Applying OWL to Build Ontology for Customer Knowledge Management

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***Abstract* —With the progress of economic globalization and the coming of knowledge economy, customers have become valuable resources grabbed by enterprises. How to retain old customers and obtain new customers is the main content and purpose of Customer Knowledge Management (CKM). Following the introduction in section 1, we analyze the need for ontology building in implementing CKM strategy considering that customer knowledge could be understood and processed by machine automatically in section 2. In section 3, we discuss Web ontology languages. In section 4, we design an ontology framework for CKM. In the framework, there exist many semantic relations that could be expressed using OWL (Ontology Web Language). In section 5, we analyze the environment of Protégé 3.4.4 in which we develop the ontology based on the framework. We elicit several paragraphs of source code as examples to show how OWL can represent the semantic relations of the ontology, i.e. cardinality restrictions, classes declared to be disjoint, Boolean combination, hasValue restrictions, enumeration class, and property definition.**

***Index Terms*—customer knowledge management (CKM), ontology, OWL, framework, representation**

I. INTRODUCTION

With the progress of economic globalization and the coming of knowledge economy, the environmental uncertainty has changed from one that is primarily local in focus to one that encompasses regional and international forces, thus exerting great threaten on enterprises. Numerous papers and practices have shown that ongoing efforts to meet customers' needs are critical and customers have thus become valuable resources grabbed by enterprises. It is argued that "Customer relationship management (CRM) in the global and digital economy has forced organizations to rethink the ways in which they build relationships with a broadened customer base" [1]. It is also argued that "CRM and knowledge management (KM) initiatives are directed towards the same goal: the delivery of continuous improvement towards customers", and initiating CRM in the context of KM has been labeled 'customer knowledge management' (CKM) or 'knowledge-enabled CRM' [2]. CKM is defined as ''managing customer knowledge to generate value-creating lock-ins and channel knowledge to strengthen relationships and collaborative effectiveness" [3].

For a given enterprise, retaining old customers and obtaining new ones is the main content and the aim of its CKM. There are different kinds of customers and "it is important to understand customer behavior by analyzing customer information to differentiate between customers, to identify the most valuable customers over time, and to increase customer loyalty by providing customized products and services" [4]. In general, "companies divide customers into numerous groups with similar preferences and examine distinct characteristics of each group in order to determine the most profitable segments" [5]. Each group of customers can be regarded as a class. Customer as a whole is a class and it has many subclasses such as VIP customers and normal customers. No matter superclass or subclass, each one has its unique characteristic. For example, loyal customer is the subclass of customer, referring to the customers who have interests in and focus on the product from one enterprise or few enterprises. Long-term customers are the customers who purchase the same product for a long time. High contribution customers are the customers whose amount of accumulative purchased products or once purchased products is larger. Also, enterprises should be able to identify low contribution customers, low loyalty customers, short-term customers, and so on. More over, customers own many properties concerning with the knowledge about customer and the knowledge from the customer. The knowledge from the customer refers to the feedback coming from the customer. The knowledge about the customer refers to the demographic knowledge such as name, gender, age, marriage status, number of children, income, affiliation, telephone, email, and so on.

Collecting and processing abundant of knowledge about and from customers brings potential for enterprises to create opportunities to gain competitive advantage. However, how to manage customer knowledge more efficiently and effectively is still a great challenge in implementing CKM strategy.

II. ANALYSES OF THE NEED FOR ONTOLOGY BUILDING IN CKM

Information technology has made it possible for enterprises to collect a large volume of knowledge about and from customers. With respect to CKM, there are

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many concepts as well as relations between the concepts that need to be expressed and managed efficiently.

Customer knowledge should be shared among departments within an enterprise and enterprises within a supply chain. In establishing a customer knowledge sharing platform, many technologies have been used. For example, customer knowledge could be stored in database. "A customer service database usually stores two types of service information: one is unstructured customer service reports, another one is structured data on sales, employees, and customers for day-to-day management operations" [6]. Given the structured data of customers in database, large number of customers can be managed with high efficiency. For instance, given customers could be retrieved very quickly. Anyway, database can't define class and property, lacking the ability to express semantic relations about customer knowledge.

