Development of Domain Ontology,
Targeted at the Creation of Learning Materials
from Digital Archives

Kamenka Staykova[1], Danail Dochev[1], Desislava Paneva[2],
Lilia Pavlova-Draganova[3], Valia Saraydarova[1]

[1]Institute of Information Technologies– Bulgarian Academy of Sciences
Sofia, Bulgaria
{staykova, dochev, saraydarova}@iinf.bas.bg
[2]Institute of Mathematics and Informatics – Bulgarian Academy of Sciences
Sofia, Bulgaria
dessi@cc.bas.bg
[3]Laboratory of Telematics – Bulgarian Academy of Sciences
Sofia, Bulgaria
lilia@cc.bas.bg

Abstract. The paper presents the design solutions and development steps of the domain ontology 'Bulgarian Iconographical Objects' built largely upon the content of the Virtual Encyclopedia of the Bulgarian Iconography. On the one hand, the created ontology follows the standards already established in the domain of art documentation by CIDOC, on the other hand, it aims at playing a specific role as an annotation schema for purposes of the project LOGOS "Knowledge-on-Demand for Ubiquitous Learning". The paper gives a summarized view of the content of the ontology.

Keywords: Ontology, Bulgarian Iconography, Conceptual Graphs

1 Introduction

The paper presents the design solutions and development steps of the domain ontology Bulgarian Iconographical Objects created under the project LOGOS "Knowledge-on-Demand for Ubiquitous Learning" http://logosproject.com. The project deals with accessing existing large-scale repositories of digitized information and facilitating their transformation into learning content, considering also possibilities for its cross-media delivery. The overall aim of the project is to contribute to the adequate enhancing and facilitating the knowledge building during eLearning processes. Ontologies and their processing were included in this project in order to realize content- and context-sensitive search in large digital repositories with considerably less explicit input information from the users.
The Ontology of Bulgarian Iconographical Objects (OBIO for the sake of brevity) concerns religious art objects of the Christian Orthodox Church created from the end of the twelfth to the beginning of the twentieth centuries by Bulgarian iconographers

and located on the present territory of Bulgaria. The ontology considers objects of art (icons, wall-paintings, etc.) registered within the multimedia digital library "Virtual Encyclopaedia of the Bulgarian Iconography" http://mdl.cc.bas.bg [7, 9] OBIO targets semantic annotation and search of digital objects which set up the creation of courseware materials in the field of Bulgarian Iconography, to be used in a set of learning areas (iconography, arts, history, culturology, theology, etc.).

The paper is organized as follows: Section 2 briefly presents the main principles and general steps of present-day ontology building. Section 3 discusses the OBIO construction. The ontology itself is sketched in Section 4. Section 5 contains some conclusions.

2   Ontologies, Ontology Creation

Currently in the field of Knowledge Technologies ontologies are the constructions representing semantics of human realm in form usable by software programs. The term *ontology* is borrowed from Philosophy and especially from that philosophical branch, which deals with the nature and organization of reality. Taken to the field of Information Technologies the term has similar meaning, concerning a data model to describe the known entities and relations between them in a particular domain.

Computers are essentially symbols-manipulating machines, and ontologies play a crucial role for applications in which meaning is shared between parties. The ontologies fix the interpretation of symbols against some semantics, typically model-theoretic semantics, and are "formal specifications of a shared conceptualization of a certain domain" [4].

In Computer Science ontologies refer to engineering artifacts, which means that a specific vocabulary of concept types is used to describe a certain reality and also a set of explicit assumptions is defined regarding the intended meaning of the vocabulary. Apart from the explicit specification of a conceptualization, ontologies are "a shared understanding of a domain of interest" [13]. Ontologies provide taxonomic organization of concepts, relations between concepts (possibly with type and cardinality constraints), and instantiation relations.

