Ontology-Based Design of Intelligent Systems in the Field of History

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***Abstract* — The article considers the usage of ontological approach to design of intelligent systems in the field of history.**

Keywords -- subject area, ontology-based design, history, artefact

I. INTRODUCTION

A. Purpose and Relevance

The work is devoted to the ontology-based approach to constructing intelligent systems in the field of history, the specific nature of this kind of systems and the features of their design.

The need to formalize, systemize and process knowledge is equally critical in historical studies as in any other science. At the same time, humanities are the field where formalizing knowledge is somewhat difficult, reasoning is less transparent, and knowledge is based not on concepts, but on ideas, which, in their turn, require clarification and specification [1].

The relevance of the intelligent systems' design in the field of history is related to the growing interest of the society and the academic community to retrospective methods that are making history a tool for research, as well as to history as a way to preserve and transmit culture in its broadest sense.

B. The issues to be addressed in order to achieve the goal

- compatibility of historical systems of various purposes needs to be ensured for the most complete and effective representation and usage of historical knowledge;
- in order to ensure wide dissemination and use of intelligent systems in the field of history we need to move beyond narrow specializations and to develop multifunctional and multi-purpose systems.
- the large volume of dynamically changing knowledge requires such a technology for designing the systems of similar purpose that would allow to create flexible, easily modifiable and reconfigurable intellectual systems;
- since formalization of historical knowledge needs contribution from experts in specific areas of historical knowledge, there is a need to support such teamwork in development of knowledge bases that eventually turns experts into knowledge engineers.

C. Proposed Approach

The proposed approach to building intelligent systems in the field of history is based on the following provisions:

- OSTIS Technology is set as a basis for building intelligent systems which ensures compatibility of design solutions. OSTIS is a technology for component-based design of intelligent systems, which allows to develop intelligent systems quickly and efficiently [2]
- the ontology-based approach to design of intelligent systems that can solve the problem of compatibility of various intelligent systems and their components ensures flexibility of the systems under development and enables teamwork in their design.

II. THE SYSTEM OF ONTOLOGIES AS THE BASIS FOR BUILDING INTELLIGENT SYSTEMS IN THE FIELD OF HISTORY.

The hierarchical system of subject domains and their corresponding ontologies permits to specify all concepts used within a particular paradigm, allocating them to subject domains and specifying them within relevant ontologies.

The following types of ontologies can be identified:

- *structural ontology*
- *set-theoretical ontology*
- *terminological ontology*
- *logical ontology*

Each ontology is a model (specification) of a certain subject domain, or, more specifically, it is a specification of a paradigm of concepts that are used in a subject domain [3].

Explicit definition of ontologies in knowledge bases of intelligent systems is necessary in order to:

- record the current coordinated version of interpretation (clarification) of all concepts used;
- ensure the efficient and continuous process of development and harmonization of concepts used [4].

A number of subject domains common for all historical systems can be distinguished within historical knowledge [5]. Such subject domains can include:

- *Subject domain of artefacts* describing all historically significant artificial man-made material entities, produced as a result of purposeful action.
- *Subject domain of individuals and social communities,* which researches humans and all communities of people emerged as a result of human activity.
- *Subject domain of historical actions, events and situations.*

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- *Subject domain of ideas*, describing all the ideas arising as a result of purposeful activity.

Subject domain of artefacts is partial in relation to the *Subject domain of temporary entities*, specification of which is presented in IMS Metasystem [6]. Let us take a look at the main classes of the research concepts in the *Subject domain of artefacts* [7].

documentary artefact
= material information carriers in the form of texts, graphic images, audio, video, and images, with historical and cultural value.
<= partitioning:*
- *written document*
  <= partitioning:*
  - *handwritten document*
  - *printed document*
    <= partitioning:*
    - *cartographic document*
    - *official document*
    - *narrative document*
      <= partitioning:*
      - *personal document*
      - *fiction document*
      - *historical document*
      - *scientific document*
- *film- and photo- document*
- *phonodocument*

construction
= immobile man-made artefcat with historical and cultural importance
*<= partitioning *:*
- *building*
  <= partitioning:*
  - *residential building*
  - *public building*
    *<= partitioning *:*
    - *civic building*
    - *administrative building*
    - *religious building*
  - *production building*
    *<= partitioning *:*
    - *industrial building*
    - *agricultural building*
- *structure*
  <= partitioning:*
  - *hydraulic structure*
  - *utility network*
  - *fortification structure*