Customer knowledge could also be stored in data warehouse. The design of a data warehouse does not need to follow the strict norms that are required in database design since the purpose of a data warehouse is primarily analytical. "At the front end of a data warehouse, multi-dimensional databases (MDDB) or cubes allow users to perform advanced OLAP, data mining, and advanced reporting functions"[7] so as to analyze and discover some rules and relations concerning customers.

Technologies such as COM (Component Object Model), CORBA (Common Object Request Broker Architecture) and Agent have also been developed to solve the technical problem of information sharing [8]. In addition, a knowledge base (KB) is a special kind of database for knowledge management, providing the means for the computerized collection, organization, and retrieval of knowledge. So, KB can be used to manage customer knowledge.

Although these technologies behave relatively well in processing customer knowledge, "they remain syntax sharing basically and cannot describe customer knowledge semantically as well as express implied axiom, facts, judgments and rules relevant to customer knowledge already existed in the information system" [9]. As a result the structured information inferred from knowledge base or other information sources is unavailable as yet. In this case, any new and useful knowledge about customer can hardly be produced or induced. More importantly, the processing of customer knowledge which is not based on semantic relation is more likely to lead people to confusion given the same concept with different name or title in the same or different context when discussing something about business [10]. In order that customer knowledge could be understood and processed by machine automatically, more semantic descriptions are needed. Ontology has become a promising technology to express semantics.

As a substitute for the mode of information sharing, ontology has gained more attention from researchers due to its ability to express semantic relation [11]. The same concept may be identified with two different identifiers in two different fields. If a program wants to compare and connect knowledge between two different fields, it must know that the two identifiers in fact represent the same meaning. Ontology could help solve this problem.

Ontology is a concept in philosophy. In the fields of artificial intelligence and Web, ontology is the description about domain concepts and their relations. Ontology is the theory about objects and their ties. It provides standards for differentiating kinds of objects (concrete and abstract, existent and non-existent, realistic and ideal, independent and dependent) and their ties (relations and dependency). Ontology is formal structure to support knowledge sharing and reusing. It could be used to express explicitly the semantics of structured and semi-structured information in order to support information acquiring, maintaining and accessing automatically [11]. Ontology provides methods to solve the heterogeneous expression of Web resource. The domain model hidden in ontology could be regarded as providing a general semantic structure for information. Since this kind of information sharing can provide a uniform communication platform, being able to cope with the problem of the same concepts with different name or title in different context, many efforts have been made to design ontology to mediate information and knowledge sharing in terms of this mode within or beyond one enterprise.

Ontology describes the concepts and relationships that are important in a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary. "Ontologies range from taxonomies and classifications, database schemas, to fully axiomatized theories". In recent years, ontologies have been adopted in much business as a way to share, reuse and process domain knowledge, such as in scientific knowledge portals, information management and integration systems, electronic commerce, and semantic web services [12]. More concrete examples are such as an ontology development for a supply chain[13], a general manufacturing system engineering (MSE) knowledge representation scheme, called an MSE ontology model[14], an enterprise architecture ontology[15].

Applying ontology on the Web facilitates the development of Semantic Web. Building CKM ontology on the Semantic Web would facilitate machine to process and share customer knowledge automatically without human interference. OWL has the ability to express semantic relations in building ontology for CKM. In implementing CKM strategy, the complex concepts can be defined as classes and subclasses and the relations between the concepts can be defined as properties in formal OWL expressions so that machine can process the customer knowledge automatically.

III. WEB ONTOLOGY LANGUAGES

Ontologies are used to capture knowledge about some domain of interest. An ontology describes the concepts in the domain and also the relationships that hold between those concepts. Different ontology languages provide different facilities [16].

XML (eXtensible Markup Language) has brought hope to Semantic Web. XML plus XML Schema specifies the syntax, structure and data type, but lacks semantic constraints. Tim Berners-Lee, creator of Semantic Web, considers the objective of Semantic Web as creating representative languages and describing information in the machine understandable form. He summarizes the functional framework of Semantic Web as metadata layer, schema layer and logical layer [17].