A particular ontology introduces its particular domain or *world*. The problem with knowledge exchange among different *worlds* arises when a connection among *worlds* is needed. In [5] four different general types of ontologies are defined. A Top-level Ontology describes very general concepts like space, time, event, which are independent of a particular problem or domain. A Domain Ontology describes the vocabulary related to a generic domain by specializing the concepts introduced in the Top-level Ontology. A Task Ontology describes the vocabulary related to a generic task or activity by specializing the Top-level Ontologies. Concepts in an Application Ontology often correspond to roles played by domain actors while performing a certain activity. Usually all the four types of ontologies are involved in real complicated tasks.

It is to be expected that a well-defined Domain Ontology could be maintained and adjusted to new tasks, so knowledge engineers pay attention to the Ontology Lifecycle [12] as a whole. An Ontology Lifecycle begins with a Feasibility Study

followed by an Ontology Kickoff, which gives requirements specification and semi-formal ontology description. The Refinement Phase includes phases of Evaluation and Application Evolution. This means that ontology could pass through Refinement Phase many times when it is involved in real knowledge management application.

There are many similar schemes for ontology development phases in the literature. According to [3] the construction of ontology consists of the following steps:

1. Specification of the purpose, usage, scope and degree of formality of the ontology.
2. Data collection using various elicitation methods.

These two steps cover the *knowledge level* of the classical methodology for development of knowledge engineering systems [11].

3. Conceptualization of domain terms, resulting in a preliminary ontology.
4. Possible integration with other ontologies.

The two steps described above cover the *symbol level* of knowledge systems development.

5. Formalization in an ontology language.
6. Evaluation of completeness, consistency and redundancy.

These two steps concern the *implementation level* of knowledge systems development.

3 Development Steps of OBIO

3.1 Knowledge Level

The domain ontology 'Bulgarian Iconographical Objects' is created to be used inside the LOGOS Authoring Studio for semantic annotation and access to digital objects, which construct desirable learning content. In the hierarchy of data models of LOGOS architecture the digital objects are media objects accompanied by identification, technical and semantic metadata. Learning objects are (combinations of) digital objects, complemented by educational metadata [6]. Courseware objects integrate learning objects according to schemes of learning experiences [1]. Authors of learning materials have access to digital archives, search for appropriate digital objects, combine them in learning objects and further - in courseware objects using the services of the LOGOS Authoring Studio. The aim to offer easy access to digital archives determines the following requirements to the ontology Bulgarian Iconographical Objects and its development process:

− The ontology is intended to describe religious art objects created for the Christian Orthodox Church by Bulgarian iconographers and located on the present territory of Bulgaria.
− The domain (world) has to be reasonably restricted to contain only objects and relations needed for semantic annotation and search of digital objects to be used for creation of courseware objects in the field of Bulgarian iconography, according to:

- The general functionality, presupposed by the learning and authoring scenarios developed in the project [10, 8];
- The usage scenarios in the terms of LOGOS concepts and terms concerning its data models and architecture;
- The content of the multimedia digital library "Virtual Encyclopaedia of the Bulgarian Iconography" - the source of digital objects in targeted domain.

− The formalization in the Conceptual Graphs has to be considered during ontology development in order to adequately fit the expressiveness and functionality of the LOGOS Ontology Management Tool, based on this formal model.

− The ontology development has to fit with the incremental prototyping implementation of LOGOS Authoring Studio.

So the ontology 'Bulgarian Iconographical Objects' in its current form is not intended to be used as a general-purpose ontology of Bulgarian iconography, but is limited to the pragmatic use of semantic descriptors for the needs of LOGOS Authoring Studio.

As a result of knowledge elicitation in a number of brainstorming sessions and interviews with a team of domain experts and developers of the multimedia digital library "Virtual Encyclopaedia of the Bulgarian Iconography" from IMI – BAS the list of potentially relevant terms were produced first. Within some iterations the basic concept types - ICONOGRAPHICAL OBJECT, ICONOGRAPHER, ICONOGRAPHIC SCHOOL, etc. and relations among them were fixed. The concepts were provided with definitions satisfying both the domain experts and knowledge engineers.

