A socio-cultural ontology for urban development

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Abstract. The paper presents an outline of a methodology for developing a socio-cultural ontology starting from Engeström's Activity Theory and the triadic categorization scheme of C.S. Peirce. It also discusses some general ideas on the usage of ontologies in knowledge-based processing. A skeleton of an ontology containing the basic concepts related to the socio-cultural aspects in urban development is introduced. Implementation alternatives are discussed.

Keywords: Ontology, Activity Theory, Urban Development, Knowledge Acquisition, Knowledge-Based Systems

1 Introduction

The growth of towns, combined with the fast cultural changes due to globalization and the population migrations, emphasize the importance of considering socio-cultural aspects of urban development. One desired goal in the near future is the building of the Knowledge-Based Society, in which the already omnipresent computer programs will rather process knowledge that only information. Knowledge processing supposes frameworks that gather the basic concepts or, using a more technical word, the ontology of the considered domain, in order to provide more personalized, more intelligent services. The same ideas determine the evolution of the Web towards a Semantic Web [2], which extends the facilities for knowledge-based processing, collaboration and information retrieval. Ontologies and knowledge processing are also major ingredients of this new generation of the Web.

A socio-cultural ontology for urban development is an essential component if we want to have flexible, extensible, intelligent, knowledge-based programs that can assist urban development specialists to consider socio-cultural aspects in their projects. For example, such an ontology may be used in the semantic search and

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combination of web services in urban related applications. It also may be very helpful for the development of natural language processing programs that provide help, answer questions and give advice about, for example, the issues to be considered for further analysis.

The importance of having good ontologies became clear in the knowledge acquisition activities needed in symbolic artificial intelligence programs. However, their success was probably definitively assured in the actual context of information overload due to the expansion of the Web, and in the route to the Semantic Web.

Building an ontology is not a simple activity. It implies philosophical thinking and it is helped if some theoretical outline is provided for the domain for which they are built. For example, John Sowa proposed a top-level ontology [6] starting from the categories introduced by important philosophers (e.g. Aristotle, Kant, Peirce, and others). WordNet, a very successful ontology for natural language processing applications (see, for example, http://wordnet.princeton.edu), was developed starting from psycholinguistic experiments. In the case of urban development, where huge communities of people share buildings, roads, parks, etc., such a theoretical skeleton may be provided by the Activity Theory of Yrjö Engeström [3].

The paper continues with an introduction in ontologies. The third section, after it introduces the Theory of Activity, discusses which could be the basic components of a socio-cultural ontology and how could new concepts be derived.

2 Ontologies

In recent years, the term "ontology" is widely used in computer knowledge-based systems. Probably the most well known definition is the following: "An ontology is a specification of a conceptualization... That is, an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents" [4]. Probably one of the reasons of the success of this definition is the fact that it considers several perspectives, going from the computational view to the social particularities of communities.

Ontologies in computer science are represented in computer readable languages (e.g. OWL, see http://www.w3.org/2004/OWL/) as collections of concepts, relations and restrictions. However, their genealogy may be considered from different perspectives: philosophical, computational, and psychological.

Each philosophic system starts with a theory about reality, a theory about what is considered that exists, a so-called ontology. In the process of building an ontology in a computer application, the designer must identify the fundamental categories, the relations and the differences among them. This is exactly one of the main activities that many philosophers, like Aristotle, Kant, Hegel, Peirce also have done. Therefore, philosophy has an important role in ontology engineering. For example, John Sowa, in a knowledge engineering book [6], wrote an entire chapter about the basic ontology he developed, that integrates ideas from the above famous philosophers and from others like Heraclit, Hegel, Leibniz, Whitehead, Husserl and Heidegger. Table 1 shows the basic categories he identified. There is, in fact, nothing surprising. It is normal that an artificial intelligence program has a model of reality and to take into account the very useful work of philosophers in constructing ontologies about reality.

Table 1. Basic categories in Sowa's ontology [6]

	Physical		**Abstract**	
	Continuant	**Occurrent**	**Continuant**	**Occurrent**
Independent	Object	Process	Schema	Script
Relative	Juncture	Participation	Description	History
Mediating	Structure	Situation	Reason	Purpose

Artificial intelligence aims at developing artifacts able to display an intelligent behavior, similar to that of a human being. Some well-known examples are anthropomorphic robots, expert systems, human language dialogue programs, and, recently, intelligent agents, programs or robots that search information on Internet or give personalized advice to an user.

