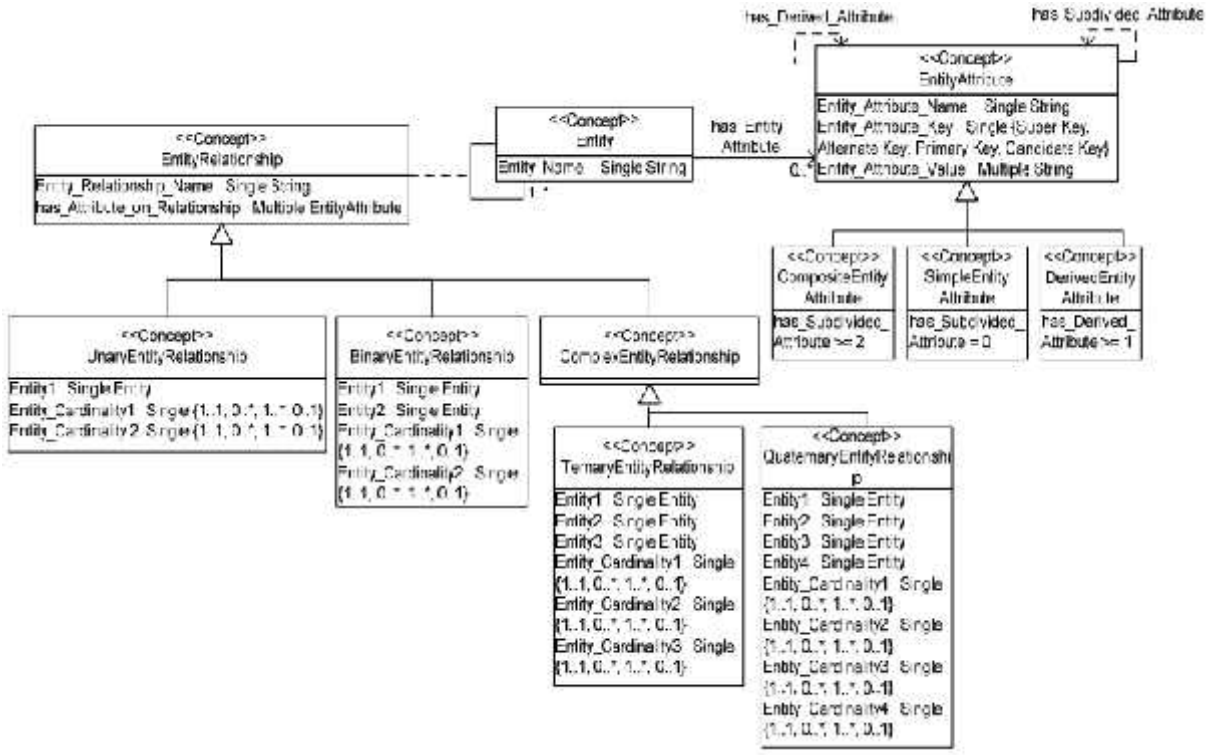


Fig. 9 Entity diagram ontology

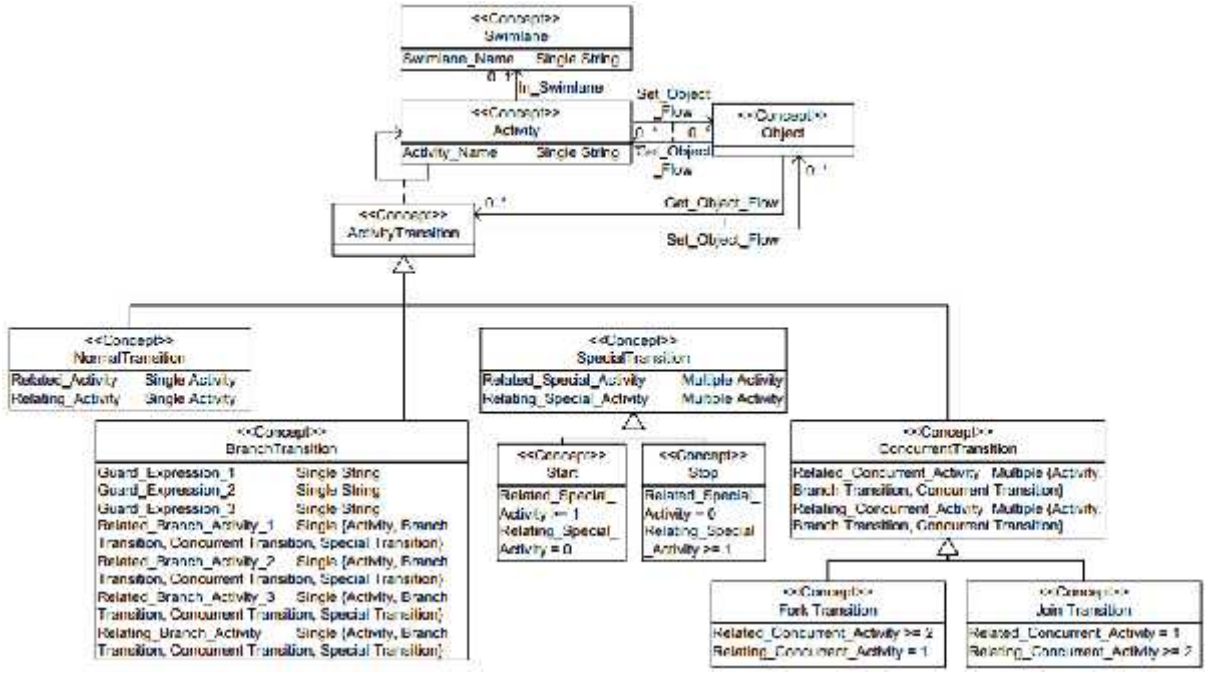


Fig.10 UML activity diagram ontology

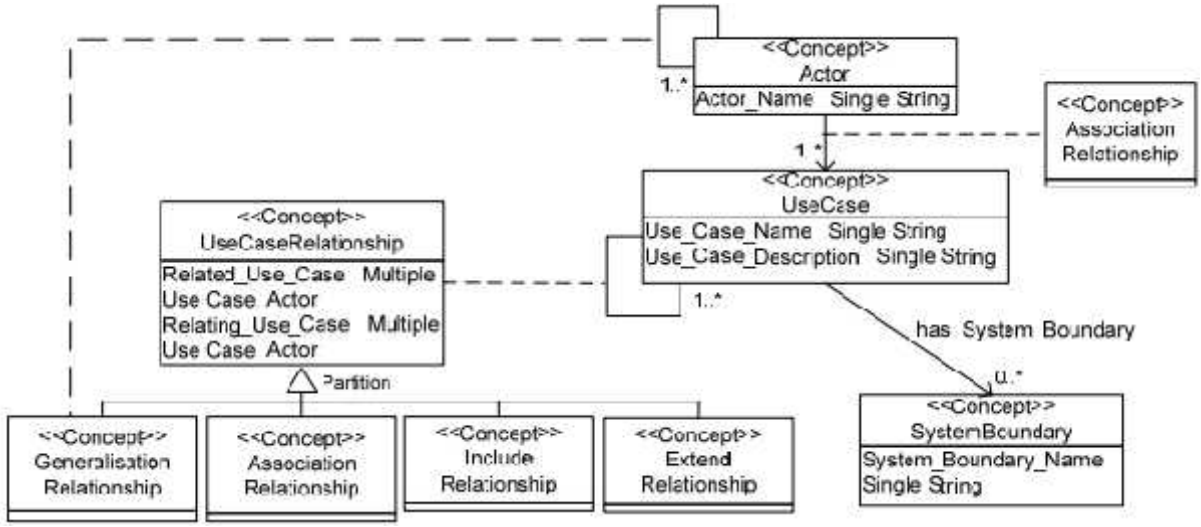


Fig.11 UML usecase diagram ontology

thereby providing rational and shared understanding of project matters. In the platform, software engineering instance knowledge, in accordance with domain knowledge that is described in software engineering ontology, is extracted. By consulting the software engineering ontology, the platform enables references of software engineering domain knowledge and enables extraction of instance knowledge. For example, class diagrams referred to in the software engineering ontology assert how a set of classes is formed in the diagram. The specification imposing a structure on the domain of class diagrams i.e. elicitation of each class consists of class name, class attributes, class operations and relationships hold with other classes. Using software engineering domain knowledge, together with instance knowledge, the platform dynamically and automatically acts for a certain class instance that the member navigates to retrieve accordingly attribute instances, operation instances, and relationship instances together with the related class instance details. Fig. 12 shows examples of instances of class diagrams ontology that are navigated in the platform. In Fig. 12(a), Classinstance CR_Customeris navigated to consequently retrieve ClassAttributeinstances and ClassOperationinstances.

