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ONTOLOGY FOR THE KNOWLEDGE PORTAL ON RADIO ENGINEERING AND TELECOMMUNICATION HISTORY

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The article is devoted to ontology for the knowledge portal on radio engineering and telecommunication history development. We emphasize the ontology for basic portal which consists of eleven classes: “researchers”, “researching techniques”, “sources”, “events”, “organizations”, “geographical location”, “memorial object”, “period”, “scientific result”, “branch of science” and “subject under investigation”. The last three classes are represented as metanotions of portal subject ontology which include 19 first level subclasses and 60 second level subclasses. Inheritance and implication, as well as “class — data” dependences have been determined on the base of classes and subclasses. Thirty most actual associative dependences have been emphasized. The division of large sources (monographs and reviews) into smaller fragments and organization of subclass “quotations” in order to simplify the process of ontology development and to realize the most relevant search are proposed. Set theory tools and “two-level” concept of science and technology historiography as a metascience have been used in the process of formalization.

Introduction. Problem Statement

Nowadays the Internet-related research becomes considerably promoted. Scientific terminology has been widened by such concepts as “semantic Web”, “intellectual networks”; theoretical methodology of scientific and technological knowledge has been extended. In this context we should emphasize the areas of ontological research, which (the majority of experts agrees with it) will form a development basis of the following generations of the Internet including an idea of the semantic Web.

In recent years the Ukrainian scientific centers of Kiev, Kharkov, and Donetsk have been carrying out a number of serious developments in the field of formal computer ontologies [1]. The creation of a united Antarctic research data space [2] at the Institute of Telecommunication Systems of National Technical University of Ukraine should also be ranked among them.

Up to nine different problems are being solved by ontology’s application [3]:

1. Creation and application of knowledge bases;
2. Organization of effective search in databases, information catalogs, knowledge bases;
3. Creation of the reasoners implementing systems;
4. Organization of meaning search in text information;
5. Semantic search in the Internet;
6. Representation of meaning in metadata;
7. Building and application of the general knowledge databases for various intellectual systems;
8. Provision of general terminology for a great number of experts and shared applications;
9. Repeated use of knowledge bases and data stores providing data on technical systems at various stages of their life cycle.

The following problem may be added to the listed ones:

10. Repeated use of data stores providing data on the results of specific scientific research.

The formation of a knowledge portal on the Antarctic research [2], archeology [4], atmospheric aerosols [5] etc. belong to the latter problem. The same problem is developed in the paper.

Unlike the general statement [6], the division into basic and subject ontologies in the problems concerning specific scientific research is made taking into consideration specifics of an object under investigation.

If we concern only science and technology historiography area, then in addition to such traditionally related to the basic ontology classes as RESEARCHERS (persons), SOURCES (publications), EVENTS, ORGANIZATIONS, GEOGRAPHICAL PLACE, it is necessary to add a class RESEARCH METHODS. We use the research methods classification developed by Prof. N. I. Smolenskyi, according to which the descriptive-narrative and biographic methods, as well as the method of terminological analysis [7, 8] are allocated. Recently bibliometric approach [9] also becomes widespread in science and technology historiography; in this connection the three above listed methods are supplemented with a method of bibliometric analysis.

Specifics of such knowledge portal restriction also provokes a division of large sources (SOURCES instances, which can include monographs and reviews on

the portals subject) into smaller fragments (subclass "quotations"). As a result of such division ontology creation becomes simpler and search in the portal becomes more relevant.

Besides, such terms (classes) as MEMORIAL OBJECT and PERIOD are specific for basic ontology for a portal on science and technology historiography.

The metanotions SCIENTIFIC RESULT, BRANCH OF SCIENCE and SUBJECT UNDER INVESTIGATION are traditionally referred to the subject ontology as well as to the basic ontology. They emphasize the most significant sections and subsections in the field of knowledge under consideration (radio engineering and telecommunication development historiography), set typification of subjects under investigation and describe results of scientific activity. These concepts (classes) are collated into the hierarchy of "general — particular" or "part — whole".

