ONTOLOGICAL PRESENTATION OF EAST-CHRISTIAN ICONOGRAPHICAL ART DOMAIN*

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ABSTRACT. In the recent years the East-Christian iconographical art works have been digitized providing a large volume of data. The need for effective classification, indexing and retrieval of iconography repositories was the motivation of the design and development of a systemized ontological structure for description of iconographical art objects. This paper presents the ontology of the East-Christian iconographical art, developed to provide content annotation in the *Virtual encyclopedia of Bulgarian iconography* multimedia digital library. The ontology's main classes, relations, facts, rules, and problems appearing during the design and development are described. The paper also presents an application of the ontology for learning analysis on an iconography domain implemented during the SINUS project "Semantic Technologies for Web Services and Technology Enhanced Learning".

1. Introduction. In an attempt to answer the need for virtual presentation and preservation of the valuable artefacts of the East-Christian iconographical art and particularly of the Bulgarian iconography, a team from the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences developed a multimedia digital library called *Virtual encyclopedia of Bulgarian iconography* (`http://bidl.cc.bas.bg`). The main aim of the developers was the creation of a complete web-based environment for registration, documentation, access and exploration of Bulgarian iconographical artefacts and knowledge, providing wide accessibility and popularization of the East-Christian iconographical art works. The need for effective classification, indexing and retrieval of the iconography repository appeared during the content digitization. This was the main motivation for designing and development of systemized ontological structure for description of iconographical art objects, also called ontology of the East-Christian iconographical art.

The process of ontology building is necessarily iterative. The first activity was the definition of the scope of the ontology. Scoping has been mainly based on several brainstorming sessions with iconographers, content providers and semantic web specialists. Having these brainstorming sessions allowed the production of most of the potentially relevant terms. At this stage, the terms alone represented the concept, thus concealing significant ambiguities and differences of opinion. A clear issue that arose during these sessions was the difficulty in discovering definite number of concepts and relations between these concepts. The concepts listed during the brainstorming sessions were grouped in areas of work corresponding to naturally arising sub-groups of concepts. Most of the important concepts and many terms were identified. The main work on building the ontology was then to produce accurate definitions. During the experimental use of the ontology several facts and rules for the target objects appeared and were included in order to complete the description of the iconography domain.

This paper presents the ontology of the East-Christian iconographical art, main classes (concepts), relations, some facts and rules. The paper also discusses problems appearing during the ontology design and development and used approaches for domain formalizing. During the SINUS project "Semantic Technologies for Web Services and Technology Enhanced Learning"[1] the ontology is used for e-learning purposes, i.e., learning analysis execution on the Bulgarian iconography domain. In the paper a short overview of the *Virtual encyclopaedia*

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[1]An interdisciplinary research project whose main goal is to demonstrate creative learning-by-doing through active learners' authoring of specific learning materials, using resources delivered through the *Virtual encyclopedia of Bulgarian iconography* multimedia digital library.

of the Bulgarian iconography multimedia digital library was made in order to show the environment in which the valuable phenomena of this idiosyncratic art are kept.

2. Bulgarian Iconography Digital Library. Orthodox (East-Christian) iconographical art is recognised as one of the most significant areas of the art of painting. Until recently, it had been neglected in the digital documentation and the registry of the art of painting. But the accessibility to this valuable part of mankind's cultural and historical ancestry was enhanced greatly with the appearance of the *Virtual encyclopaedia of the Bulgarian iconography*[2] multimedia digital library (also called Bulgarian iconography digital library, BIDL) in the world virtual space. This Internet-based environment becomes a place where iconographical objects (IOs) of different kinds and origins were documented, classified, and "exhibited" in order to be widely accessible to both professional researchers and the wide audience. Rare specimens, private collections, icons from difficult-to-access storages, distant churches, chapels, and monasteries, objects in a risk environment or unstable conditions, etc. are appearing for new e-exposition. The library provides services for registration, documentation, access and exploration of a practically unlimited number of Orthodox iconographical artefacts and knowledge [11, 9] and the end users can use this rich knowledge base through its interactive preview, objects complex search, selection, and group. A complete description of the BIDL functionality is made in [14]. Until now, the library is used in several cross-media, ubiquitous and technology-enhanced learning applications [7].

