DESIDOC Journal of Library & Information Technology, Vol. 33, No. 4, July 2013, pp. 295-299

Domain Visualisation Using Concept Maps: A Case Study

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ABSTRACT

In the present study, an attempt has been made to visualise relationships among concepts using concept maps. Identification and categorisation of relationships is a fundamental process in effective knowledge organisation and retrieval. This cognitive process of identification of relationships can be facilitated by generating concept maps. Basic concept maps have been developed for an interdisciplinary subject domain; accelerator driven systems (ADS). These concept maps can be used as aids for conceptualisation in a domain ontology.

Keywords: Domain visualisation, domain ontologies, concept maps, interdisciplinary subjects, associative relationships, accelerator driven systems, INIS database

1. INTRODUCTION

In the area of knowledge organisation & retrieval (KO&R), traditionally, indexing tools such as classification schemes and thesauri have been used, to organise, store and retrieve domain knowledge. It's only recently, that ontologies, particularly domain ontologies[1] are being researched by information scientists as alternatives, to organise the vast amount of information on the web and make it available to their clientele, through various web-based information services.

The basic difference between conventional KO&R tools and ontologies is the ease with which relationships between keywords, either free-text or controlled can be specified. For instance, in a thesaurus, only three types of relationships can be expressed: Hierarchical, Equivalence, and Associative. Some basic differences between a thesaurus and a domain ontology are given in Table 1.

Through domain ontologies, Associative, Lateral or Related term relationships[2] can be better expressed. This is particularly important in developing domain ontologies in fast growing, interdisciplinary subject areas, where related term relationships are very significant for search and subsequent retrieval of information. Thus domain ontologies, tailored to the KO&R needs of a particular organisation or user community, can be specifically created by ontology developers. The process of conceptualisation is at the core of developing domain ontologies. Conceptualisation is done through the identification and interlinking of keywords/descriptors in the selected domain. A keyword in combination with other keywords semantically related to it is transformed into a more comprehensive 'concept'. Using theoretical principles of classification and facet analysis[3], keywords can be converted into semantically-rich concepts through generation of one-to-many correspondences or linkages between them. These associations or linkages are developed according to user requirements by the ontology developers. Thus, every domain ontology is unique since it represents a part of the reality of the universe conceptualised by it. The concepts can then be grouped into clusters for search and retrieval, based on user requirements.

Concept mapping is an intellectual process wherein basic knowledge about the domain as well as a deep understanding about the needs of the user community is required. As visual aids or graphical tools in the process of conceptualisation, Concept maps[4-6] can be used to organise domain knowledge. They offer an excellent means of conceptualising, visualising and mapping the entire domain, so that a user can easily follow the linkages and get a better understanding about the domain.

2. OBJECTIVES

A case study was undertaken to develop concept maps in the area of accelerator driven systems (ADS). These concept maps can form the basis of a domain ontology on ADS. The ADS is an

Received 20 February 2013, online published 22 July 2013

Table 1. Basic differences between a thesaurus and a domain ontology

S. No.	Thesaurus	Domain ontology
1.	A controlled vocabulary, consists of descriptors, that have been authorised to represent the subject contents of a resource	Incorporates both free index terms as well as a controlled vocabulary. Along with a listing of terms (not necessarily alphabetical), a set of inference rules are also incorporated in ontology that allow the system or agent, to make inferences about the represented knowledge, to identify connection across resources, or to discover new knowledge.
2.	Rigid	Totally flexible
3.	Unidimensional	Multidimensional
4.	A thesaurus can either be manually created or machine-generated	Ontology can only be created using special software programmes.
5.	Use of a vocabulary is binding, on both the knowledge managers and knowledge searchers	Enables sharing of common understanding of the structure of information among people, allows free use of terms
6.	Controlled vocabulary terms are mostly restricted to domain knowledge	Ontology incorporates both domain knowledge and operational knowledge
7.	Built on the concept of literary warrant. Terminological concepts and their relationships (including incorporation of new terms) are purely based on Literary Warrant	Literary Warrant as well as other problem solving practical tools, devices and elements are used. Terminological concepts as well as other characteristics and properties are defined in the purpose of the ontology and may be shifted to new slots, or deleted from existing slots, depending on emerging applications.
8.	Only qualified descriptors are used both during storage as well as retrieval	Though a vocabulary is an inherent part of an ontology, other concepts and terms are freely used, both during storage and retrieval, as well as for other applications
9.	All descriptors in a thesaurus are slotted or assigned to mutually exclusive classes	Ontology does not create classes into which domain sources are slotted. Rather, ontology defines a set of elements (or slots) as appropriate, represent the physical and conceptual features of a resource.
10.	Superordinate and subordinate classes are determined solely by the knowledge domain or the subject field.	Superordination and subordination of classes mostly decided by the Ontology developer depending on the purpose of the Ontology.
11.	There are only three kinds of relationships between any two descriptors in a thesaurus: Hierarchical, Equivalence and Associative	The relationships between classes or properties are potentially polyhierarchical; a class may be a subclass of one, two, three or more superordinate classes
12.	Descriptors in a thesaurus exist purely at a conceptual level.	Terms or classes in ontology can be assigned values. Ontology consists of a catalogue of controlled and well-defined slots that are meaningless when applied to a resource, unless they are paired with an appropriate value.