ClassRelationshipinstances can also be navigated to subsequently retrieve Classinstances that hold in the relationship and applicable properties of the relationship. For example, in accessing ClassAssociationinstance, Classinstances held in the relationship and properties like role name and cardinalities are automatically retrieved as shown in Fig. 12(b). Similarly, if those Classinstances are accessed, then a list of ClassAttributeinstances and a list of ClassOperationinstances are retrieved to show its attributes and its operations respectively. In accessing each ClassAttributeinstance, details of attribute's name, attribute's data type, and attribute's visibility are shown as referred to ClassAttributeontology in the software engineering ontology. In Fig. 12(c), navigating ClassAttributeinstance CR_CustomerID, its name of 'Customer ID', its data type of 'integer', and its visibility of 'public' can be revealed. The same as ClassOperation ontology referred in the software engineering ontology, in accessing each ClassOperationinstance, details of operation's name, operation's visibility, and operation's parameters and parameters' data type can be retrieved.

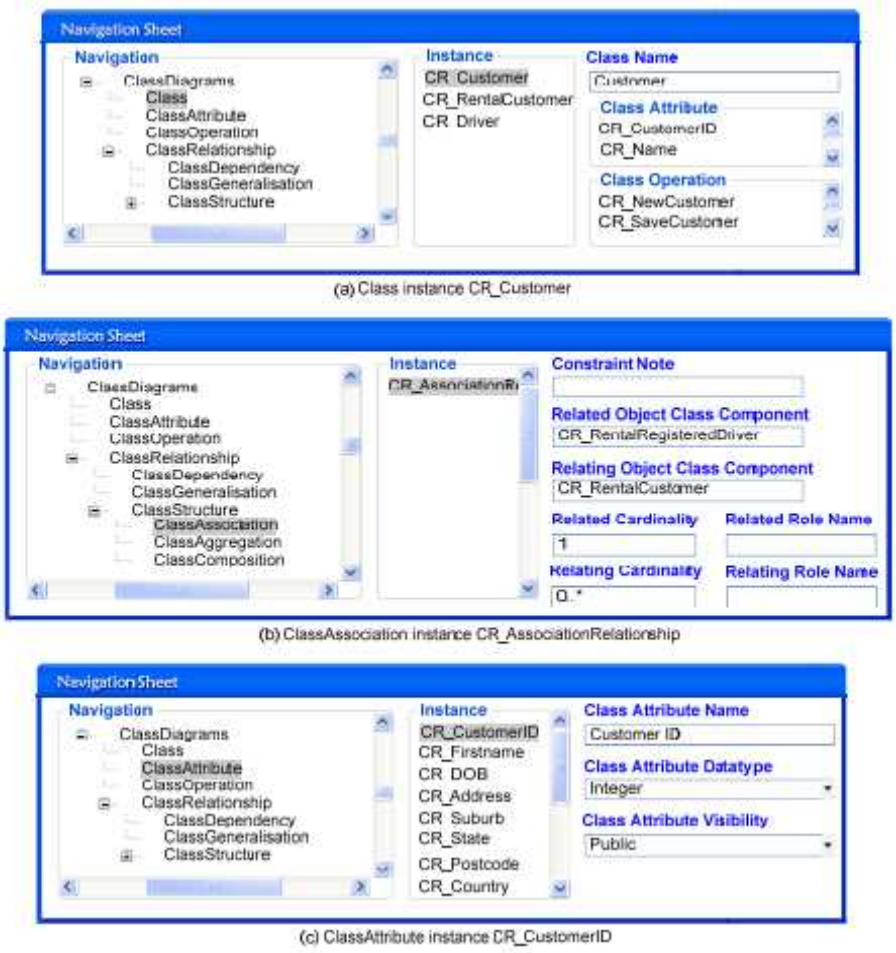


Fig. 12 Examples of instances of class diagrams ontology being navigated in the platform

6. CONCLUSION

In this paper, we have analysed the characteristics of software engineering ontology. We have then defined graphical notations of modelling software engineering ontology as an alternative formalism. The modelling notations are used to design software engineering ontology. We have only covered some distinguished part of modelling domain knowledge of software engineering as example. The practical software engineering ontology has been implemented and deployed. Deployment has been discussed in aspects of knowledge sharing and communication framework.