Aim of the paper is to develop an ontology for the knowledge portal on radio engineering and telecommunication history.

To achieve this aim the set theory apparatus and the "two-layer" concept of science and technology historiography as metasciences [10] are applied.

The Ontology for Portal

The ontology for knowledge portal is formally represented as a tuple of such kind:

$$O = \langle C, R, T, D, A, F \rangle,$$

where $C = \{C_1, ..., C_n\}$ is a finite nonempty set of classes which describes concepts of some knowledge or problem domain; $R = \{R_1 ... R_m\}$, $R_i \subseteq C \times C$, $R = \{R_T\} \bigcup \{R_P\} \bigcup \{R_A\}$ is a finite set of binary relations defined at classes (concepts): R_T — an ancestral relation, R_P — an inclusion relation ("part — whole"), R_A — a finite set of associative relations; T —a set of standard types of data; $D = \{d_1, ..., d_n\}$ — a set of domains $d_i = \{s_1, ..., s_k\}$, where s_i is a value of standard type of T; $TD = T \bigcup D$ — the generalized type of data including a set of standard types and a set of domains; $A = \{a_1, ..., a_w\}, A \subseteq C \times TD \bigcup R_A \times TD$ — a finite set of the attributes describing properties of concepts C and the relations of R_A, F — a set of restrictions of attribute values of concepts and relations, i.e. predicates like $p_i(e_{i1}, e_{i2})$, where e_{ik} is either an attribute name $(e_{ik} \in A)$, or a constant $(e_{ik} \in td_j$, where $td_j \in TD)$.

The feature of the relation R_T is that in case of inheritance from a parental class its class descendant accepts not only all attributes, but the relations as well. An inclusion relation ("part – whole") R_P is allocated with the property of transitivity, due to this fact it is possible to carry out transitive closure for this relation when searching the objects.

The set of associative relations R_A is defined by an ontology developer. The existence of such relations allows to organize the knowledge portal content retrieval and navigation. An important feature of the R_A relations is that they can have their own attributes specifying relation between arguments [6, 11].

The feature of a task under consideration is the creation of the ontology for a more restricted field of knowledge. One more type of the relations is therefore entered into the ontology — the relations of "class — data" type (see, e.g., [2]). As a result, the ontology is represented as follows

$$O = \langle C, R, R_{CD}, T, D, A, F \rangle,$$

where R_{CD} — the relations of "class — data" type.

Classes, Attributes and Domains

It was stated above that in contrast to the ideology of knowledge portal creation in general a specialized knowledge portal shall be notable for its type and ratio of the basic and subject ontologies. In view of this fact it is expedient to represent a structure of classes of the knowledge portal on radio engineering and telecommunications history in the format of three-level classes: a class itself and two subclasses of the 1st and the 2nd level. In compliance with it, as well as taking into consideration the "two-layer" concept of science and technology historiography as a metascience [10], formal expressions for the class itself and subclasses of the 1st and the 2nd level, respectively, will be represented as follows:

$$C^i, C^{iH},$$
$$C^{i.j}, C^{iH.j},$$
$$C^{i.j.k}, C^{iH.j.k}$$

(where the index H corresponds to the fact that a class or a subclass describes only historiographic aspects of the portal), and the n[th] copies of the corresponding classes and subclasses will be presented as:

$$C_n^i, C_n^{iH},$$
$$C_n^{i.j}, C_n^{iH.j},$$
$$C_n^{i.j.k}, C_n^{iH.j.k}.$$

Let's describe the classes and subclasses of the ontology for the knowledge portal on radio engineering and telecommunication history in details (see Fig. 1).

Class C^1 describes a RESEARCHERS set and contains the following attributes and domains (hereinafter domains are specified in brackets):

Surname,
Name,
Middle name,
Initials,
Country,
Sex (female / male),
Academic rank (without an academic rank / senior staff scientist / associate professor / professor / corresponding member / academician),
Academic degree,
Awards,
Titles of honour,
E-mail,
Office ph.,
Mobile ph.,
Postal address,
Date of birth (year, month, day),
Date of death (year, month, day),
Surname and initials in other languages,
URL.