interdisciplinary and multidisciplinary subject domain. It is a part of the broad area of physics, especially particle physics and atomic and nuclear physics. It also includes nuclear and reactor engineering, reactor fuels and radioactive waste management. Basically, an ADS is a hybrid system. It combines a particle accelerator, particularly a high-power proton accelerator with a subcritical nuclear reactor to accomplish various tasks. R&D work on ADSs assumes importance due to their inherent safety features, their use of thorium as fuel and their non-proliferative advantage.

3. METHODOLOGY

To develop the concept maps, concepts on ADS needed to be identified and harvested. For this purpose, the International Nuclear Information System (INIS) database was selected. This is a comprehensive international database in the area of nuclear science and technology for peaceful uses of atomic energy. Query formulations on this database (2008-2012) resulted in the retrieval of 739 records on ADS. Complete records, each containing data fields like author, corporate author, title, publication details, language, abstract were downloaded. Descriptors (indexer-assigned) (10-15 for each bibliographic record) were downloaded separately and these were used in developing the concept maps. A total of 1777 unique descriptors on ADS were harvested. High ranking, major descriptors (with a threshold level of more than 10, numbering 187) were selected.

The following steps were taken:

(a) Identification and downloading of descriptors (a total of 1777) and additional keywords/ concepts on ADSs (a total of around 300) from the abstracts of the downloaded records using content analysis.

(b) Numerical listing of the selected descriptors on ADSs, based on frequency count and selection of those with a threshold level of 10 and above. A partial list of high-ranking descriptors on ADS is given in Table 2.

(c) Developing a semantic network of selected descriptors and keywords on ADSs through the creation of EXCEL files

All the descriptors and keywords were linked to each other through subordinate, superordinate and affinitive relationships. A sample of one of the EXCEL files is shown in Table 3.

Table 2. High ranking descriptors on accelerator driven systems (INIS database 2008-2012)

Frequency of occurrence	Descriptors
123	spallation-
109	neutron-sources
103	design-
101	proton-beams
84	transmutation-
83	subcritical-assemblies
79	fast-reactors
76	neutrons-
72	actinides-
69	lead-
66	radioactive-wastes
64	nuclear-fuels
60	quantum-chromodynamics
58	protons-
55	cross-sections
54	fuel-cycle
53	liquid-metals
51	reactor-cores
49	neutron-flux
48	computerised-simulation

(d) Developing core clusters on the basis of expert advice

Certain descriptors were identified as core descriptors and clusters were developed around them through the generation of one-to-many correspondences or linkages using the information from the Excel files. These descriptors were:

1. Accelerators
2. Subcritical assemblies
3. Targets
4. Transmutation
5. Nuclear energy
6. Spallation

The ADS is a comparatively new area of R&D, which gained world-wide attention in 1995, due to the Nobel Prize winning work of Dr Carlo Rubbia. Rapid advances in the field from 1996 onwards resulted in several publications. Descriptors of the INIS thesaurus proved inadequate to map the

Table 3. A sample of the interlinked EXCEL file of keywords/descriptors on ADS

Keyword	Superordinate	Subordinate	Affinitive
accelerator-breeders			accelerators-; breeder-reactors; breeding; fissionable-materials; nuclear-fuels
accelerator-driven-transmutation	transmutation		accelerator-breeders; accelerators; radioactive-waste-processing
accelerator-facilities		target-chambers	accelerators-; beam-dumps; beam-monitors; laboratory-equipment; reaction-product-transport-systems
accelerators		coherent-accelerators; collective-accelerators; cyclic-accelerators; electrostatic-accelerators; heavy-ion-accelerators; linear-accelerators; meson-factories; particle-beam-fusion-accelerator	acceleration; accelerator-breeders; accelerator-driven-transmutation; accelerator-facilities; beam-dumps; beam-dynamics; beam-separators; impact-fusion-drivers; isotope-production; particle-boosters; storage-rings; targets; target-chambers

Table 4. Partial list of additional keywords/concepts as identified from abstracts (INIS database 2008-2012)

