Technology of Ontology Building for Knowledge Portals on Humanities*

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Abstract. The paper presents a technology of ontology building for specialized Internet portals providing content-based access to scientific knowledge and information resources related to humanities. The information basis for such portals is formed by ontologies, which allows heterogeneous data and knowledge to be presented in a unified manner ensuring their relatedness. Based on the ontology, internal storages of the portal data are constructed and management of its information content, as well as navigation and search, are organized. To meet the portal objectives, the ontology should be well-structured and adequately present its problem and subject domains. Therefore the portal ontology is divided into the domain-independent ontologies and subject domain ontology. The technology of ontology building includes the methods of ontology building, the ontology description language and ontology editor. The methods of ontology building are defined by its structure and supported by the facilities of the ontology editor. The ontology description language and ontology editor are selected and designed in such a way that they are easy to understand and use for experts in humanities. The ontology editor is also designed taking into account its use in the distributed development of ontologies.

Keywords: Knowledge portal, ontology, content-based access, technology of ontology building, ontology editor.

1 Introduction

Recently, a great amount of scientific knowledge and information resources relating to humanities has been accumulated in the Internet. However, the access to and the use of these knowledge and resources is rather complicated as they are disembodied and ill-structured, or distributed over various Internet sites, electronic libraries and archives. At the same time, researchers need an efficient access to scientific papers and other information resources containing descriptions of methods and approaches developed in the framework of the field of science interesting to them.

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To meet the need described above, we have suggested a conception and architecture of specialized Internet portals – knowledge portals [1] intended to provide systematization and integration of knowledge and information resources related to a given field of science, as well as content-based access to them from any Internet spot. In addition, according to the conception, the knowledge portal should not only provide the access to its own information resources, but also support effective navigation through relevant Internet resources previously remarked (indexed).

In addition to support flexible and consistent representation of some field of science (using special entities like persons, organizations, events, methods, objects and results of researches etc.), as well as content-based access to integrated knowledge and information resources, an important requirement to the knowledge portal is the possibility of its declarative adjustability to any area of knowledge both at the development and operation stage. This possibility allows us to track up the dynamics of appearance of new knowledge and information resources related to the topics of portal and in that way to secure maintenance of its topicality and utility.

The requirements described above were satisfied owing to the fact that ontology was chosen as a conceptual basis and an information model of the knowledge portal. Thus, the problem of ontology development for the scientific knowledge portal is rather actual. The paper describes our experience in designing and using such an ontology.

2 Requirements to Knowledge Portal Ontology

Above all we have to clarify what we mean by "ontology". We use the concept of "ontology" in the sense as it is used in computer science and artificial intelligence. Basing on the definitions presented in [2–5], we can say that an ontology is an explicit specification (model) of some part of the world as applied to a specific area of interests. In the context of this paper, an ontology will present a description of a certain branch of humanities and research activity related to it.

Let us consider the main requirements to the portal ontology.

The ontology should not only provide a formal presentation of concepts of the subject domain of the portal, but also support all necessary functionality, i.e. it should afford a basis for effective representation of diverse information related to the portal topic and provide a convenient content-based access to it. Besides, the ontology should provide integration of relevant information resources into information space of the knowledge portal and convenient navigation through it.

To support an effective representation of the subject domain knowledge, the ontology should provide a description of concepts with a complex structure and diverse semantic relations between them. An important requirement to the portal ontology is the possibility to order subject domain concepts in a "generic-specific" hierarchy and to support inheritance of properties through this hierarchy.

Since the ontology should provide the content-based declarative adjustment of the portal on a given area of knowledge and support its functionality, it should be designed in such a way that it could be used for automatic generation of the following components: the portal data base scheme (the logical structure of DB and data integrity constraints), forms for data base filling (with information objects being instances of the ontology concept), the scheme of navigation through the portal information space (along with the ontology relations), and query forms (using the ontology relations and concepts).

To make the knowledge portal easily adjustable to any area of knowledge, we should define the ontology structures that are independent of the subject domain of the portal.

Moreover, the ontology should have certain properties, such as extensibility and integrability with an existing ontology.