3. Presentation of East-Christian Iconographical Art Semantics. The need for effective retrieval of the icons of East-Christian iconographical art in BIDL is motivated by the increasing number of digitized iconographical objects. For the solution of this problem we develop *a domain ontology for the East-Christian iconographical art*. This ontology is used for the semantic metadata description and indexing of the iconographical art content. Similar work is done in [17, 18]. It defined a semantic classification for the Byzantine icons. This classification is used for icon separation on semantic regions in order

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[2]The first release of the library was developed five years ago within the national project "Digital Libraries with Multimedia Content and its Application in Bulgarian Cultural Heritage" (contract 8/21.07.2005 between the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, and the State Agency for Information Technologies and Communications).

to provide face detection, analysis of the facial characteristics and sacred figure recognition.

The conceptualization and formal presentation of the iconographical art semantics posed specific challenges for our team of ontologists, art domain specialists and BIDL content creators. Several problems in "Icons" domain formalization appeared. These challenges are mainly related with:

- Determining the set of separate ontological sub-structures of the iconographical object domain, the iconographic school, the author of iconographical objects, the iconographic character/scene, etc.;

- Determining in a unique way the descriptors of the different types of iconographical objects (icon, wall-painting, miniature, plastic iconographical object, etc.) according to accepted canons of Orthodox painting;

- Reducing the complexity of the structures that describe different aspects of the iconographical object domain (especially for technological specifics, hierarchy of characters, descriptions of scenes, etc.) without loss of important content;

- Presenting relations between classes and constructing their complete network;

- Defining in a unique way the domain rules, axioms, constraints and facts (because of the incompleteness, inaccurateness or subjectivity of the existing information presenting the iconographical art domain);

- Creating standardized and consistent descriptions of iconographical objects following the available standards for cultural heritage content presentation.

In our ontological model the iconographical art world is described by three "thematic entities" (also called levels of knowledge). Each of these entities is enriched with a set of sub-levels, covering a wide range of characteristics. The first one is the "Identification" entity, which consists of general data identifying aspects of the iconographical object[3] (IO) such as IO title, type[4], author, author's

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[3]A sacred image ($\varepsilon\iota\kappa\nu$, image from Greek), created on a stone or metal relief, bone, ceramics, glaze, mosaic, wall-painting (encaustic, fresco, seco), art textile, as a miniature on parchment or paper and on a wooden board with tempera paint.

[4]A variation of the iconographical object determined by the techniques, bases, materials, purpose and location.