=> inclusion:*
- *construction complex*
- *architectural complex*

household item
= article of daily use
= household product
<= partitioning:*
- *tableware*
- *clothing*
- *furniture*
- *weapons*
- *jewelry*
- *tools of trade*
- *means of transportation*

visual art item
= artifact created as a result of creative actions of humans
<= partitioning:*
- *painting item*
- *sculpture*
- *decorative-applied item*

The following subject domains are partial for the *subject domain of artifacts*:
- *Subject domain of archaeological artifacts*
- *Subject domain of ethnographic artifacts*

Let us consider the main classes of research objects for the *Subject domain of individuals and social communities* [8], [9].

person
= individual

social community
= group of people with similar functions, goals, social statuses, social roles, and cultural requirments.
<= partitioning:*
- *ethnic community*
  <= partitioning:*
  - *race*
  - *tribe*
  - *ethnos*
  - *nationality*
  - *nation*
- *socio-territorial community*
  <= partitioning:*
  - *city*
  - *village*
  - *quarter*
  - *region*
- *social stratum*
  <= partitioning:*
  - *caste*
  - *estate*
  - *etacratic group*
  - *socio-professional stratum*
  - *class*
- *primary group*
  <= partitioning:*
  - *family*
  - *friend*

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- *classmate*
- *colleague*

- *social organization*

<= *partitioning **:

- *formal organization*
- *informal organization*

<= *partitioning **:

- *labor organization*

<= *partitioning*:*

- *manufacturing organization*
- *scientific organization*
- *educational organization*
- *medical organization*
- *cultural and educational organization*
- *administrative organization*

<= *partitioning*:*

- *governmental organization*
- *cooperative organization*
- *joint stock organization*
- *organization owned by labor collective*
- *private organization*
- *joint organization with foreign capital*
- *foreign organization*

- *public organization*

<= *partitioning*:*

- *environmental organization*
- *sports organization*
- *political organization*
- *leisure organization*
- *charitable organization*
- *cultural organization*
- *religious organization*

=> *inclusion*:*

- *crowd*
- *quasigroup*
- *audience*

Subject domain of historically important actions, events, and situations is a partial subject domain to the *Subject domain of actions*. Let's take a look at some of the classes of research objects:

historically significant action

=> *inclusion*:*

- *goal-oriented rational action*
- *action of value*
- *affective action*
- *traditional action*

=> *inclusion*:*

- *labor action*
- *intellectual action*
- *religious action*
- *creative action*
- *communication*
- *play*

Let us consider *structural ontology* on the example of the *Subject domain of constructions.*

Subject domain of constructions

=> *ontology**

Structural ontology of the Subject domain of constructions

= [*

Subject domain of constructions

<= *partial subject domain**:

Subject domain of historical artifacts

=> *partial subject domain**:

- *Subject domain of buildings*
- *Subject domain of structures*

∋ *maximal class of research objects'*:

construction

∋ *nonmaximal class of research objects'* :

- *building*
- *structure*
- *construction complex*
- *architectural complex*
- *ruin*
- *authentic construction*
- *restored construction*
- *lost construction*

∋ *concept researched in other subject domain':*

- *architectural style*
- *construction element*

∋ *researched relation'*:

- *architect**
- *material of structure**
- *owner**

*]

Let us consider the *set-theoretical ontology* of the *Subject domain of constructions*.

Subject domain of constructions

=> *ontology**:

Set-theoretical ontology of the Subject domain of constructions

=[*

construction

∈ *historical artifact*

<= *partitioning**:

- *building*

<= *partitioning**:

- *residential building*
- *public building*

<= *partitioning**:

- *civic building*
- *administrative building*
- *religious building*

- *production building*

<= *partitioning**:

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- *industrial building*
- *agricultural building*

- *structure*

<= *partitioning**:

- *hydraulic structure*
- *utility network*
- *fortification structure*

=> *inclusion**:

- *construction complex*
- *architectural complex*

material of construction*

∈ *binary relation*

=> *definitional domain**:

construction ∪ *construction material*

=> *first domain **:

construction

=> *second domain **:

construction material

architect*

∈ *binary relation*

=> *definitional domain**:

construction ∪ *individual*

=> *first domain**:

construction

=> *second domain**:

individual

location*:

∈ *binary relation*

=> *definitional domain**:

construction ∪ *geographic coordinates*

=> *first domain **:

construction

=> *second domain **:

geographic coordinates

***]**

Each *logical ontology* contains the entire set of axioms, definitions, and statements over the concepts of a subject domain, helping to build a logical ontology-based set of logical reasoning about this subject domain. Let us take a look at a fragment of *logical ontology* of the *Subject domain of family relationship.* This subject domain is a *partial subject domain* of the *Subject domain of individuals and social communities.*

The subject domain of family relationship

=> *ontology**:

Logical ontology of the subject domain of family relationship

=[*

parent*

=>*explanation**:

[A ***parent**** is a *binary relation* that connects two *persons*, one of whom is a parent of another one]

∈ *Russian language*

mother*

=>*explanation**:

[A ***mother**** is a *binary relation* that occurs at the place of a *parent**, if the second domain is an *person* that belongs to a class of *woman*.]

∈ *Russian language*

∈ *key sc-element':*

...

∈*statement*

=> *sc-text translation**:

[Every *person* can have only one *person*, which is *mother** for that *person*]

∈ *Russian language*

sibling*

=>*explanation**:

[A ***sibling**** is a *binary relation* that connects two persons whose both *parents** are identical]

∈ *Russian language*

<= *used constants**:

{

- *parent**
- *person*

}

female cousin*

=>*explanation**:

[A ***female cousin**** is a binary relation that connects two *persons*, the second of which belongs to a class of *woman* and whose parents are connected with a *sibling** relation]

∈ *Russian language*

<= *used constants**:

{

- *parent**
- *individual*
- *female*
- *sibling**

}

*]

Let's look at how formal definitions, corresponding to given explanations, appear in SCg language [6]:

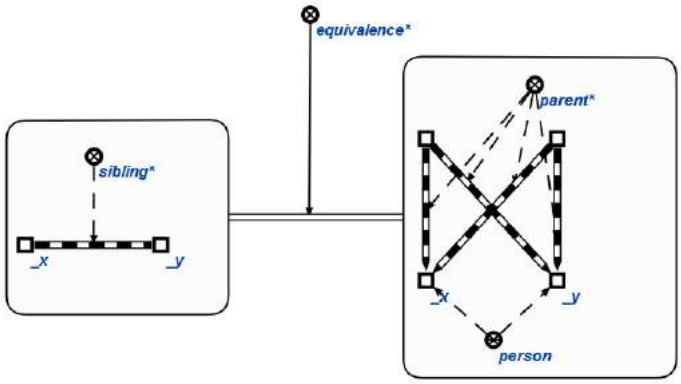

Figure 1. Definition of ***sibling**** relation

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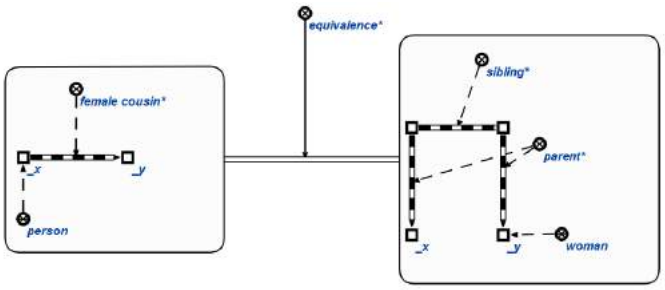

Figure 2. Definition of ***female cousin**** relation

The above mentioned ontology fragment shows that it can be a good basis for performing a number of tasks in historic systems. In particular, for finding an individual's relatives of different degrees of kinship, even if these links are not evidently present in the subject domain. Or, for finding possible family relationship between any two individuals in the knowledge base.

Distinguishing subject domains and their data ontologies allows to distinguish independent areas within the system, which can be developed without the need to harmonize actions in the subject domain with the developments in other subject domains. At the same time, it clearly prescribes the development stages that would require such harmonization.

III. Types of Intelligent Systems in the Field of History

A large number of various historical systems is present at the moment. Historical systems can be classified as following, by the **subject of research**:

- systems describing a specific area of historical knowledge: history of mathematics, history of literature, archeology and history of archeology [10], [11];
- systems describing a specific period of time: history of the Middle Ages, the Modern history [12];
- systems describing the history of a certain territory: history of Europe, history of the city of Minsk [13].