3 Structure of Knowledge Portal Ontology

3.1 Definition of Portal Ontology

An ontology satisfying the requirements described above can be represented by following structure:

$$O = \langle C, A, R_C, T, D, R_A, F \rangle, \tag{1}$$

where

C is a set of classes describing the concepts of a certain problem or subject domain;

A is a set of attributes describing the properties of concepts and relations;

$R_C = \{r_C | r_C \subseteq C \times C\}$ is a set of relations defined on classes (concepts);

T is a set of standard types of attribute values (*string, integer, real, date*);

D is a set of domains (the sets of values of a standard type *string*);

$R_A = R_{AT} \cup R_{AD}$, where $R_{AT} \subseteq A \times T$ is a relation that links attributes with the data types of their admissible values, $R_{AD} \subseteq A \times D$ is a relation that defines a discrete set of values (a domain) for each attribute;

F is a set of constraints on the values of attributes of concepts and relations.

From the informal point of view the portal ontology serves for representing concepts that are required for the description of both research activity and scientific knowledge in whole and specific areas of knowledge in particular.

3.2 Structuring of Knowledge Portal Ontology

To meet the portal objectives, the ontology should be well-structured and adequately present its problem and subject domains. Therefore the portal ontology is divided into domain-independent (basic) ontologies and the subject domain ontology.

The basic ontologies are the ontology of research activity and the ontology of scientific knowledge (see Figure 1) that are independent from the subject domain of the portal.

The ontology of research activity is based on the ontology suggested in [6]. Practically, it is a top-level ontology that includes the basic classes of concepts related to the research activity management such as *Person* (*Researcher*), *Organization*, *Event*, *Activity*, *Publication*. These classes are used when describing the participants of research activity, scientific events, research programs and projects, various types of publications and the materials represented in a printed or electronic format (such as monographs, articles, reports, proceedings of conferences, periodicals, photo and video data, etc.). This ontology includes a class *Information resource* that serves for description of relevant information resources presented in the Internet.

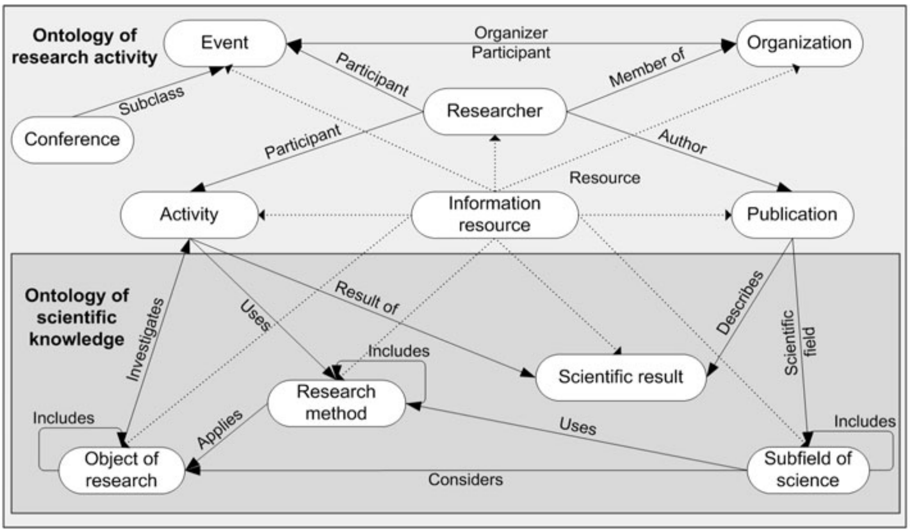

Fig. 1. The basic ontologies of a knowledge portal

The ontology of scientific knowledge is virtually a meta-ontology. It states the main structures that are used for building the lower-level ontologies, i.e. the subject domain ontologies describing some specific areas of knowledge or fields of science. In particular, this ontology contains the meta-concepts that specify the structures for the description of concepts of a specific subject domain, such as *Subfield of science*, *Research method*, *Subject or Object of research*, *Scientific result*. Using these meta-concepts, we can describe fields and subfields significant for a given science, determine a classification of methods and objects of research, and describe the results of research activity.

The concepts of the ontology of scientific knowledge are interconnected with each other and with the concepts of the ontology of research activity by associative relations, the main of which are the following:

– "Scientific field" – links events, publications, organizations, persons or information resources with subfields of science;
– "Describes" – links a publication with a scientific result, method or object of research;

- "Uses" – links a research method with activity, person or organization;
- "Investigates" – attaches some activity to the object of research;
- "Result of" – serves for linking scientific results with research activity;
- "Resource" – links information resources with any concept of the ontology;
- "Member of" – links a person with the organization where he works.

Note that the last relation has three additional attributes "appointment", "date of hiring" and "date of dismissal" that allow us to specify the position and working period for a person.