The study of ontologies similar to OBIO and covering art objects showed that it would be reasonable to use the framework of concepts and relations of the recommended standard in documentation of art collections, namely the CIDOC Conceptual Reference Model http://cidoc.ics.forth.gr/ as a Top-level ontology. It is an upper level ontology developed by the International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM) for description of museum collections of art and cultural heritage artifacts. The Conceptual Reference Model provides descriptions of high level notions (time, place, artifact, collection, organization etc.) and methodological guidance in creating domain ontologies for art objects. Some ontologies for specific *worlds* of art objects are developed as (conceptual at least) specializations of the higher level Conceptual Reference Model. This approach was adopted also for the creation of the ontology Bulgarian Iconographical Objects.

3.2 Symbol Level

Conceptual Graphs are the underlying formalism of the LOGOS Ontology Management Tool. According to the Conceptual Graphs terminology [2] an ontology is presented by a construction called *support* and contains taxonomy over a vocabulary of concept types and taxonomy over a vocabulary of relation types. Individual markers could also be provided.

A simple conceptual graph defined over a *support* is a graph that has two kinds of nodes: concept nodes, which represent entities and relation nodes, which connect these entities. Concept nodes are labelled by a concept type and a marker. Relation

nodes are labelled by a relation type. Homomorphism (or projection) is the main notion of conceptual graphs processing. A homomorphism from a conceptual graph P to a conceptual graph H is a mapping from the node set of P to the node set of H, which preserves the structure of P and may decrease the node labels. While conceptual graphs represent formalized knowledge, the projection is the core operation of a knowledge management system based on Conceptual Graphs. Basically a knowledge base contains taxonomically ordered vocabulary and a set of graphs (factual knowledge), but may also contain a set of rules and a set of constraints.

3.3 Implementation Level

The 'Bulgarian Iconographical Objects' ontology was implemented using the Ontology Management Tool of the LOGOS Authoring Studio called CoGui http://gforge.lirmm.fr/projects/cogui and developed in The Montpellier Laboratory of Computer Science, Robotics, and Microelectronics. CoGui provides functionality to create and maintain multilingual vocabularies of concept types and relation types and also functionality for posing constraints, rules, fact graphs, prototypical graphs, pattern graphs, *etc*.

The OBIO vocabulary of concept types and relation types was implemented by means of CoGui generated structures. Main prototypical graphs corresponding to the claims of OBIO knowledge were also provided, as far as the first pattern graphs to be used in the process of annotation.

4 Presentation of OBIO

The formalization of the acquired knowledge for OBIO development went through the following steps:
1. Development of vocabulary of the necessary domain concepts and relations.
   The OBIO vocabulary is developed in Bulgarian and English. Each concept type is defined by   two elements:
   – *Description* – in lexicographer style – a short condensed explanation of the content with general terms when possible, oriented mainly towards annotators and end-users and available in corresponding GUI explanation boxes;
   – *Scope* – a more detailed and sometimes more formal interpretation of the concept scope, oriented mainly to knowledge engineers, who develop and will enhance the ontology further.
2. Specialisation of the Conceptual Reference Model of CIDOC corresponding to the OBIO concepts and relations.
   The Conceptual Reference Model of CIDOC gives clear formal definitions for the more general concepts and relations of OBIO domain. For example, the CRM's concept IMAGE is defined as VISUAL ITEM and CONCEPTUAL OBJECT created by human being, and at the very high ontological level as PERSISTENT ITEM; the OBIO concept ICONOGRAPHICAL IMAGE in the sense expressed by our domain experts could be presented simply as subtype of CRM's IMAGE. Checking further the relations defined

for CRM concept IMAGE, it was demonstrated that some of them could fit the desired relations in the OBIO. This fact is not a surprise, having in mind that CRM is a general model created to cover different art collections, and the OBIO is targeted to describe particularly a collection of iconographic art objects.

Some concepts like PERSON, TITLE, TIME-SPAN were used in OBIO as they are defined in CRM, some other CRM concepts like IMAGE, DESIGN OR PROCEDURE, GROUP were specialized to capture the specificity of the domain of Iconography: ICONOGRAPHICAL IMAGE, TECHNIQUE, ICONOGRAPHIC SCHOOL, CLAN. The general ideology of CRM (monotonic reasoning, multiple inheritance, endurant-perdurant discrimination, etc.) has been followed and its definitions used as much as possible. No inconsistencies with domain knowledge have been detected; not all branches of CRM Concepts Hierarchy were used. The ontology Bulgarian Iconographical Objects had just been compiled in its first variant.