Subclasses $C^{1.1}$ and $C^{1.2}$ describe sets of technology researchers and historiography researchers respectively.

Class C^{2H} describes a RESEARCH METHODS set and, as it was stated above, it belongs to an element of the basic ontology for the knowledge portal on science and technology historiography. The class and its subclasses do not contain instances; the class description contains only a list of the methods described in affiliated subclasses:

$C^{2H.1}$ — descriptive and narrative,
$C^{2H.2}$ — biographic,
$C^{2H.3}$ — terminological analysis,
$C^{2H.4}$ — bibliometric analysis.

Attributes of the class C^{2H} and its subclasses:
Other names of a method,
Description,
URL,
Date of initiation.

Class C^3 describes a SOURCES set.

The class contains the following attributes and domains:
Bibliographic reference to source,
Source language (Rus. / Ukr. / Eng. / Ger. / Fr. / Spa. / another),
Source type (author's abstract / archival document / biobibliographic index / directive material / thesis / paper / instruction / catalogue or booklet / cartographical publication /monograph or chapter / report / patent or certificate of authorship / preprint / paper / review / manuscript (typescript) / collection / reference book / standard / article / theses / educational and methodical publication / e-resource),
Date of origin,
Date of publication,
Brief summary,
URL.

The only subclass of class C^3 is subclass $C^{3.1}$— Quotations entered according to the reasons mentioned above. This subclass contains two attributes:
Reference to a parental class,
Bibliographic reference to a source with indication of a page number.

Class C^4 describes an EVENTS set. The class contains the following subclasses:
$C^{4.1}$ — events in science and technology,
$C^{4.2}$ — events in historiography.

Class C^4 and its subclasses have the following attributes and domains:
Name of event,
Event start date (year / month / day),
Event expiration date (year / month / day),
Short description of event.

Class C^5 describes an ORGANIZATION set.

The class does not contain subclasses and has the following attributes and domains:
Name of organization,
Type of organization (association / library / military or strategic facility / publishing house / Institute of Academy of Sciences / company / museum / informal organization / branch of scientific research institute / industrial enterprise / university)
Abbreviation,
Description of organization,
Address,
Phone,
Fax,
e-mail,
Date of foundation,
Date of liquidation.

Class C^6 describes a GEOGRAPHICAL LOCATION set. The class does not contain subclasses and has the following attributes and domains:
Place name,
Geographical type (gully / boulevard / bay / mountain / city / valley / cemetery / barrow / monastery / bridge / cape / island / peninsula / settlement / avenue / area / region / river / republic / village / country / street / farmstead),
Name in other languages.

Class C^{7H} describes a MEMORIAL OBJECTS set. The class does not contain subclasses and has the following attributes and domains:
Object name,
Location,
Object type (memorial plate / museum piece / monument or memorial sign / toponym),
Name in other languages.

Class C^{8H} describes a PERIOD set.

The class does not contain subclasses, its periodization is expressed in the class attributes and domains:

Period name,

Period beginning (year, month, day),

Period end (year, month, day).

Class C^{9H} describes a SCIENTIFIC RESULT set. The class and its subclasses do not contain instances, the class description contains only a list of affiliated subclasses:

$C^{9H.1}$ — methodological problems of radio engineering and telecommunication (RaT) development historiography,

$C^{9H.2}$ — problems of technology history,

$C^{9H.3}$ — problems of radio processing history,

$C^{9H.4}$ — problems of research and development work history,

$C^{9H.5}$ — problems of scientific schools history.