These associative relations have been chosen taking into account not only completeness of presentation of the problem and subject domain of the portal, but also convenience of navigation through the portal information space and of content-based search.

The subject domain ontology of the knowledge portal describes some field of science. It is built for organizing an effective access to information resources related to a certain research area, so it should meet the requirements described in section 1.

The concepts of the subject domain ontology are at the same time realizations of meta-concepts of the ontology of scientific knowledge and can be ordered in the "generic-specific" hierarchy.

As a rule the ontology of a concrete subject domain includes four basic hierarchies: *Subfield of science*, *Research method*, *Object of research*, *Scientific result*.

4 Technology of Ontology Building

The technology of ontology building includes the ontology description language, ontology editor that supports ontology constructing, and methods of ontology building.

The ontology description language and ontology editor were selected and designed in such a way that they are easy to understand and use for experts in humanities. In particular, to conform to these requirements, we refused to use such popular means as the ontology representation language OWL [7] and editor Protege [8] (at the same time we provided the possibility of translation the developed ontology to OWL representation).

Besides, the ontology editor was also designed taking into account its use in the distributed development of ontologies.

4.1 Ontology Description Language

The knowledge representation language of Semp-TAO system [9], a tried-and-true one, was taken as a basis of the ontology description language.

The classes of concepts in this language are described as follows:

```
class Name_of_Class (Class_Parent);
        Description_of_Attributtes;
constraints
        Description_of_Constraints;
end;
```

Below we give an example of simplified descriptions of the class *Person* and its successor – the class *Reseacher*:

```
class Person;
        Family_Name: string;
        Name: string;
        Patronymic_Name: string;
        Sex: Sex;
        Date_of_birth: date;
        Date_of_death: date;
constraints
        Date_of_birth < Date_of_death;
end;

class Reseacher (Person);
        Academic_Degree: Academic_Degree;
        Academic_Sstatus: Academic_Sstatus;
        E-mail: string;
        Office_Phone: string;
end;
```

The description of a relation looks like:

```
relation Name_of_Relation (Name_of_Argument1: Class1;
                           Name_of_Argument2: Class2);
        Mathematical_Properties_of_Relation;
        Description_of_Attributtes;
constraints
        Description_of_Constraints;
end;
```

Relations can have mathematical properties, such as transitivity, symmetry or reflexivity.

Let us give an example of the relation "Work in"

```
relation Work_in (who: Person; where: Organization);
        Appointment: Appointment;
        Date_of hiring: date;
        Date_of_dismissal: date;
constraints
        Date_of_hiring > Date_of_Birth + 18;
        Date_of_dismissal > Date_of_hiring;
end;
```

Domains are described in the following way:

```
Domain Name_of_Domain = Set_of_String_Values;
```

Let us give examples of descriptions of some domains:

```
Domain Sex = {mail, female};
Domain Position = {Director, Head_of_Laboratory, Researcher,
        Senior_Researcher, Junior_Researcher, Laboratory_Assistant};
```

4.2 Ontology Editor

The ontology editor is intended for ontology building by means of the language described in section 4.1. It includes graphical interface that simplifies the development of ontology and facilities that ensure its correctness.

The ontology editor is implemented as a Web-application accessible to authorized users. To make possible a distributed development of ontologies, the ontology editor has a procedure for granting privileges to experts of different levels.

Using the ontology editor, an expert can create, modify and delete any elements of the ontology: classes of concepts, relations, and domains.

When a class is created, it takes its name, a set of attributes that define various properties of concepts, as well as constraints on the attributes values. A parent of the class under creation can be selected from the set of already created classes. Thereby this class inherits from the parent class not only all its attributes, but also its relations, whereas the parent class gets linked to a new class by "subclass" ("is-a") relation.

For each attribute of the class, its name and status (mandatory or not), the range of values (type or domain), and the number of possible values (one or a set) are defined.

The domain is described by its name and the set of elementary (string) values. For each value from the domain, an expert can define the language (Russian or English).

The ontology classes can be linked by directed binary relations. The peculiarity of these relations is their (relations') ability to have their own attributes that specify the nature of the link between the relation's arguments.

To make the presentation of information more convenient for a user of the portal, the possibility of adjustment of knowledge and data visualization is provided. For this purpose, the templates of visualization are created for objects of each class of the ontology and for references to these objects.

A template of visualization for a class of objects contains all its attributes and all relations associated with it. By default, its attributes and relations are depicted in the same order as defined in the ontology, but the user can change this order.