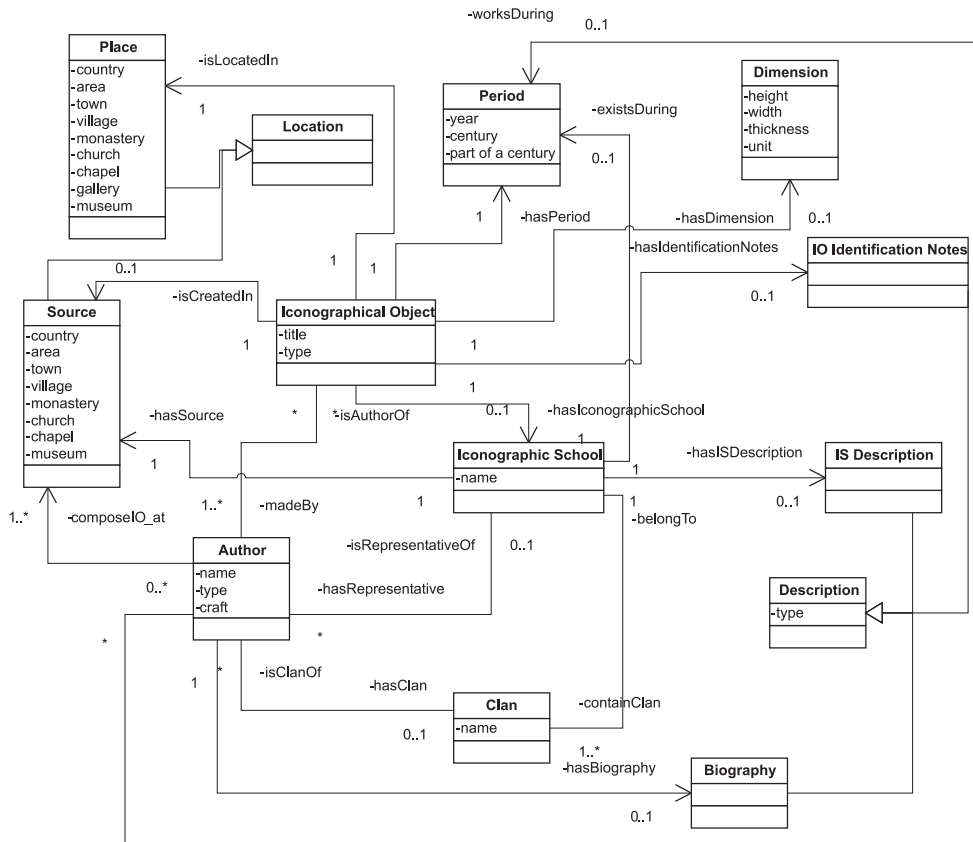**Identification entity of the Ontology of the East-Christian iconographical art**

Fig. 1. Identification entity of the ontology of the East-Christian iconographical art

clan[5] and biography, iconographic school[6], period[7], dimensions, current location and source, and IO object identification notes (for example, distinctive features, possession (private or museum collection/s), inventory number, author's signature, donor inscriptions, etc.), and iconographic school description (see Figure 1).

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[5]The author's clan/family represents a group of people with heritage relations who create iconographical objects passing the craft of iconography to the following generations and who use a common style of icon painting, ermeniya, techniques, carbon paper, etc.

[6]The iconographic school is a community of authors–iconographers (including whole families), which produces iconographical objects in a given period and region, stylistically subordinate to one concept (style, techniques, specific materials and methods of creation).

[7]Temporal characteristic (including year, century, part of the century) dating the iconographical object.

Description entity of the Ontology of the East-Christian iconographical art

Fig. 2. Description entity of the ontology of the East-Christian iconographical art

The second entity (see Figure 2) covers information concerning the descriptive details of the theme and forms of representation, providing a better understanding of the content. The main concepts included are: depicted character/s, iconographical scenes, character/s in the scene/s, symbol/s in the scene/s, characters' gestures, characters' vestment, detailed description of the depicted content[8], etc.

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[8]Example from the Ermenya of Dicho Zograph–Painting of *The Nativity of St. John the Forerunner* – *"Houses. To the right: a porch with curtains down, Elizabeth sitting on a couch. Pillows behind her. She is half covered. Servants wandering around her. Opposite to Elizabeth, Zacharias is sitting on the left, holding a plate in his hand, with a writing on it, which says "His name is John." Below, there is a woman washing John and another one preparing his bed. If you wish, (paint) them to lull him – it is all right."*