In metadata layer, data model only includes resources and properties, and RDF (Resource Description Framework) is regarded as the popular data model in this layer. RDF is a language for representing information about resources on the World Wide Web. It represents metadata of Web resource, such as title, author, modifying date of Web content, copyright and registering information of Web documents, language, format, content items, and etc [18]. RDF is intended for situations in which this information needs to be processed by applications, rather than being only displayed to people. RDF provides a common framework for expressing this information so that information can be exchanged between different applications without loss of meaning. “Since it is a common framework, application designers can leverage the availability of common RDF parsers and processing tools. The ability to exchange information between different applications means that the information may be made available to applications other than those for which it was originally created” [19].

In schema layer, Web ontology language is introduced, being used to describe concepts and relations between concepts. RDF Schema is regarded as the best light weighted candidate. RDF Schema does not provide a vocabulary of application-specific classes and properties. Instead, it provides the facilities needed to describe such classes and properties, and indicates which classes and properties are expected to use together. “The RDF Schema facilities are themselves provided in the form of an RDF vocabulary; that is, as a specialized set of predefined RDF resources with their own special meanings” [20].

In logical layer, more powerful Web ontology languages are introduced. These languages provide richer modeling sets mapping to the influential expressive logics. OIL（Ontology Inference Layer，2000）and DAML-OIL （ Darpa Agent Markup Language-Ontology Inference Layer，2001） was once popular languages in logical layer. At present, OWL (Ontology Web Language) is widely accepted. OWL is designed to apply in not only presenting information but also processing the content of information. OWL facilitates greater machine interpretability of Web content than that supported by XML Schema and RDF Schema by providing additional vocabulary along with a formal semantics such as classes stated to be disjoint from each other, enumerated classes, classes stated to be equivalent, properties stated to be symmetric, cardinality restrictions, hasValue restrictions, etc. [21][22].

Building ontology on the Web is the core drive to push the development of Semantic Web. XML Schema, RDF Schema and OWL could be regarded as Web ontology languages with increasing capabilities to express semantics, meeting the needs of knowledge processing and knowledge management in different periods.

An OWL ontology can describe classes, properties and their instances. Given an ontology, the OWL formal semantics can specify how to derive its logical consequences, i.e. facts not literally present in the ontology, but entailed by the semantics, based on a single document or multiple distributed documents that have been combined using defined OWL mechanisms [23].

IV. AN ONTOLOGY FRAMEWORK FOR CUSTOMER KNOWLEDGE MANAGEMENT

We design an ontology framework for customer knowledge management (see Fig. 1). We would not hope to put this ontology as a standard ontology in CKM, since the standardization of CKM ontology depends on the cooperation and endeavors of experts coming from many fields. While implementing CKM strategy, there exist many concepts and semantic relations between the concepts that need to be expressed so that machine could understand and process it automatically. How to change statements expressed in natural languages to statements of formal descriptive logic is the key task in ontology building [24]. In designing the ontology framework for CKM, we have considered the capability of semantic expressions provided by OWL.

OWL classes are interpreted as sets that contain individuals, which are described using formal (mathematical) descriptions that state precisely the requirements for membership of the class. “One of the key features of OWL is that these superclass-subclass relationships (subsumption relationships) can be computed automatically by reasoners” [25]. Properties are binary relations on individuals, i.e. properties link two individuals together. In OWL properties are used to create restrictions, used to restrict the individuals that belong to a class. “Restrictions in OWL fall into three main categories: Quantifier Restrictions, Cardinality Restrictions, hasValue Restrictions” [16]. Properties can have inverses. Properties can be limited to having a single value, i.e. to being functional. They can also be either transitive or symmetric. Individuals represent objects in the domain that we are interested in.

In Fig. 1, classes are represented as ovals. The arrows without labels show the superclass-subclass relationships. The class with the arrow entering is the superclass, and the class with the arrow going out is the subclass. OWL is property-centricity. Property is each represented with a label on the arrow line. For each property, the class with the arrow entering is its range, and the class with the class with the arrow going out is its domain. According to this rules, we draw the ontology framework.