A template of visualization for a reference to a class object can include both the attributes of this class and the attributes of classes that are linked with it by relations and attributes of these relations. The values of attributes included in this template are used for building a text representation of a hyperlink to a class object.

4.3 Features of Methodology of Ontology Building for a Knowledge Portal

The methodology of ontology building for a knowledge portal has much in common with other well-known methodologies that use core ontologies, for example Cyc [10] or SENSUS methodologies [11], but it has its own features. On the one hand, this methodology is wholly defined by the ontology structure defined in part 3, and on the other hand it is supported and at the same time restricted by the ontology editor facilities.

The subject domain ontology building is founded on usage of the basic classes (meta-concepts), defined in the ontology of scientific knowledge, as the root classes of such hierarchies as the hierarchy of subfields of science, hierarchy of research methods, hierarchy of objects of research, and hierarchy of scientific results.

When building a subject domain, new classes are defined as descendants of the basic classes. These classes are automatically inserted into the corresponding hierarchies by means of the inheritance relation. Let us remind that inheritance is implemented in such a way that the derived class inherits all attributes and relations from the parent class. Besides, this new class can have its own properties represented, as usual, by means of attributes and constraints and by binary relations linking this class with other classes.

Note that the specific character of the subject domain may need introduction of new classes which will not be descendants of the five basic classes described above. Extension of the ontology of research activity may also be required. This can be done by either introduction of new classes that are descendants of the basic classes of this ontology or definition of new classes independent of the basic ones.

Formal descriptions of concepts and relations so defined determine structures for representing real objects existing in some subject domain and provide their interconnections.

When the knowledge portal is already in service, new knowledge on its subject domain can be found or gaps and inaccuracies in the presented knowledge can be revealed. Undoubtedly this situation requires evolving and correcting the ontology. However, when the ontology is edited, it is necessary to maintain consistency of the portal knowledge system and exclude loss of information [12].

Modification of the ontology can consist in extension or rebuilding of its system of concepts, as well as addition, deletion or renaming of concepts, relations and/or attributes.

First, let us consider the cases concerned with extension of the system of concepts (conceptual framework).

In the simplest case, this extension consists in addition of a new attribute to some concept. Here we must take into account that the same attribute can belong to one of the concepts being a descendant of the editing concept. Therefore we have to look through all such descendants and if necessary to rename the corresponding attributes.

Addition of a new concept to a lower level of the concept hierarchy does not take any efforts for maintaining consistency of the portal's knowledge system, as in this case the new concept will simply inherit all attributes and relations of the higher level concepts.

When adding a concept which will become a root concept for one of the concept hierarchies, it is necessary to consider the attributes and relations of all concepts in this hierarchy. It is possible that we'll need to remove a part of attributes and relations from these concepts to the new concept. We should perform this action also taking into account the possibility of appearance (creation) of new branches of the hierarchy springing from the new concept.

Insertion of a new concept into the hierarchy between two "old" concepts also requires some methodological efforts. To avoid duplication and possible conflicts of names, it is necessary to select carefully the attributes and relations for the new concept from the lower level concepts.

When deleting a "leaf" concept, i.e. a concept situated at the lowest level of the hierarchy, to avoid loss of knowledge and data, it is necessary to consider the possibility of transferring its attributes and relations to some concept from the higher level of the hierarchy. We should realize that if there exist information objects created on the basis of the deleting concept then, to avoid loss of data, it is necessary to "attach" them to the parent of the deleting concept. But it can appear that such "attachment" is not enough for maintenance of all information on these objects if the attributes and relations of the deleting concept were not previously transferred to the higher level (parent) concept.

If the deleting concept is not a "leaf" concept, before its deletion we should consider the possibility of transferring its attributes and relations to one of its descendants. Analogously to the case with a "leaf" concept, the corresponding information objects should be "attached" to the parent concept and modified in accordance with its structure.

Deletion of "root" concepts of the knowledge portal ontology being in service or at the stage of its content creation is not recommended because of possible loss of information.

When deleting attributes from concepts, we also should take into account possible loss of information. A particular case of deletion of an attribute is its moving to the higher level or lower level concept. As a result of this moving, the attribute can become more general or more specific. In the former case information is not lost because in any case the moving attribute will be inherited by the modifying concept. In the latter case loss of information is possible, therefore we have to take measures for information recovery.