Class C^{10H} describes a BRANCH OF SCIENCE set. The class and its subclasses do not contain instances, the class description contains only a list of affiliated subclasses of the 1st and the 2nd level:

$C^{10H.1}$ — groundwork,

$C^{10H.1.2}$ —classical heritage study and analysis,

$C^{10H.1.3}$ — theoretical and methodological works in the field of radio engineering and telecommunication history,

$C^{10H.1.4}$ — states technical policy study,

$C^{10H.1.5}$ — theoretical and methodological bases of teaching RaT development history,

$C^{10H.2}$ — scientific and engineering thought and technology history,

$C^{10H.2.1}$ — RaT general history research,

$C^{10H.2.2}$ — general history research of separate RaT areas development,

$C^{10H.2.3}$ — history of international scientific and technological cooperation in the field of RaT,

$C^{10H.2.4}$ — regional research of RaT directions development history,

$C^{10H.2.5}$ — the history of certain technological facilities, engineering systems, devices,

$C^{10H.3}$ — historical materials on scientific and technical institutions and manufacturing enterprises,

$C^{10H.3.1}$ — research scientific work and development work organization and implementation history,

$C^{10H.3.2}$ — main scientific and technical institutions history research,

$C^{10H.3.3}$ — radio industry general history research,

$C^{10H.3.4}$ — certain organizations and companies history research,

$C^{10H.4}$ —RaT fact ground history,

$C^{10H.4.1}$ — research of science and technology material monuments (their creation and development history, monuments and museum pieces description),

$C^{10H.4.2}$ — research of RaT area museum affairs (structure of museums, search and scientific processing of museum pieces, restoration activities),

$C^{10H.4.3}$ — publication of certain documents and materials, description of certain facts of RaT history,

$C^{10H.4.4}$ — scientists and radio experts epistolary heritage research,

$C^{10H.4.5}$ — autobiographic literature research,

$C^{10H.4.6}$ — scientific and biographic literature (including obituaries) study and replenishment,

$C^{10H.5}$ — RaT history source study basis,

$C^{10H.5.1}$ — RaT development history source study,

$C^{10H.5.2}$ — study and creation of bibliographic and reference books: catalogs, lists of works, thematic indexes, personalia indexes, biographic dictionaries and encyclopedias, chronological indexes, calendars of significant dates, etc.

Class C^{11} describes an OBJECT OF INVESTIGATION set. The class description includes only a list of affiliated subclasses of the 1st and the 2nd level:

$C^{11.1}$ — research, development, tests,

$C^{11.1.1}$ — tests, proving grounds and equipment,

$C^{11.1.2}$ — instrumentations and systems,

$C^{11.1.3}$ — models and modeling,

$C^{11.1.4}$ — designing,

$C^{11.1.5}$ — systems of remote sensing and monitoring,

$C^{11.2}$ — ships and vessels (as carrying objects),

$C^{11.2.1}$ — surface ships,

$C^{11.2.2}$ — submarine vessels and deep-diving submersibles,

$C^{11.2.3}$ — auxiliary vessels,

$C^{11.3}$ — navigation, targeting and control,

$C^{11.3.1}$ — targeting and control,

$C^{11.3.2}$ — navigation,

$C^{11.4}$ — detection and tracking,

$C^{11.4.1}$ — hydrolocation,

$C^{11.4.2}$ — detection and tracking,

$C^{11.4.3}$ — identification and classification of targets,

$C^{11.4.4}$ — radiolocation,

$C^{11.4.5}$ — escort and targeting,

$C^{11.5}$ — electronic warfare,
$C^{11.5.1}$ — protection of radioelectronics,
$C^{11.5.2}$ — location masking,
$C^{11.5.3}$ — suppression of radioelectronics by interference,
$C^{11.5.4}$ — radio-electronic protection of objects,
$C^{11.5.5}$ — reconnaissance by radioelectronics,
$C^{11.5.6}$ — characteristics of radioelectronics,
$C^{11.6}$ — telecommunications,
$C^{11.6.1}$ — communication lines,
$C^{11.6.2}$ — communication networks,
$C^{11.6.3}$ — television,
$C^{11.6.4}$ — cable communication,
$C^{11.6.5}$ — telecommunication,
$C^{11.6.6}$ — the communication theory,
$C^{11.6.7}$ — communication centers,
$C^{11.6.8}$ — information enciphering,
$C^{11.7}$ — radioelectronics,
$C^{11.7.1}$ — antennas and distribution of radiowaves,
$C^{11.7.2}$ — radio-transmitting devices,
$C^{11.7.3}$ — radio-receiving devices,
$C^{11.8}$ — radiotechnologies in medicine and biology,
$C^{11.8.1}$ — EHF-therapy,
$C^{11.8.2}$ — SHF hypothermia,
$C^{11.8.3}$ — intracavitary pH-metry and manometry,
$C^{11.9}$ — radio amateurism,
$C^{11.9.1}$ — radio clubs,
$C^{11.9.2}$ — common radio stations,
$C^{11.9.3}$ — personal radio stations,
$C^{11.9.4}$ — radio sport.

Relations and Attributes

For an ontology under development the following relations and their attributes specifying connection between arguments are important.

Ancestral relations R_T (transfer of attributes and domains of a parental class to an affiliated one) and **inclusions** R_P (establishment of the relations "part — whole") are used in the following classes and subclasses corresponding to them (see Fig. 1):

$$R_{T(C^1)}, R_{P(C^1)} \to R_{T(C^{1.i})}, R_{P(C^{1.i})},$$
$$R_{T(C^{2H})}, R_{P(C^{2H})} \to R_{T(C^{2H.i})}, R_{P(C^{2H.i})},$$
$$R_{P(C^3)} \to R_{P(C^{3.1})},$$
$$R_{T(C^{9H})}, R_{P(C^{9H})} \to R_{T(C^{9H.i})}, R_{P(C^{9H.i})},$$
$$R_{T(C^{10H})}, R_{P(C^{10H})} \to R_{T(C^{10H.i})}, R_{P(C^{10H.i})} \to R_{T(C^{10H.i.j})}, R_{P(C^{10H.i.j})},$$
$$R_{T(C^{11})}, R_{P(C^{11})} \to R_{T(C^{11.i})}, R_{P(C^{11.i})} \to R_{T(C^{11.i.j})}, R_{P(C^{11.i.j})}.$$

Associative dependencies will be studied in the context of attributes which are typical for the ontology under consideration. From 55 possible associative dependencies between classes we will assign 30 most important ones (see Fig. 1):

1. *researcher_method* is used for establishing connection between a researcher and a research method he/she applies

$$R_{A_1} = \left\{C^1 \times C^{2H.i}\right\};$$

2. *author_publication* is used for establishing connection between an author of a publication, and the publication itself, which is an element of the class C^3

$$R_{A_2} = \left\{C^1 \times C^3\right\};$$

3. *researcher_works_in* connects a researcher with an organization he/she represents

$$R_{A_3} = \left\{C^1 \times C^5\right\};$$

4. *researcher_describes_memorial_object* connects a researcher with a memorial object he/she describes

$$R_{A_4} = \left\{C^1 \times C^{7H}\right\};$$

5. *researcher_obtained_scientific_result* connects a researcher with scientific results he/she has obtained

$$R_{A_5} = \left\{C^1 \times C^{9H.i}\right\};$$

6. *author_investigates_branch_of_science* connects a researcher with a branch of science

$$R_{A_6} = \left\{C^1 \times C^{10H.i}\right\} \bigcup \left\{C^1 \times C^{10H.i.j}\right\};$$

7. *author_investigates_object* connects a researcher with an object under investigation

$$R_{A_7} = \left\{C^1 \times C^{11H.i}\right\} \bigcup \left\{C^1 \times C^{11H.i.j}\right\};$$

8. *events_are described_in* connects events with a source, where the events are described

$$R_{A_8} = \left\{C^4 \times C^3\right\} \bigcup \left\{C^4 \times C^{3.1}\right\};$$