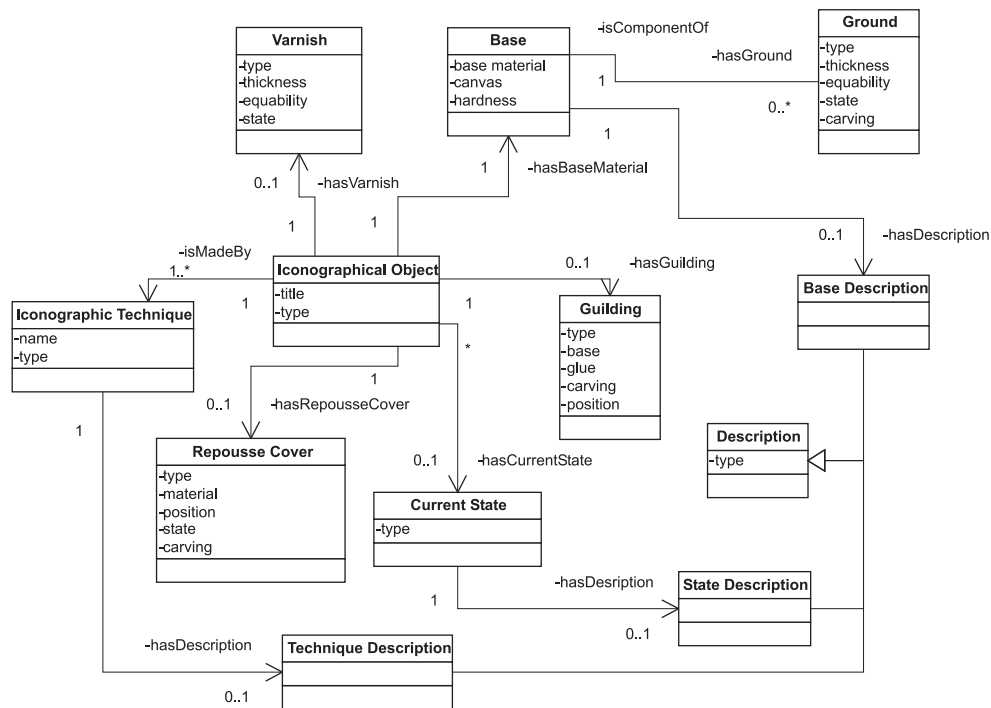**Technology entity of the Ontology of the East-Christian iconographical art**

Fig. 3. Technology entity of the ontology of the East-Christian iconographical art

The third entity (see Figure 3) includes technical information revealing iconographic techniques[9], base materials[10], gildings, repousse covers, etc., used in the creation of the iconographical object/collection, and also concerning examinations of the condition, such as diagnosis or history of the conservation treatment [12].

In the ontology several rules and facts are defined. For example, the following statement determines the dependence between the *Author* of an *Iconographic School* and the value of the *Period* in which he worked.

If *Author* isRepresentativeOf *Iconographic School* = A then the *Author* works during *Period* p for the *Iconographic School* A.

For example, if we have an unknown author from Bansko-Razlog iconographic school we could periodize their works (in identity search).

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[9]Tracking the overall process of iconographical object creation.

[10]Material on or of which the iconographical object is produced.

The next example tracks the relation between the *Iconographic Scene* and the depicted *Iconographical Character(s)* on it.

If *Iconographic Scene* = A then *Iconographic Scene* depicts *Iconographical Character* = $\{a_1, a_2, ..., a_n\}$, where $\{a_1, a_2, ..., a_n\}$ is predefined set.

Similar statements are made for the *Vestment* and *Gesture* of the *Iconographical Character* in the *Iconographic Scene* and the depicted *Iconographical Symbol*. The *Iconographical Character* itself also has similar dependencies with its *Vestments, Gestures* and *Iconographical Symbol*. These rules could aid the annotation action in the library. When these rules are clearly indicated in the annotation objects template, the relevant concept class value[11] could be filled automatically or could be proposed to be chosen for different painting interpretations (i.e. one annotation value could be used for several similar objects). These rules could also give possibilities for some inferences[12] about the emphasis, trends, and priorities in the work of an author, an iconographic school or the art during a fixed period. These rules of the description entity of the ontology are defined according the canons of the Orthodox painting described in special technology guides (manuals) on icon painting called *Ermeniya*[13] of icon painting.