AAA, Advanced Accelerator Applications aka AFCI (Advanced Fuel Cycle Initiative)
ABC, Accelerator Based Conversion (of Plutonium) (with 2 blanket regions; inner fast and outer thermal) (subproject of ADTT) under BNL
ABR, Actinide Burning Reactor
AD-RCNPS, Accelerator driven radiation clean Nuclear Power System Concept (China)
ACS, Above Core Structure (component of ADS)
ACS, Accelerator Coupled System for actinide transmutation
ACWL, Argonne Continuous Wave Linac (earlier known as CWDD)
ADAPT, Accelerator Driven Assembly for Pu Transmutation of BNL
Accelerator current
ACCELERATOR DESIGN CONCEPTS (Major Concepts)
ACCELERATOR SYSTEMS AND COMPONENTS (Major Concepts)
ACCELERATOR OPERATIONS AND SYSTEMS MODELING (Major Concepts)
AD-GT-MHR + accelerator subcritical GH-MHR for Pu incineration Accelerator Driven Gas Turbine Modular Helium cooled Reactor
AD-SPR, An accelerator driven sub-critical system based on a swimming pool reactor
ADC, Accelerator Driven Core (along with fusion neutron source are proposed as external neutron sources for fission products transmutation in SCNES)
ADEP, Accelerator Driven Energy Production (subproject of ADTT) comprises five subsystems:
(1) Target/blanket primary system,
(2) After-heat removal system,
(3) Off-gas collection system,
(4) Fuel salt clean-up system, and
(5) Waste streams
ADMAB, Accelerator Driven Minor Actinide Burner (OECD/NEA/NSC)
ADONIS, A precursor of MYRRHA (Belgium) (under ADT)
ADPT, Accelerator Driven Particle fuel Transmuter of BNL

growing field. Therefore to make the concepts more comprehensive, several keywords were identified from the abstracts of the downloaded records. These were very important to the process of conceptualisation. A partial list of such keywords starting with Alphabet A is given in Table 4.

(e) Creation of concept maps for each of the selected core descriptors

It would help in visualising and mapping the domain of ADS. These maps were developed using the CMap Tools Knowledge Modeling Kit (CMap Lite). This is a freely available software and has been developed by the Florida Institute of Human & Machine Cognition (IHMC), a non profit institute. Concept maps generated for each of the selected core descriptors on ADS are shown in Figs. 1-6.

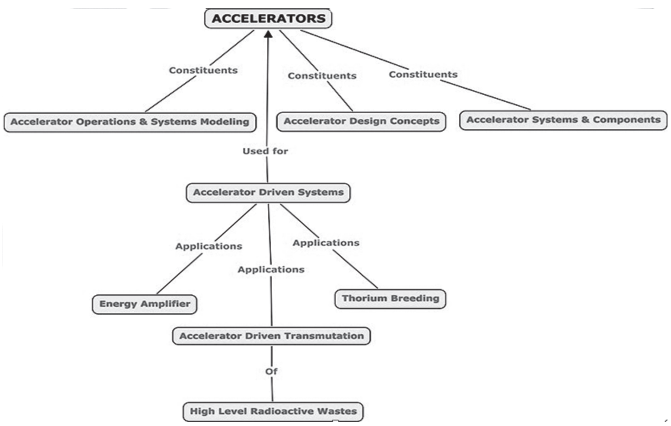

Figure 1. Basic concept map on accelerators.

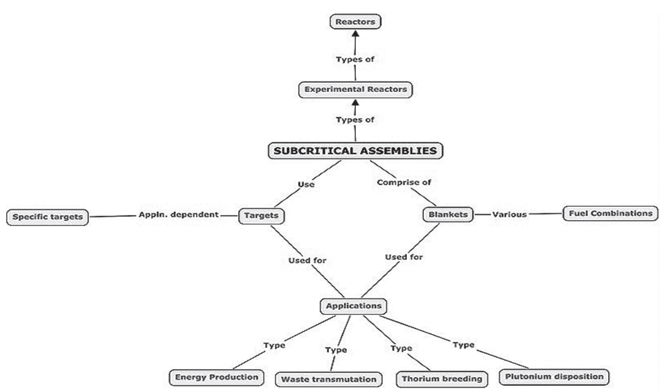

Figure 2. Subcritical assemblies.

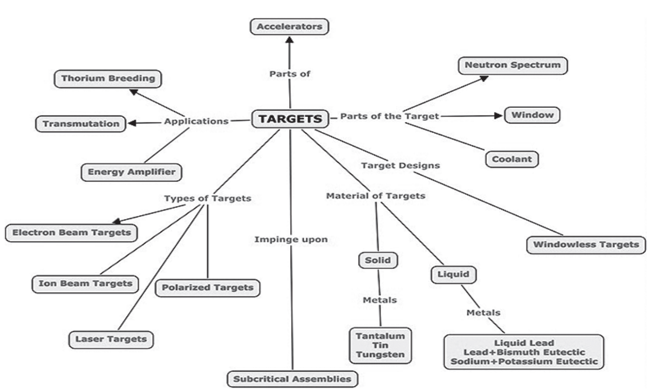

Figure 3. Targets.