9. *issued_in* connects a source (publication) with a publishing house (organization)

$$R_{A_9} = \left\{C^3 \times C^5\right\};$$

10. *memorial_object_is described_in* connects a memorial object with a source, where the object is described

$$R_{A_{10}} = \left\{C^{7H} \times C^3\right\} \bigcup \left\{C^{7H} \times C^{3.1}\right\};$$

11. *period_is_described_in_sources* connects a period and its description in sources

$$R_{A_{11}} = \left\{C^3 \times C^{8H}\right\};$$

12. *branch_of_science_is_described_in_sources* connects a branch of science and its description in sources

$$R_{A_{12}} = \{C^3 \times C^{10H.i}\} \cup \{C^3 \times C^{10H.i.j}\};$$

13. *subject_under_investig._is_described_in_sources* connects a subject under investigation and its description in sources

$$R_{A_{13}} = \{C^3 \times C^{11.i}\} \cup \{C^3 \times C^{11.i.j}\};$$

14. *event_occured_in_organization* connects an organization and the event, which occurred in it

$$R_{A_{14}} = \{C^{4.i} \times C^5\};$$

15. *event_occured_in* connects an event and a geographical location where it occurred

$$R_{A_{15}} = \{C^{4.i} \times C^6\};$$

16. *memorial_object_is_devoted_to_event* connects an event and a memorial object devoted to it

$$R_{A_{16}} = \{C^{4.i} \times C^{7H}\};$$

17. *event_occured_in_period* connects an event and a period, in which it occurred

$$R_{A_{17}} = \{C^{4.i} \times C^{8H}\};$$

18. *event_concerns_object* connects an event and an object under investigation

$$R_{A_{18}} = \{C^{4.i} \times C^{11H.i}\} \cup \{C^{4.i} \times C^{11H.i.j}\};$$

19. *organization_and_memorial_object* connects a memorial object and an organization that took part in its creation

$$R_{A_{19}} = \{C^5 \times C^{7H}\};$$

20. *scientific_result_is_obtained_in_organization* connects an organization and scientific results obtained in it

$$R_{A_{20}} = \{C^5 \times C^{9H.i}\};$$

21. *branch_of_science_is_investig._in_organization* connects an organization and a branch of science investigated in it

$$R_{A_{21}} = \{C^5 \times C^{10H.i}\} \cup \{C^5 \times C^{10H.i.j}\};$$

22. *object_is_investigated_in_organization* connects an organization and an object under investigation which is being studied in it

$$R_{A_{22}} = \{C^5 \times C^{11H.i}\} \cup \{C^5 \times C^{11H.i.j}\};$$

23. *memorial_object_is_located_in* connects a memorial object and its geographical location

$$R_{A_{23}} = \{C^6 \times C^{7H}\};$$

24. *subject_under_investigation_is_located_in* connects an object under investigation and its geographical location

$$R_{A_{24}} = \{C^6 \times C^{11H.i.j}\};$$

25. *memorial_object_is_created_in_period* connects a memorial object and a period when it was created

$$R_{A_{25}} = \{C^{7H} \times C^{8H}\};$$

26. *memorial_object_is_dedicated_to_object* connects a memorial object and an object under investigation to which memorial object is dedicated

$$R_{A_{26}} = \{C^{7H} \times C^{11H.i.j}\};$$

27. *object_under_investig._is_created_in_period* connects an object under investigation and a period of its creation

$$R_{A_{27}} = \{C^{8H} \times C^{11H.i.j}\};$$

28. *scientific_result_is_obtained_in_branch_of_sci.* connects a branch of science and obtained scientific results

$$R_{A_{28}} = \{C^{9H.i} \times C^{10H.i}\} \cup \{C^{9H.i} \times C^{10H.i.j}\};$$

29. *scientifical_result_is_obtained_concerning* connects an object under investigation and obtained scientific results

$$R_{A_{29}} = \{C^{9H.i} \times C^{11H.i}\} \cup \{C^{9H.i} \times C^{11H.i.j}\};$$

30. *branch_of_science_investigates_object* connects a branch of science and an object under investigation

$$R_{A_{30}} = \{C^{10H.i} \times C^{11H.i}\} \cup \{C^{10H.i} \times C^{10H.i.j}\}.$$

The associative dependencies defined above reflect only the main binary connections and may be transitively closed onto another ontology objects.