In many artificial intelligence approaches, computer programs manipulate symbolic structures that represent knowledge, grouped in a so-called knowledge base. Both humans and programs use these structures as intermediates or substitutes for objects in the world. One of the most difficult problems that appear in this kind of systems is the knowledge acquisition problem, which means the process of "filling" the knowledge base with concepts, relations and restrictions. Knowledge acquisition can be facilitated by the existence of an ontology (similarly to a young researcher that much more easily finds his way if he has a sound foundation of basic concepts).

From another point of view, the idea that an artificial intelligence can be achieved via developing a base that includes knowledge that a human has, is directly related to cognitive psychology, which considers that human memory is organized as a semantic network with concepts as nodes and arcs as relations.

Viewing knowledge bases as ontologies has a series of very important advantages for developing knowledge based systems. First of all, an ontology is developed as a coherent framework for the reality and therefore it facilitates knowledge acquisition and machine learning. New concepts may be easily added in such a framework by finding one or some more general concepts and defining some differences between the new concept and the more general ones.

Another advantage is the possibility of developing generic ontologies, including fundamental concepts and to extend such ontologies for every particular application. Finally, ontologies may also enable a friendlier human-computer interaction by tailoring dialog to objects' features from a given context and to users particularities. In fact the ontology of an intelligent program may include not only knowledge about program's environment but also goals, choices, commitments of the program and of the partner (when a dialog is going on).

3 A socio-cultural ontology for urban development

Socio-cultural aspects are major issues in urban development because, of course, towns are built for communities of people. A problem is that communities and collaborative activities cannot be reduced to the sum of individuals. Therefore, for developing a socio-cultural ontology that takes into account all the needed concepts, a theoretic background that considers communities as a basic concept is extremely important. Such a theoretical outline is, in our opinion, Engeström's Activity Theory.

3.1 The Activity Theory

Yrjö Engeström developed his Activity Theory [3] starting from the ideas of the twentieth century Russian school of psychology. The initiator of this prolific sequence of ideas was Lev Vygotsky, which emphasized the role of tools, of words and, in general, of artifacts, as mediators between subjects (humans) and objects [7]. Mediators may be external (physical) or internal (mental) [1]. Therefore, a mediating triangle like that in figure 1 may be identified [7].

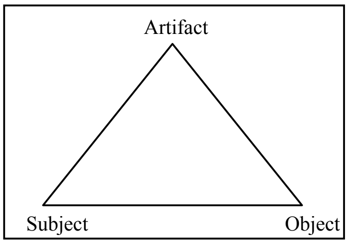

Fig. 1. Vygotsky's mediating triangle

Engeström extended the ideas of Vygotsky by considering the role of communities. Moreover, he identified two new types of mediators: Social rules mediate between subjects and communities, and the division of labor mediates the relation between communities and objects [3]. Vygotsky's triangle is therefore extended with two new triangles, obtaining the diagram from figure 2.

3.2 The basic concepts of the socio-cultural ontology

A problem in ontology development viewed as knowledge acquisition is how to find the methods that identify new concepts and to discriminate among them. Probably the most used method is categorization: identifying the basic categories that encompass a given segment of reality and their particularizations. We will also use this method, the novelty of the paper being its adaptation to the context of the Activity Theory.

John Sowa developed an upper level ontology starting from the basic categories identified by the most famous philosophers, like Aristotle, Kant, Whitehead or Peirce [6]. Similarly, the Activity Theory of Yrjö Engeström provides a theoretical framework that can be used for developing an ontology for urban development that has as basic concepts the two group of entities:

- The three categories: subjects, objects, and communities;
- The three mediators: general artifacts, social rules and division of labor.