We also determined a set of rules and facts for dependence between *Iconographical Object type* and the *Iconographic Technique types,* the *Base,* the *Guilding and* the *Repousse Cover type* for its production; the *Iconographic School* and the *Period, Source town, village* and *area*; temporal and spatial dependences, etc. These statements could be used for critical analysis of technology/art, learning, inferences for trends and priorities in the domain, finding implicit data/content, dependences, tendencies, etc.

The interpretations of the iconographical knowledge are not considered isolated from the standards and specifications in the field of representation of cultural information because the goal is to maximize the reusability and portability of the designed ontological model. The most significant new development is the CIDOC Conceptual Reference Model (CRM), "object-oriented domain ontology" for expressing implicit and explicit concepts in the documentation of cultural her-

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[11]For example, values of the Iconographical Character and its Vestments, etc.

[12]For example, for finding main characters depicted on the *Iconographic Scene* "Deisis with Apostles" or typical/different *Vestments, Gestures* or *Iconographical Symbols* depicted, etc.

[13]Ermeniya (E$\rho\mu\eta\nu\varepsilon\acute{\iota}\alpha$ from Greek) are those "hidden" books, used by painters to help them follow the canons and the technology of the iconography. They trace the sequence of actions to create iconographical objects (main techniques, grounds, pigments, plating techniques, etc., as well as the way they are prepared); the painting in the icon with its specifics and symbols, the way to fix it to the foundation, measures, proportions, prescriptions, etc. For example: the ermeniya of Zakharij Petrovich, the ermeniya of Dicho Zograf, etc.

itage. During the creation of the "East-Christian iconographical art" ontology we observe the conceptualization approaches of CIDOC CRM ontology. We use part of its concepts and properties in our ontology. We extend another part in order to make it fit the iconography domain. For example, our "Iconographical Object" class is a sub-class of CIDOC CRM E22–Man-Made Object, our "IO Author" is CIDOC CRM E21 – Person, our "Clan" is CIDOC CRM E74 – Group, etc. The juxtaposing approach and a rich set of examples are included in [5].

The main entities and the corresponding metadata values in the ontology are supported, documented and provided by the scientific diagnosis, which has been applied to the iconographical objects and collections [12]. The main knowledge sources for the Bulgarian iconography domain are [2, 16, 15, 4, 3].

To represent efficiently the iconographical annotation framework and to integrate all the existing data representations into a standardized data specification, the "East-Christian iconographical art" ontology needs to be represented in a format (language) that does not enforce semantic constraints on iconographic data, but can also facilitate reasoning tasks on these data using semantic query algebra. This motivates the representation of this ontological model in Web Ontology Language (OWL). OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema by providing additional vocabulary along with a formal semantics. Knowledge captured from iconographic data using OWL is classified in a rich hierarchy of concepts and their inter-relationships. OWL is compositional and dynamic, relying on notions of classification, reasoning, consistency, retrieval and querying. We investigated the use of OWL for making our ontology using Protégé OWL Plug-in.

4. Learning analysis based on the Ontology of East-Christian Iconographical Art. The ontology of East-Christian iconographical art can be used in a wide area of research and analysis in the domain, such as: analysis of the religious meaning of an iconographical image which is the object of research, art analysis of the development of iconographical objects and scenes in the different iconographical schools through time, tracing the iconographical technology development in different iconographical schools and time periods, a technological analysis of a piece of art (base, primer, painting layer, polish, etc.), tracing the current condition and the restoration manipulations, exploring the donor and author signatures, tracing the authentication of an object, etc.

At present, such an analysis with learning aim is performed using the objects and knowledge of the "Virtual encyclopedia of the Bulgarian Iconography"

multimedia digital library in a special learning layer, developed during the SI-NUS project "Semantic Technologies for Web Services and Technology Enhanced Learning". A formal use case scenario of this activity is created. It models a technology-enhanced learning on iconographical art domain, presented in [13]. According to this scenario the ontology of East-Christian iconographical art is used for the annotation, semantic indexing, and search of iconographical arte-facts and knowledge included in this library in order to provide a knowledge base for semantic inferences. The next examples demonstrate a real learning analysis, included in the scenario and played away during the project.