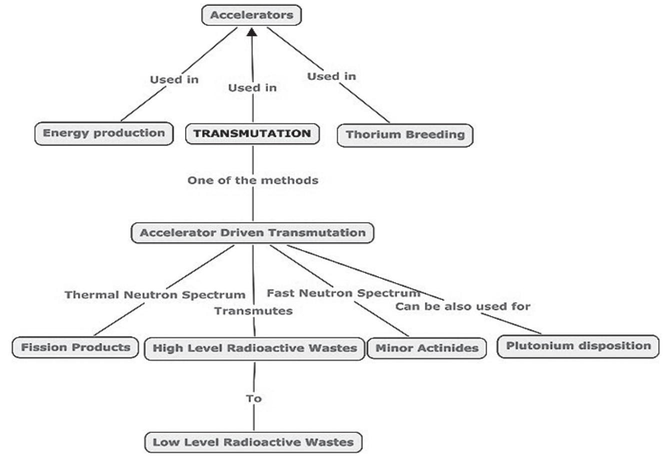

Figure 4. Transmutation.

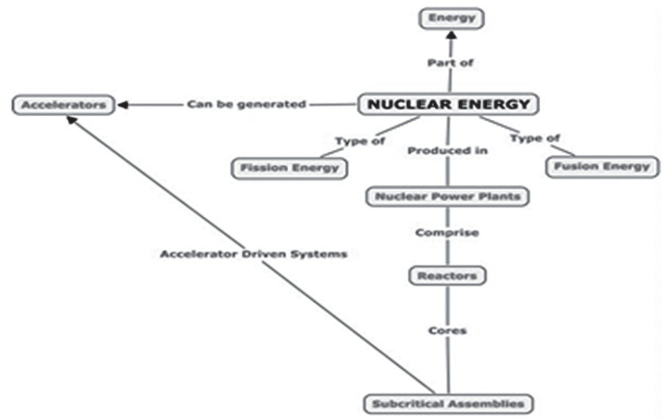

Figure 5. Nuclear energy.

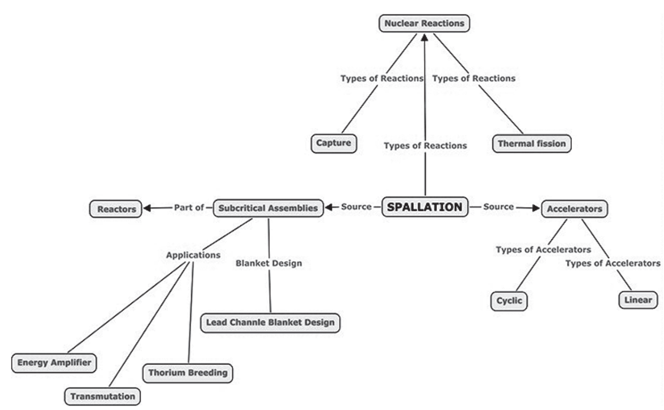

Figure 6. Spallation.

4. RESULTS AND CONCLUSIONS

Each of the six selected core descriptors is in turn, linked with other descriptors both from the thesaural word block as well as from the additional keywords identified from the abstracts. Thus, a compact, basic concept map of the entire domain of ADS can be developed. The ADS can be used for various applications such as Energy production, Waste transmutation or Thorium breeding. The major concepts on ADS in general are Accelerators, Subcritical Assemblies, Targets, and Spallation. The concept maps on these terms, can be used as basic ontology modules for developing more specific domain ontologies. In the present case study, concept map on energy production can be linked with the four major concepts to develop a unique domain ontology on energy production and similarly for waste transmutation. Domain ontologies are very flexible and can be developed in the form of several reusable modules.

The INIS thesaurus, which is the most comprehensive vocabulary control tool in nuclear science and technology, is very broad in scope to represent an interdisciplinary narrow domain like ADS. Developing a domain ontology becomes necessary for harnessing latest information on the subject. Domain visualisation which is one of the first steps in developing a domain ontology, becomes easier through detailed concept maps. New linkages between concepts can be developed and previous associations can be removed on the basis of literary warrant and institutional requirements. Representation of associative term relationships is crucial for interdisciplinary domains. These relationships have the potential of substantially enhancing the search and retrieval processes and are thus the backbone of a domain ontology.

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