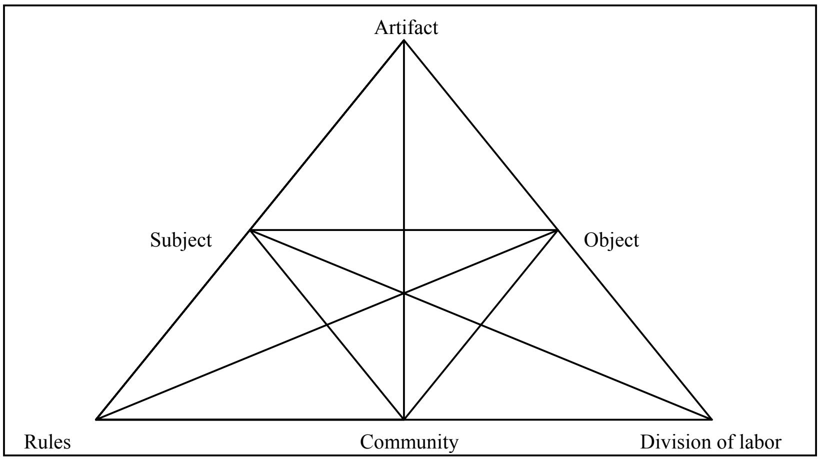

Fig. 2. The activity diagram of Engeström

Each of these six entities will be a basic concept (or "class") in the socio-cultural ontology. These concepts may have attributes, sub-concepts (that may be also sub-concepts of several other concepts, i.e. multiple inheritance of properties is allowed), and relations with other concepts:

- *Subjects* may be classified in several ways, considering different aspects: earnings, social status, ethnicity, age, hobbies, religion, etc. These aspects may be either the basis of a taxonomy of concepts or of attributes. For example, a person that has a habit of walking in a park may either be a new concept, which inherits from the subject concept, or an instance of the subject having "walking in a park" as the habit attribute.
- Different kinds of *objects* may be identified in urban development: buildings, roads, parks, cars, etc. Each of these concepts may be the root of an entire ontology. For example, buildings may be classified in living houses, offices buildings, theaters, cinemas, sport halls, hospitals, factories, shops, etc.
- *Communities* may be classified in the socio-cultural ontology according to several criteria, some of them derived from subjects' attributes like religion or ethnic group.
- *General artifacts* may be physical (tools, objects with a given use, that means that a sub-concept of the object category may be meanwhile a sub-concept of the artifact category), symbolic (texts, prices, taxes) or mental (e.g. imagery, visual patterns, architectural styles).

- *Social rules* may be legislation, traffic rules, unwritten behavior laws or esthetics. Rules may also become artifacts (sub-concepts of the rule category may be also sub-concepts of the artifact category), used by objects in communities.
- *Division of labor* is a basis for the taxonomy of services that assure the functioning and the quality of life of communities (providers of electricity, water and gas, teaching, police, fire department, administration, etc.)

Starting from the three categories "Independent", "Relative", and "Mediating" in Table 1, proposed by Sowa starting from Peirce triads [6], we will continue, in the next two sections, the categorization process by considering pairs (relations), and triples (mediators) of concepts.

3.3 Relations

Relations are, together with concepts (classes), the most important ingredients of an ontology. We propose, following the idea of using the Activity Theory diagram, relations to be included in the ontology. For example, below are the most important relations that could be identified in the diagram from figure 2:

subject – object (owned buildings and cars)
subject – rules
subject – community
community – rules
community – object (e.g. buildings, cars, parks)
community – divisions of labor (e.g. roles)
community – artifacts (e.g. beliefs, documents like acts)
object – artifact (property acts, blueprints)
object – subject (owner)
object – rule (of use)

Relations among the vertices of the diagram in figure 2 are extremely important and may be introduced in the socio-cultural ontology in several ways: as attributes, as associations or even as distinct concepts. For example, the relation between a subject and a community may be the "belongs to" attribute of that subject. However, the link of a subject to a rule, for example, may not be a direct link or attribute value. It rather may be derived from other properties of the person (e.g. age may induce that a person has some price reductions). Eventually, the "property" relation joins a subject and an object. Having a distinct concept for this relation allows us to derive a taxonomy of types of property or rent.

3.4 Triples

Triples are not usually explicitly considered in ontologies. However, triples (triads) play an important role in many theories. John Sowa considers them as a fundamental category, following Peirce's ideas [6]. Each of these triples may be seen as articulations, where one concept mediates between other two. As is emphasized in [6], Pierce asserts that triples are the most complex conceptual combinations. Therefore, there is no need to consider quadruples or structures with a higher number of elements.