And, accordingly, any possible intersection of these three sets.

By purpose all historical systems can be divided into:

- reference systems, which provide structured information in the required subject domain [14]
- training systems, which have a knowledge monitoring complex along with the structured material [15].
- systems supporting scientific research in the field of history, or tools for historians.
- guiding systems supporting ciy or museum tours [16] [17] [18].

All these systems have two major drawbacks:

- it is impossible to use knowledge from the knowledge base of one history system for solution of any kind of problems in another one;
- the knowledge bases of these systems are ultimately incompatible due to the absence of common ontology.

However, as the systems operate with the same type of knowledge, it might provide the basis for the development of common ontologies of such systems. The ontological approach in the design of systems in the field of history, will provide an opportunity to integrate various systems, as well as to borrow the necessary components that are present in one of the systems, but not in the other ones.

IV. Conclusion

General ontology of historical knowledge as a reusable component will accelerate the development of intelligent systems in the field of history and provide opportunities for using solutions from one system within the framework of another one in order to address the necessary applied problems.

Ontology-based approach to design of intelligent systems in the field of history will provide for the flexibility of the systems being developed and for the possibility of organizing project activities in a way that these activities are maximally independent in detail elaboration of various subject domains, while preserving the integrity of the systems under development.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ В ОБЛАСТИ ИСТОРИИ

Губаревич А.В., Моросин О.Л., Ландэ Д.В.

Работа рассматривает онтологический подход к построению интеллектуальных систем в области истории, специфику данного рода системы и особенности их построения.

Вопрос о необходимости формализации, систематизации и обработки знаний стоит в исторической науке не менее остро, чем в любой другой. При этом гуманитарное знание является областью трудно формализуемого знания, где рассуждения менее прозрачны, а знание опирается не на понятия, а на идеи, которые в свою очередь требуют уточнения и определения.

Актуальность разработки интеллектуальных систем в области истории обусловлена все возрастающим интересом общества и науки к ретроспективным методам изучения, где история становится инструментом исследования, а также к истории как способу сохранения и трансляции культуры в самом широком ее понимании.

Онтологический подход к проектированию баз знаний, в том числе в области истории, подразумевает выделение предметных областей и онтологий данных предметных областей, разработка в рамках которых может вестись без необходимости согласования действий в данной предметной области с разработками в других предметных областях.

На данный момент существует большое количество различных исторических систем. Исторические системы по **предмету исследования** можно классифицировать следующим образом:

- системы, описывающие определенную область исторического знания: история математики, история литературы, археология и история археологии;
- системы, описывающие определенный период: история средних веков, история нового времени;
- системы, описывающие историю определенной территории: история Европы, история города Минска.

И соответственно, любые возможные пересечения этих трех множеств.

По назначению все исторические системы можно разделить на:

- справочные, которые предоставляют структурированную информацию в требуемой предметной области;
- системы учебного назначения, где кроме структурированного материала есть отдельный комплекс, отвечающий за контроль знаний.
- системы поддержки научных исследований в области истории, которые являются инструментом работы историка.
- системы-гиды – системы поддерживающие экскурсионное сопровождение по городам, музеям.

У всех перечисленных систем есть два основных недостатка:

- невозможность использования знаний из базы знаний одной системы по истории для решения каких-бы то ни было проблем в другой;
- принципиальная несовместимость баз знаний этих систем в виду отсутствия общей онтологии.

Тот факт, что все эти системы оперируют одним и тем же типом знания, дает основания для разработки общих онтологий подобных систем. При онтологическом подходе в проектировании систем в области истории появится возможность интеграции различных систем, а также возможность заимствования необходимых компонентов, которые представлены в одной их систем, и отсутствуют в другой.

Общая онтология исторического знания в качестве многократно используемого компонента позволит ускорить процесс разработки интеллектуальных систем в области истории и обеспечит возможность использования решений из одной системы в рамках другой системы для решения необходимых прикладных задач.

Онтологический подход к проектированию интеллектуальных систем в области истории позволит обеспечить гибкость разрабатываемых систем и возможность организации проектной деятельности таким образом, чтобы эта деятельность была максимально независима при детализации различных предметных областей, и одновременно при этом сохранялась целостность разрабатываемых систем.

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