Customer is defined as a class. It has two subclasses: VIP_Customer and Normal_Customer, each being described by three someValuesFrom restrictions. The restriction someValuesFrom describes an anonymous (unnamed) class of individuals that satisfy the restriction.

For example, the class described by someValuesFrom HighLoyalty and the class described by someValuesFrom HighTerm forms an intersection class, which is then combined with the class described by someValuesFrom HighContribution, forming the Union Class which is the superclass of VIP_Customer. In the same way, we can easily understand the meaning of Normal_Customer described in Fig. 1.

The domain of the 8 properties (hasLoyalty, hasContribution, hasTerm, hasFeedback hasContact, hasAffiliation, hasIncome, hasName) is the class Customer. Each property has its own range. For example, the range of hasFeedback is Feedback. The class Feedback represents the knowledge from customer, concerning 4 kinds of knowledge of satisfaction, complaint, expectation and requirement.

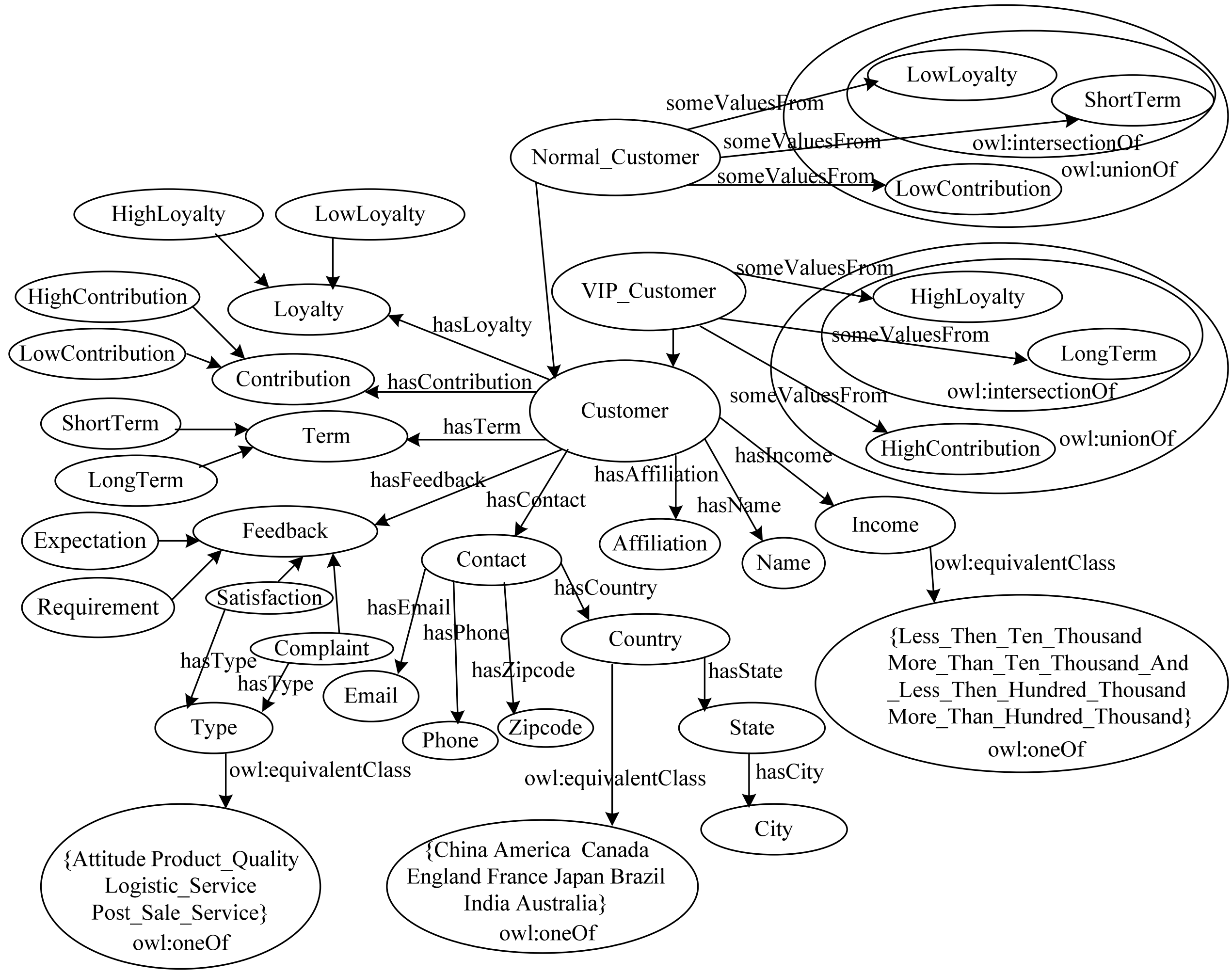

Figure 1. An Ontology Framework for Customer Knowledge Management

V. CKM ONTOLOGY BUILDING AND ANALYSES

A. Environment of Building OWL Ontology

We use Protégé 3.4.4 which was released on 8 March 2010. Protégé 3.4.4 is an integrated software tool used by system developers and domain experts to develop knowledge-based systems. Applications developed with Protégé 3.4.4 are used in problem solving and decision-making in a particular domain. Protégé is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontologies. At its core, Protégé implements a rich set of knowledge-modeling structures and actions