Sample task for the arts critics' team: Make an art critical analysis of the development in time of the iconographic image of Jesus Christ in the various iconographical schools on Bulgarian land.

Steps to be performed:

1. Collect a minimum of 6 iconographical objects containing the image of Jesus Christ in a one-figure composition (Note: The right choice requires selecting iconographical objects with the character or Jesus Christ Pantocrator, or Blessing Christ, or Jesus Christ enthroned, or St. Veronica, etc.).

2. Arrange the iconographical objects in groups (i.e. classify them) by school of iconography.

3. If a school of iconography's group contains objects by an eminent author and founder of the school, place these high on the list. Among the objects designated for art critical analysis there should be at least one by a prominent author/school founder, if available.

4. Ensure that the iconographical objects designated for art critical analysis are currently in good condition.

5. Ensure that at least one primitive iconographical object and at least one Renaissance iconographical object are included in the iconographical objects designated for art critical analysis.

6. In writing the art critical analysis compare the selected iconographical objects by contrasting clothing, gesture/s, the character proportions, object/s, the presence of other character/s and/or symbol/s, backgrounds, other element/s (e.g., clouds, etc.) in the iconography of the image of Christ. Look for changes in the iconography of these components, for example, appearance or lack of components (objects, symbols, characters, etc.), changes in the background, clothing, etc., in the selected set of samples.

In the sample task for the arts critics' team the main learning objective

of the user is to make concrete analysis in the iconography domain. The subtasks (1-6) show steps (sub-goals) to be executed in this analysis. These steps could be presented as a formula combining one of the "Bloom Taxonomy" verbs [1] with a term (concept) from the ontology of the East-Christian iconographical art. In the SINUS learning platform the **Student** will "execute" the Bloom's verb action on the concept(s) from the ontology of the East-Christian iconographical art. For example, in step 1 the **Student** *collects* iconographical objects presenting Iconographical character = Jesus Christ in a composition type = one-figure. In step 2 the **Student** *classifies* (i.e. *arranges the iconographical objects in groups*) iconographical objects by a certain iconographic school. In step 3 the **Student** has *to discover-select-show* iconographical objects by a certain author type, etc. Tracking all the sub-goals clearly shows the place of the taxonomy terms of the East-Christian iconographical art ontology needed for the learning analysis.

In this scenario similar sample tasks are determined for the arts techniques team and the theology team.

The presented learning analysis aims to demonstrate creative learning-by-doing through active learners' authoring of specific learning materials on East-Christian iconography, using multimedia and information resources delivered through BIDL. The main user groups of the project are the developers of various learning resources and the consumers of those learning resources (i.e. academic users, researchers in the target learning domain, non-academic users). In particular, the learning analysis are created and conducted by a learning advisor/tutor.

Conclusions and Future Work. This article presented a structure for helping the formal description and documentation of the iconographical art in digital libraries by means of the Semantic web. By now, hundreds of objects are annotated with the ontology of the East-Christian iconographical art in the "Virtual encyclopedia of the Bulgarian iconography" multimedia digital library and learning analysis using its conceptualization framework is performed in a real eLearning process in the SINUS project.

The presented ontology could also be used in different areas such as automatic sacred figure recognition, iconographic scene recognition and content analysis, painting technology analysis (technological point of view), dynamic personalized creation of content in the Iconography domain, matching the iconography of different interpretations of the same characters or scenes, identifying icons in risk environments, storage, preservation and promotion of our art and iconographic heritage, etc.

Future work on the East-Christian iconography domain will include the extension of its current formal specification with conceptualization of churches, monasteries, etc. repositories of iconographical artefacts, church plates; ethnographic objects used for idolatry, etc. Thus, the target domain will be completely presented and formalized and will provide tools for profound observations and interdisciplinary research.

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