We will go further with our conceptualization, and, similarly to [5], we will consider different triples that may be identified in figure 2, as suggestions of new concepts for the socio-cultural ontology, that are mediators between other two concepts. Of course, the idea of these mediating concepts might immediately be related with the idea of artifacts.

The implementation of triples in ontologies may be explicit, by including a mediator concept, like in Sowa's ontology [6]. This solution offers the possibility of developing a whole taxonomy of mediators. Another possibility is to have implicit mediators, by including the pairs of mediated concepts in the mediator concept. A third idea is to define a meta-class for mediators.

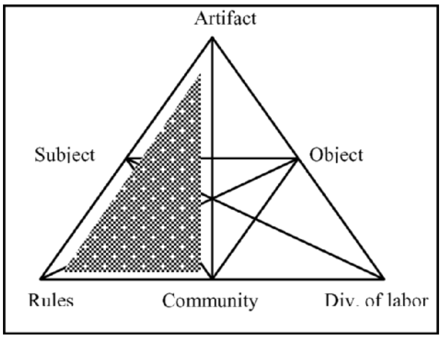

Fig. 3. Image of rules in communities

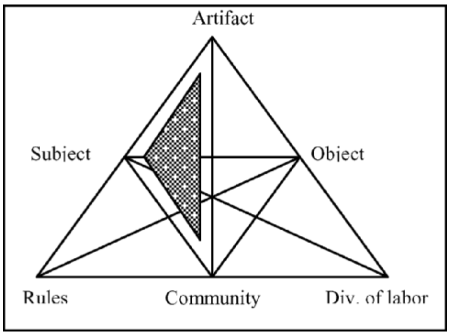

Fig. 4. Artifacts of subjects in communities

The remainder of this section will give several new examples of triples (in addition to those defining the basic mediators: artifact, rules, and division of labor). For example, the triple in figure 3 considers artifacts mediating rules and communities: the mental patterns, symbols or images that some urban or architectural rules establish in communities, like the image of a mountain village induced by the wooden houses. The triple in figure 4 identifies communities' artifacts related to subjects. We can include here history, stories, myths, songs, and collaborative habits.

The triple in figure 5 may be the basic concept for a taxonomy of roles that an individual may play into a community (for example, doctor, professor, priest, etc.). The rules that mediate the access of a community to an object is the concept that is suggested by figure 6.

Figure 7 represents rules (laws) that apply to an individual in relation to an object, for example regarding the property, the rights to modify an object, etc.

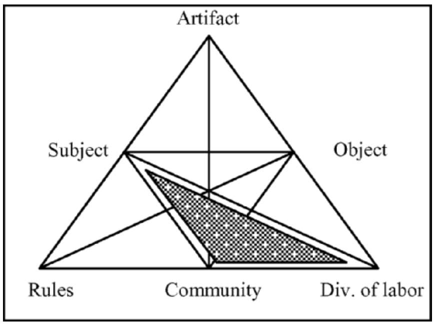

Fig. 5. Roles of individuals in a community

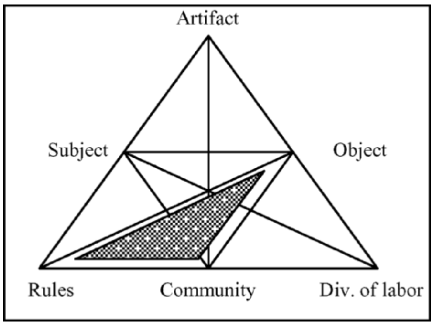

Fig. 6. Rules for objects' use in a community

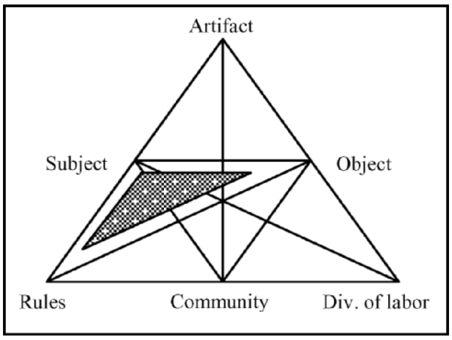

Fig. 7. Rules (laws) that apply to an individual in relation to an object

3.5 An OWL encoding

The basic concepts introduced in the above sections are part of an ontology written in OWL, which was developed and will be further extended in the Towntology COST C21 Action (http://www.towntology.net). For example, a triple of the kind exemplified in fig. 3, and some related concepts are described in fig. 8. The class diagram was generated with the OntoViz tab from Protégé (http://protégé.stanford.edu).