that support the creation, visualization, and manipulation of ontologies in various representation formats. Protégé can be customized to provide domain-friendly support for creating knowledge models and entering data. Further, Protégé can be extended by way of a plug-in architecture and a Java-based Application Programming Interface (API) for building knowledge-based tools and applications. "Protégé-OWL editor enables users to build ontologies for the Semantic Web, in particular in the W3C's Web Ontology Language: OWL" [26]. Fig. 2 is a screen of Protégé 3.4.4 while building CKM ontology. The screen is a properties view on the class VIP_Customer.

B. Ontology Building and Semantic Expression Analysis

In the environment of Protégé 3.4.4, we have built OWL ontology of CKM based on Fig. 1. OWL ontology is based on a logical model that makes it possible for concepts to be defined as well as described. Complex concepts can therefore be built up in definitions out of simpler concepts. Furthermore, the logical model allows the use of a reasoner that can check whether or not all of the statements and definitions in the ontology are mutually consistent. Based on the description (conditions) of a class the reasoner can check whether or not it is possible for the class to have any individuals. A class is deemed to be inconsistent if it cannot possibly have any individuals. A reasoner can also recognize which concepts fit under which definitions. By performing such tests on all of the classes in an ontology, it is possible for a reasoner to compute the inferred ontology class hierarchy. The reasoner can therefore help to maintain the hierarchy correctly [16] [26].