The "class — data" relations reflect the connection of the class 3 C — SOURCES and its subclass 3.1 C— Quotations with a set of content elements of S portal — SOURCES and Cit — Citations and may be represented as

$$R_{CD} = \{C_i^3 \times S_i\} \cup \{C_j^{3.1} \times Cit_j\}.$$

Conclusion

The developed ontology can serve as a tool for a knowledge portal creation, both in the field of radio engineering and telecommunications history, and in the field of history of other areas of science and technology historiography (in the latter case it is necessary to use the developed elements of the basic ontology with the appropriate addition of the subject ontology elements).

For realization of knowledge portals some software products designed for the solution of such tasks can be used, for example, a software shell for creation of knowledge portals based on ontologies [12] developed by A. P. Yershov Institute of Informatics Systems, Siberian Branch of the Russian Academy of Sciences. This software product has intuitively obvious interface and search service.

Further development of the research in this direction will be connected with realization of the knowledge portal on the history of radio technologies development in the Crimea.

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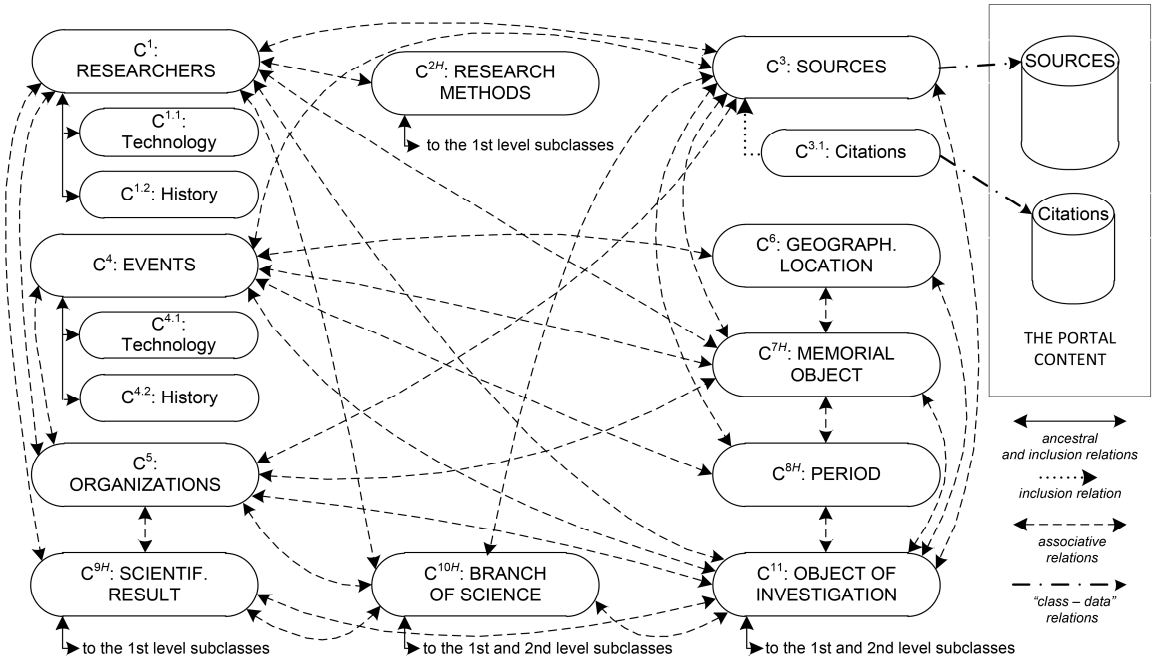

Fig. 1. The basic ontology for the knowledge portal on radio engineering and telecommunication history