3. Structuring the hierarchy of domain concepts.

The hierarchy of OBIO concept types (upper levels) is presented in Appendix 1.

4. Determination of the significant relations in the domain.

Each relation type is characterized by its Domain and its Range, which are concept types, so the process of relations elicitation was tightly connected with the process of building concept types hierarchy. Appendix 2 shows the hierarchy of OBIO relation types.

5. Development of network of concepts and relations.

Conceptual Graphs give easily applicable means to express statements of knowledge concerning the domain where the ontology is already presented. Prototypical Graphs concern the knowledge about particular concept type. Figure 1 bellow shows the Prototypical Graph of the concept ICONOGRAPHER.
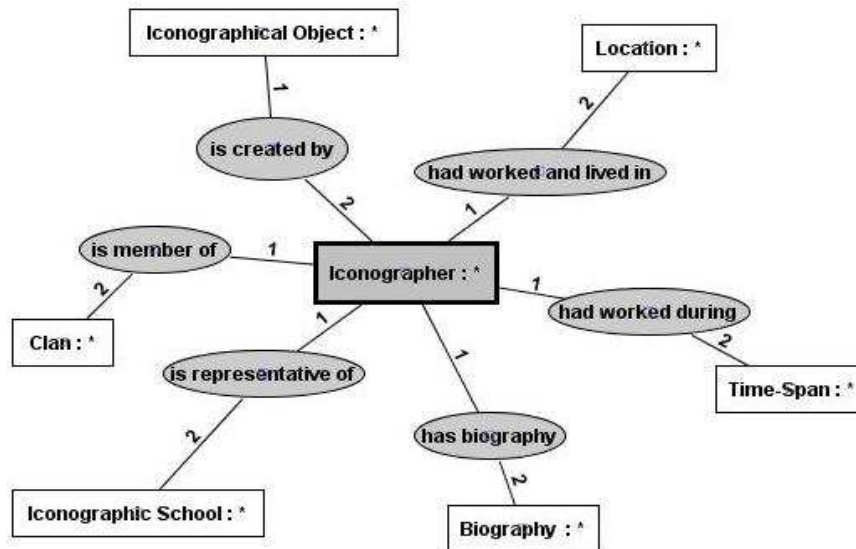

Fig. 1. Prototypical Graph of ICONOGRAPHER

Pattern Graphs will be in substantial use in the process of annotation, because they are associated with different annotation viewpoints. As the digital objects under consideration present predominantly icons, a part of a Pattern Graph created over OBIO to support the annotation of icons is presented below.
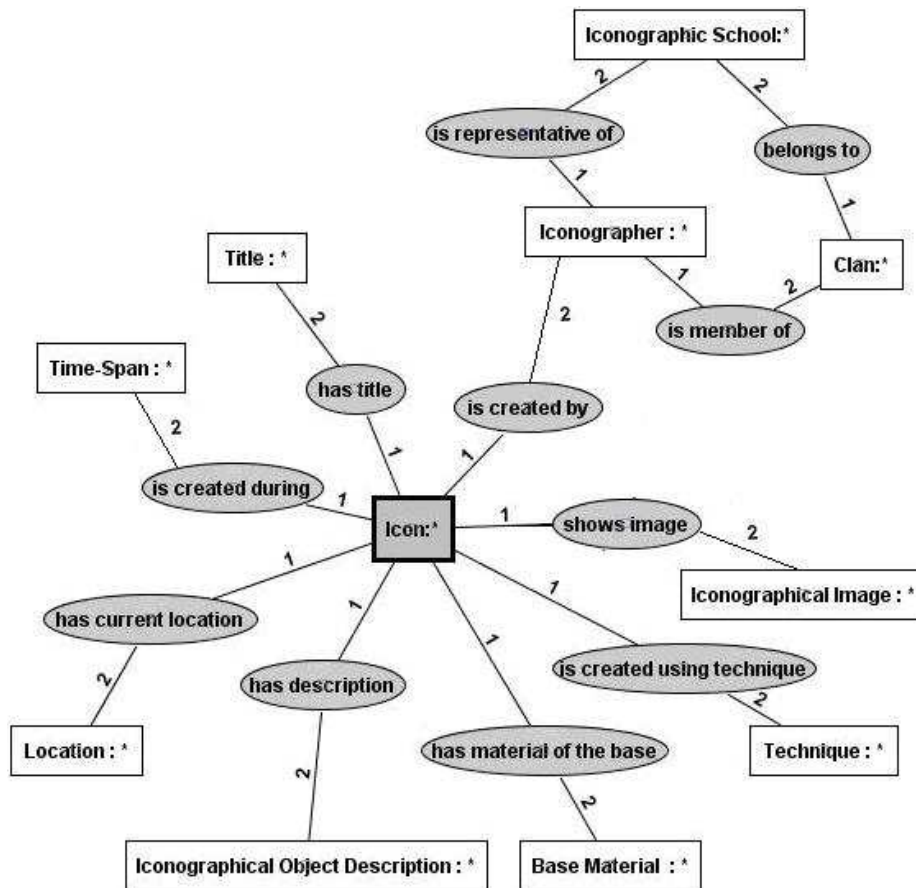