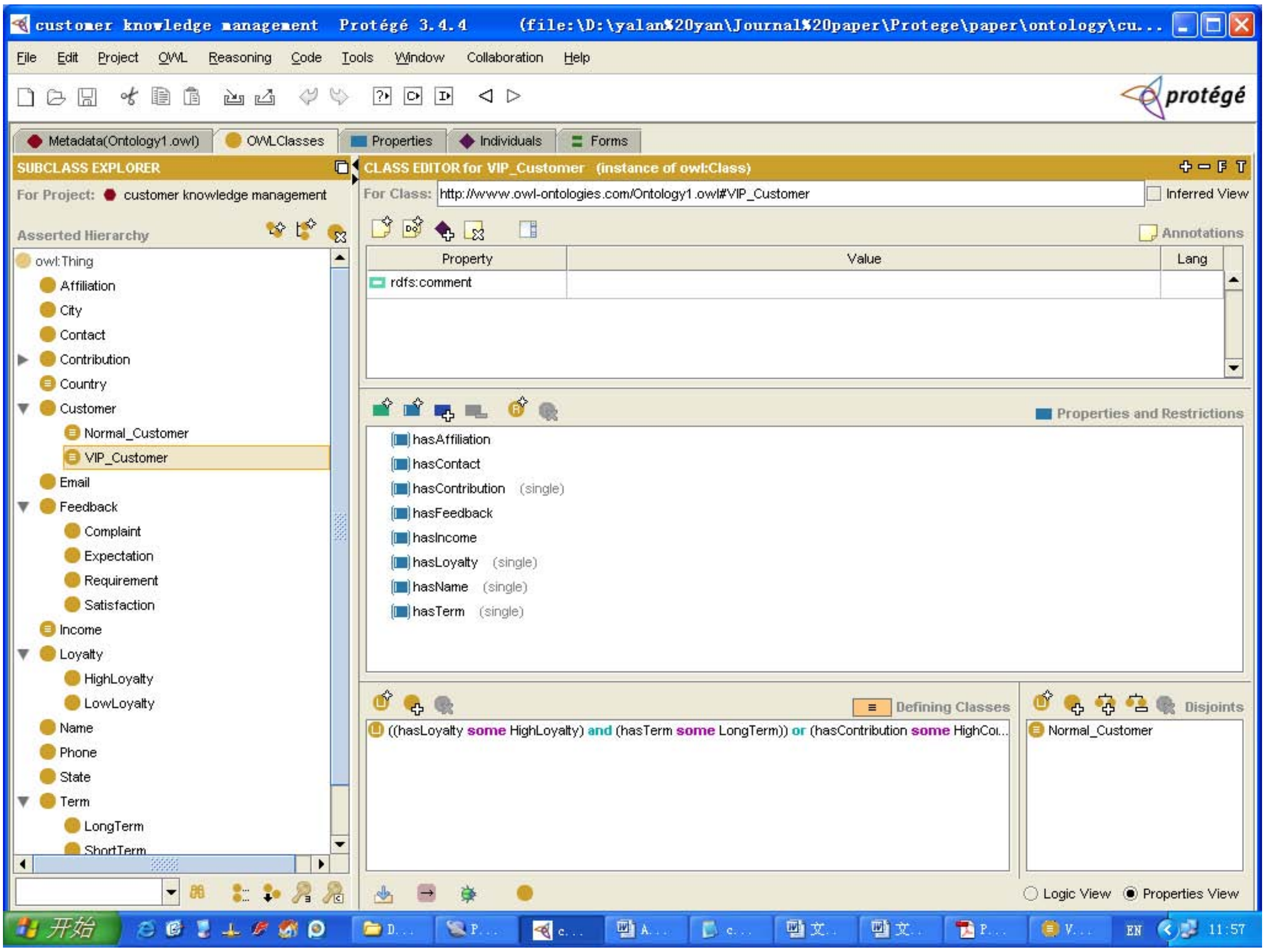

Figure 2. A Screen of Protégé while Building CKM Ontology

OWL provides rich vocabulary along with a formal semantics such as disjointWith, intersectionOf, unionOf, complementOf, oneOf, minCardinality, maxCardinality, cardinality, someValuesFrom, for the purpose of expressing powerful semantic relations and restrictions such as disjoint, intersection, union, complement, enumeration and cardinality. In the following section, we would analyze semantic expressions of OWL based on several OWL source code elicited from CKM ontology.

(1) Cardinality restrictions and classes declared to be disjoint

Classes could be declared to be disjointing with each other. In CKM ontology, Short_Term is the subclass of a new class which has maxCardinality 5 restriction on property has_Time，Long_Term is the subclass of a new class which has minCardinality 5 on property has_Time. Classes of Short_Term and Long_Term could be declared to be disjoint with each other. The OWL representation is below:

```
<owl:Class rdf:ID="LongTerm">
  <owl:disjointWith>
    <owl:Class rdf:ID="ShortTerm"/>
  </owl:disjointWith>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:minCardinality
          rdf:datatype="http://www.w3.org/2001/XMLSch
          ema#int">5</owl:minCardinality>
      <owl:onProperty>
        <owl:DatatypeProperty rdf:ID="hasTime"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Class rdf:ID="Term"/>
  </rdfs:subClassOf>
</owl:Class>
```