Sometimes moving of a concept within a hierarchy is required. In this case we should take into account that the sets of attributes and relations inherited by a concept are changed. Possibly, we'll have to manually restore some attributes and relations lost after this moving.

Moving subtrees from one branch of the hierarchy to another is a rather interesting case of evolution of the ontology. Virtually, this case is recursively reduced to the aforesaid. For the most part it is enough to “put in order” the root concept of the moving subtree, and the rest concepts of this subtree will be corrected automatically.

5 Content-Based Access to Portal Content

By introduction of formal descriptions of the subject domain concepts in the form of classes of objects and relations between them, the portal ontology defines structures for presentation of real data (objects) and relations between them. The portal data themselves are presented as a set of linked information objects.

Each information object (IO) corresponds to a certain class of ontology (it is an instance of this class) and presents a description of a certain object of the subject domain. There may be connections between information objects whose semantics is defined by relations between the corresponding classes of ontology.

Description of information resources is an important component of the information content of a portal. According to the definition of the ontology of research activity from section 3.2, each resource corresponds to such a concept of the ontology as Information resource, and its description includes an instance of this concept and a set of instances of relations that links it with the instances of other concepts of the ontology. The set of attributes and relations of Information resource is based on Dublin Core standard [13] and includes the following units: Title of the resource, Address in the Internet (URL), Subject of the resource, Resource type, Language, etc. Each resource can be linked by relations with persons, organizations, events, subfields of sciences etc.

Information content of a portal is produced (formed) by the expert with the help of a data editor that allows one to create, modify and delete information objects and relations between them. Operation of the data editor is based on the portal ontology. When a new information object is created, first of all, the expert selects the corresponding class of the ontology. Then, based on descriptions of this class and its relations, an input form for the corresponding information object is automatically generated. This form includes fields for input of the values of the object attributes and its relations with other objects already existing in the content of the portal.

Thus, the information content of the portal includes both general knowledge (presented in the ontology) and knowledge on concrete objects of the subject domain and their connections (presented by information objects and relations between them).

Navigation through the portal information space is realized in accordance with the content of its ontology. A navigation engine provides transition from the concepts of the ontology to their instances (lists of information objects) and then transition along ontological links (relations) from one information object to another.

Since the search is also based on the ontology, the user can formulate his query in terms of the portal subject domain. The basic elements of the query are concepts and relations of the ontology, as well as constraints on the required data.

Retrieval queries are formed by means of a special graphic interface driven by the portal ontology. When a user selects a class of the sought-for information objects, a retrieval form is generated where the user can define constraints on values of both the attributes of the sought-for object and objects connected with it by associative relations.

For example, the query “Find Gumilev’s publications on the ethnic history in the period from 1962 to 1989” formally looks as follows:

```
Class "Publication"
      Attribute "Date of publication": (>=1962)&(<=1989)
      Relation "Author":
          Class "Researcher"
                Attribute "Name" = "Gumilev"
      Relation "Scientific field":
          Class "Subfield of science"
                Attribute "Name of subfield" = "Ethnic history".
```

6 Building an Ontology for Knowledge Portal on Archeology and Ethnography

The technology described in the previous section was used for building an ontology for a knowledge portal on archeology and ethnography. The system classification of archeological science proposed in [14] and developed today served as the basis for building the ontology of archeology and ethnography. The concepts of the system classification are used for building the classes of the ontology and the domains of their attributes and for creation of instances of these classes.

The ontology of archeology and ethnography includes four basic hierarchies: sub-fields of science, research methods, objects of research, scientific results (Fig. 2).

These hierarchies are founded on the following classes of concepts built on the basic concepts of the ontology of scientific knowledge:

Subfield of archeology and ethnography. This class is a root class in the hierarchy of scientific fields in archeology and ethnography. For example, subfields of archeology are *General archeology*, *Field archeology*, and *Ethnic history.*

Research method in archeology and ethnography. This class serves for description of research methods that are applied in archeology and ethnography. Such “traditional” subclasses as *Approach*, *Principle*, *Technology*, *Archeological methodology*, as well as a group of methods that came into archeology from other sciences (*Biological method*, *Physical method* and *Chemical method*), were defined as the descendants of this class.