In fig. 9 and fig. 10, the description in OWL of the "mountain_house" class and the "t_community" property are presented (generated also with Protégé). OWL is a standard annotation language based on XML (http://www.w3.org/XML/) and RDF ("Resource Description Framework", http://www.w3.org/RDF/) for describing ontologies that allows definition of classes (concepts), properties and restrictions. The "mountain_house" is a subclass of the artifact_community_rule and has three properties, "t_artifact", "t_rule", and "t_community", the first two having also some attached values.

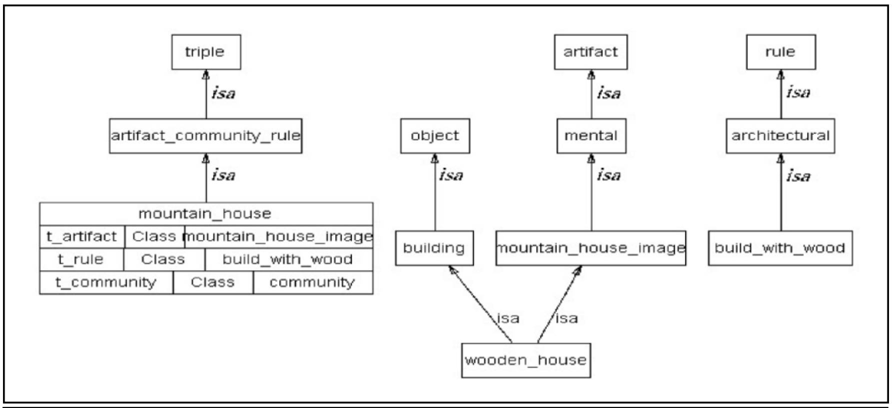

Fig. 8. The “mountain_house” “artifact_community_rule” triple and some related concepts

```
    <owl:Class rdf:ID="mountain_house">
      <rdfs:subClassOf rdf:resource="#artifact_community_rule"/>
      <rdfs:subClassOf>
        <owl:Restriction>
          <owl:hasValue rdf:resource="#build_with_wood"/>
          <owl:onProperty>
            <owl:ObjectProperty rdf:ID="t_rule"/>
          </owl:onProperty>
        </owl:Restriction>
      </rdfs:subClassOf>
      <rdfs:subClassOf>
        <owl:Restriction>
          <owl:onProperty>
            <owl:ObjectProperty rdf:ID="t_artifact"/>
          </owl:onProperty>
          <owl:hasValue rdf:resource="#mountain_house_image"/>
        </owl:Restriction>
      </rdfs:subClassOf>
    </owl:Class>
```

Fig. 9. The OWL description of the mountain_house concepts

```
    <owl:ObjectProperty rdf:ID="t_community">
      <rdfs:domain>
        <owl:Class>
          <owl:unionOf rdf:parseType="Collection">
            <rdf:Description
rdf:about="http://www.w3.org/2002/07/owl#Thing"/>
            <owl:Class rdf:about="#mountain_house"/>
          </owl:unionOf>
        </owl:Class>
      </rdfs:domain>
    </owl:ObjectProperty>
```

Fig. 10. The OWL description of the t_community property

The “t_community” property, described in OWL in fig. 10, has as domain (may be used in) the “mountain_house” class, and does not have any attached value.

4 Conclusions

A good ontology in a given domain needs a theoretical framework, that offers some obvious advantages: It facilitates the development of a consistent ontology, it suggests what other concepts should be added, and it prevents the loss of important concepts. We proposed and justified the use of the Activity Theory of Engeström as a framework for developing a socio-cultural ontology for urban development. A first skeleton of the ontology was implemented using Protégé, in the Towntology C21 COST action, and will be extended and experimented in applications.

We have proved in the paper that the usage of John Sowa's methodology of categorization [6], inspired by Peirce triads, and adapted to the Activity Theory [3], generates useful proposals of new concepts to be included in the socio-cultural ontology. However, the resulting relations and triples may be implemented in several ways, the selection of the best variant being not obvious.

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