Fig. 2. A part of a Pattern Graph for annotating ICONs against the OBIO ontology

5 Conclusion

The approbation and evaluation of OBIO adequacy and usability will be made during its use for annotation of digital objects and their further use for the creation of courseware materials inside the LOGOS project. The first approbation phase is internal for the project implemented by courseware authors from project partners' teams and is planned to be completed by the end of the current year. The phase is intended to provide valuable feedback for further enrichment of the ontology concepts

and relations, as well as for the enhancement of the ontology application modes for end users in the framework of the LOGOS Authoring Studio.

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Appendix 1: Hierarchy of Concept Types of the 'Bulgarian Iconographical Objects' Ontology

- EO
  - Base Material
  - Clan
  - Description
  - Description Type
  - Iconographer
  - Iconographic School
  - Iconographical Image
    - Character Image
      - Image of a Bulgarian Saint
      - Image of a Canon Creator
      - Image of a Righteous Man/Woman
      - Image of an Ancestor
      - Image of an Army Divine's Member
      - Image of Apostle
      - Image of Christ
      - Image of Deacon
      - Image of God – the Father
      - Image of Harbinger of peace
      - Image of Hermit
      - Image of Hierarch
      - Image of Holy Spirit
      - Image of Patriarch
      - Image of Prophet
      - Image of Reverent Man/ Woman
      - Image of St. John the Baptist
      - Image of the Virgin Mary
      - Image of a Martyr
    - Scene Image
  - Iconographical Image Compoundness
  - Iconographical Object
    - Icon
    - Iconographic Element in Psalm-Book
    - Plastic Iconographical Object
    - Wall-Painting
  - Location
  - Technique
  - Time-Span
  - Title

Appendix 2: Hierarchy of Relation Types of the 'Bulgarian Iconographical Objects' Ontology

- Binary Relation (EO, EO)
    - belongs to (Clan, Iconographic School)
    - had residence in (Iconographic School, Location)
    - had worked and lived in (Iconographer, Location)
    - had worked during (Iconographer, Time-Span)
    - has biography (Iconographer, Biography)
    - has compoundness type (Iconographical Image, Iconographical Image Compoundness)
    - has current location (Iconographical Object, Location)
    - has description (Iconographical Object, Iconographical Object Description)
    - has description of activities (Iconographic School, Iconographical School Description)
    - has description type (Description, Description Type)
    - has material of the base (Iconographical Object, Base Material)
    - has title (Iconographical Object, Title)
    - is created by (Iconographical Object, Iconographer)
    - is created during (Iconographical Object, Time-Span)
    - is created using technique (Iconographical Object, Technique)
    - is member of (Iconographer, Clan)
    - is representative of (Iconographer, Iconographic School)
    - shows image (Iconographical Object, Iconographical Image)
    - was functioning during (Iconographic School, Time-Span)