Object of research in archeology and ethnography. This class is a root of the hierarchy of objects of research in archeology. It has such properties as description of an object, date of discovery, accuracy of dating, etc. This class has two subclasses *Material object* and *Immaterial object*. *Material object* is divided into subclasses *Archeological culture*, *Historical Person*, *Ethnos.* Successors of the class *Immaterial object* are *Artifact*, *Complex*, *Monument.*

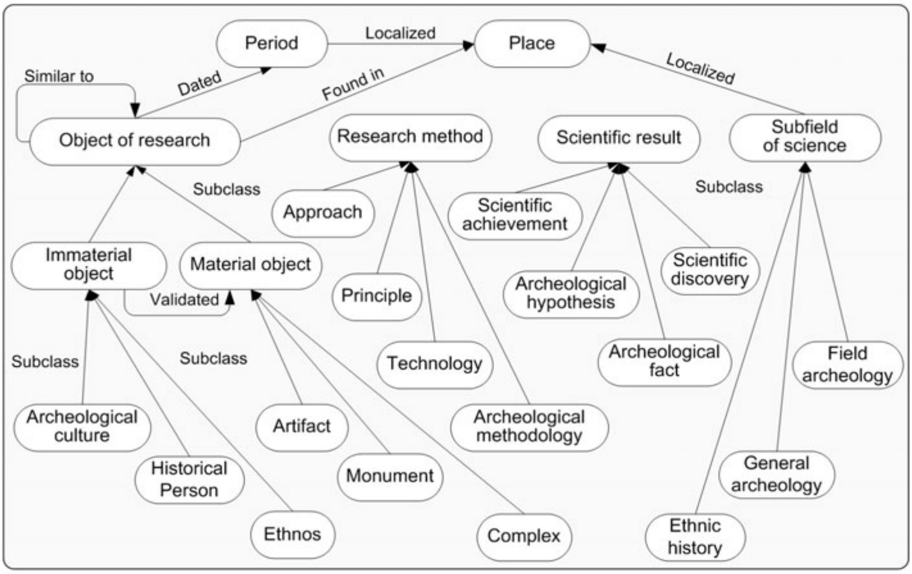

Fig. 2. A fragment of the ontology of archeology and ethnography

Scientific result in archeology and ethnography. This class serves for description of the results of research activity in archeology and ethnography such as discoveries, new laws, theories, historical facts, etc. The properties of this class are presented by such attributes as description of the result, date of obtaining and type of the result. The class includes the following subclasses: *Archeological hypothesis*, *Archeological fact*, *Scientific achievement*, *Scientific discovery*.

In addition to the above listed classes built on the basis of meta-concepts of the ontology of scientific knowledge, the classes *Archeological period* and *Place* were inserted in the ontology. The class *Archeological period* is specific for a historical science. It serves for dating of objects of research. *Archeological periods* constitute a hierarchy of nesting and historical sequence and are described by the time domain. The class *Place* serves for pointing to the location of an object of research or an organization, as well as for gridding (fixing) the subfields of science.

All hierarchies described above are interconnected with each other and with the classes of the ontology of research activity by means of associative relations. One part of these relations is inherited from the basic ontologies, the other part of them contains specific relations of a given subject domain.

So, the hierarchy of methods of research is connected with the hierarchy of objects of research by means of the relation "Uses" and the hierarchy of scientific results, that serves for typification and description of the results of research activity, is connected with activity by means of the relation "Result of".

The hierarchy of scientific results is connected with publications where scientific results are described by means of the relation "Describes". The objects of research are interconnected with each other by means of the relation “Similar to” that defines the degree of similarity of objects and by means of the relation “Materially validated” that connects an immaterial archeological object of research with a material object of research that validates its existence.

Connection between the hierarchy of scientific fields and the methods of research in use is provided by means of the relation “Uses” and the objects of research are connected with scientific fields by the relation “Study”. A chronological and geographical location of a scientific field can be defined by means of the relations “Dated” and “Localized”.

Note that a complete ontology of the portal on archeology and ethnography includes the ontology of archeology and ethnography and the ontology of research activity described in section 3.2.

7 Conclusion

The paper presents a technology of ontology building for knowledge portals related to humanities. This technology includes the methodology of ontology building, the ontology description language, and ontology editor that supports ontology construction. A specific feature of the methodology of ontology building is the usage of the basic ontologies defined in part 3.2 as the basis for constructing an ontology for a knowledge portal.

The technology was used in the development of an ontology for a knowledge portal that provides semantic access to systematized knowledge and information resources related to archeology and ethnography (the Russian version of this portal is available at `http://www.sati.archaeology.nsc.ru/classarch2/`). At present this technology is used for building an ontology for a knowledge portal on computational linguistics.

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