The evaluation of the ontology is presented of its useful in practice. Finally, the deployed software engineering ontology applied to the realities of distributed development is given to demonstrate its real value to the software engineering ontology.

However, there are many improvements that can be made through future work which could consider software engineering ontology evolution. It is a case of software engineering domain knowledge changing with the introduction of new concepts, and change in the conceptualisation as the semantics of existing terms have been modified with time.

This is totally outside the scope of this study because we assume that software engineering domain knowledge is mature and has undergone no further changes. Instead, instantiations in the software engineering ontology change with corresponding changes to the ontology.

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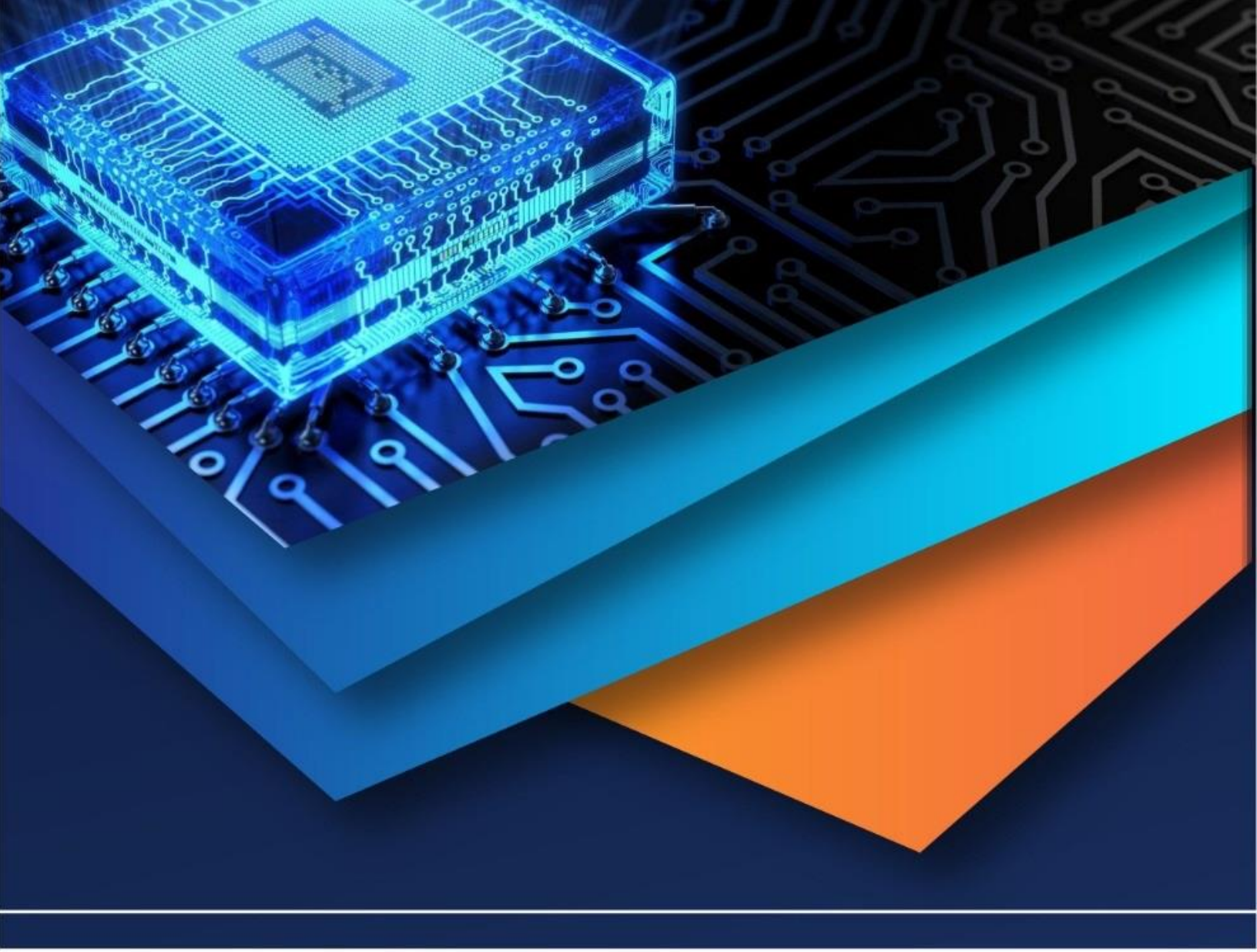
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