(2) Boolean combination and hasValue Restrictions

OWL permits arbitrary Boolean combination of classes and properties. The restriction someValuesFrom is one kind of hasValue Restrictions. It describes the set, or the class, of individuals that have at least one individual from a given class. In CKM ontology, we define the restriction someValuesFrom on the property hasLoyalty, hasTerm and hasContribution respectively to each create a new class. The newly created classes are combined by intersection or union. We explain the meaning of VIP_Customer in section 4. Its OWL representation is below, from which we can see the powerful semantic expressions in OWL.

```
<owl:Class rdf:ID="VIP_Customer">
  <owl:equivalentClass>
    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
        <owl:Class>
          <owl:intersectionOf rdf:parseType="Collection">
            <owl:Restriction>
              <owl:onProperty>
                <owl:ObjectProperty rdf:ID="hasLoyalty"/>
              </owl:onProperty>
              <owl:someValuesFrom>
                <owl:Class rdf:ID="HighLoyalty"/>
              </owl:someValuesFrom>
            </owl:Restriction>
            <owl:Restriction>
              <owl:onProperty>
                <owl:ObjectProperty rdf:ID="hasTerm"/>
              </owl:onProperty>
              <owl:someValuesFrom
                     rdf:resource="#LongTerm"/>
            </owl:Restriction>
          </owl:intersectionOf>
        </owl:Class>
        <owl:Restriction>
          <owl:someValuesFrom>
            <owl:Class rdf:ID="HighContribution"/>
          </owl:someValuesFrom>
          <owl:onProperty>
            <owl:ObjectProperty
                   rdf:ID="hasContribution"/>
          </owl:onProperty>
        </owl:Restriction>
      </owl:unionOf>
    </owl:Class>
  </owl:equivalentClass>
  <owl:disjointWith>
    <owl:Class rdf:ID="Normal_Customer"/>
  </owl:disjointWith>
  <rdfs:subClassOf>
    <owl:Class rdf:ID="Customer"/>
  </rdfs:subClassOf>
</owl:Class>
```

(3) Enumeration class

Class could be described by enumerating all the individuals composing the class. The member of class is just the collection of enumerated individuals. In CKM ontology, Type is an enumeration class and its individuals are: Product_Quality, Post_Sale_Service, Attitude, Logistic_Service. Its OWL representation is below:

```
<owl:Class rdf:ID="Type">
  <owl:equivalentClass>
    <owl:Class>
      <owl:oneOf rdf:parseType="Collection">
        <Type rdf:ID="Product_Quality"/>
        <Type rdf:ID="Post_Sale_Service"/>
        <Type rdf:ID="Attitude"/>
        <Type rdf:ID="Logistic_Service"/>
      </owl:oneOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>
```

(4) Defining Property

OWL is a property-centricity ontology language. Each property has its domain and range. In CKM ontology, we define an object property hasType. The domain of hasType is the union class combined by Complaint and Satisfaction. Its range is type which is an enumeration class which we discuss above. Its OWL representation is below:

```
<owl:ObjectProperty rdf:ID="hasType">
  <rdfs:domain>
    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Complaint"/>
        <owl:Class rdf:about="#Satisfaction"/>
      </owl:unionOf>
    </owl:Class>
  </rdfs:domain>
  <rdfs:range rdf:resource="#Type"/>
</owl:ObjectProperty>
```

VI. CONCLUSIONS

In this paper, we analyze the need for ontology building in implementing CKM strategy considering that customer knowledge could be understood and processed by machine automatically. We design an ontology framework for CKM and develop the ontology based on the framework in Protégé 3.4.4. We elicit several paragraphs of source code as examples to show how OWL has powerful capability of expressing the semantic relations while building CKM ontology. Until now, Web ontology languages have been standardized. XML, XML Schema, RDF, RDF Schema and OWL contribute largely to the standardization of Web ontology languages. However, the standardization of CKM ontology has a long way to go due to its complexity. While building the ontology, we consider and analyze the concepts and the semantic relations of CKM expressed in natural languages and the formal descriptive logic capabilities of OWL altogether. CKM ontology expressed as OWL is the base of implementing efficient CKM strategy. We believe our research can promote the standardization of CKM ontology, and further the implementation of CKM strategy.

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