© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

ER Model Transformation Using Conceptual Modelling With Description Logic

Vandana M. Patil

Research Scholar, Department of Information Technology, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India

ABSTRACT

Description logic (DL) is a language for knowledge representation which is used to represent the terminological knowledge of an application domain in a structured and well-understood way. Two important features of DL are expressivity and decidability. Description Logics use two types of data structures for representing knowledge viz T-Box and A-Box. T-Box stores the basic terminologies of the application domain whereas A-Box consists of the assertions resulted from inference. Description Logics use two types of inference patterns: classification of individuals and classification of concepts. The process of inference is called as Reasoning. There are several types of reasoning. The reasoning procedures used in DL are Decision Procedures. The purpose of this paper is to understand the basic issues involved in conceptual modeling using DLs. We briefly review the basics of DL along with its architecture, syntax and semantics of DL. Then we will see how we can model a real world application using DL at conceptual level.

Keywords: Description Logics, knowledge representation language, reasoning, decision procedures Introduction

I. INTRODUCTION

A. Knowledge Representation

Knowledge representation is crucial in AI. This is because problem solving using AI requires lots of knowledge. Efficiency of problem solving depends upon how the knowledge is represented and manipulated. Knowledge must be represented efficiently, and in a meaningful way because it would be impossible (or at least impractical) to explicitly represent every fact that may be needed. The knowledge should be represented such as new facts can be inferred properly from existing knowledge. However, the representation language should achieve a tradeoff between inferential power (what we can infer) and inferential efficiency (how quickly we can infer it).

- KR languages features-
  - It should allow to express knowledge
  - It should support inference
  - It should have clear, well defined syntax and semantics.
  - The representation language should achieve a tradeoff between inferential power (what we can infer) and inferential efficiency (how quickly we can infer it) [1].

B. Description Logic

Description Logic is a knowledge representation language which allows the structural representation of the given knowledge with all the desired features listed above alongwith high expressivity and decidability. It allows user to represent queries in very effective way since it has very easy and simple syntax. It also provides many advantages over conventional languages. Hence it is very interesting to learn such language and to model some applications using it [1,2].

- DL uses two types of inference patterns
  1. Classification of individuals
  2. Classification of concepts

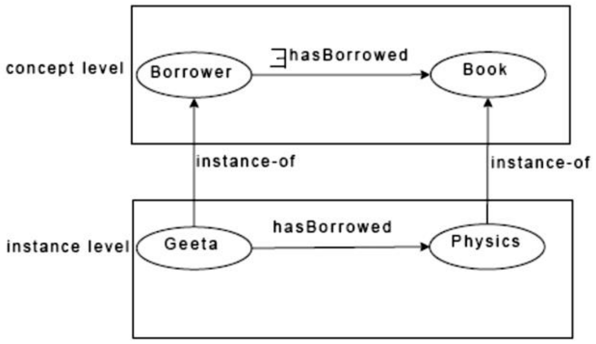
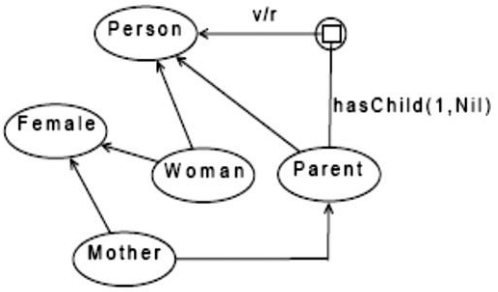


Figure 1. Classification of individuals

- An example of network representation



C. Syntax of DL

- Syntax refers to rules for writing sentences in a language.
- The syntax of DL consists of -
  - A set of unary predicates symbols which denote concept names.
  - A set of binary relation or predicates which denote role names.
- A recursive definition for defining concept terms from concept name and role names using constructors.

D. Semantics in DL

Semantics are defined by interpreting concepts as set of individuals and roles as pair of individuals.Semantics of non-atomic concepts and roles are defined in terms of atomic concepts and atomic roles respectively using recursive definition.Semantics is given by means of interpretation I that consists of a non-empty set ΔI (the domain of interpretation) and an interpretation function(.I) which assigns to every atomic concept A a set AI ΔI and every atomic role R a binary relation RI ΔI [1].

E. Notations in DL

A, B - atomic concepts

C, D - concept description

R, S - roles and

f, g - attributes

m, n - non-negative integers individuals are denoted by letters a, b. This convention is followed when defining syntax and semantics and in abstract examples. In concrete examples following conventions are used:

1) Concept names start with an uppercase letters followed by lowercase letters e.g. Human, Male.
2) Role names start with lowercase letters e.g. hasChild,marriedTo.
3) Individual names are all uppercase. e.g. CHARLES, MARY.

F. Notations in Description Logic[1]

Constructor	Syntax	Semantics
concept name	A	$A^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
top	$\top$	$\Delta^{\mathcal{I}}$
bottom	$\bot$	$\emptyset$
conjunction	$C \sqcap D$	$C^{\mathcal{I}} \cap D^{\mathcal{I}}$
disjunction ($\mathcal{U}$)	$C \sqcup D$	$C^{\mathcal{I}} \cup D^{\mathcal{I}}$
negation ($\mathcal{C}$)	$\neg C$	$\Delta^{\mathcal{I}} \setminus C^{\mathcal{I}}$
universal	$\forall R.C$	$\{x \mid \forall y : R^{\mathcal{I}}(x,y) \to C^{\mathcal{I}}(y)\}$
existential ($\mathcal{E}$)	$\exists R.C$	$\{x \mid \exists y : R^{\mathcal{I}}(x,y) \wedge C^{\mathcal{I}}(y)\}$
cardinality ($\mathcal{N}$)	$\geqslant n\ R$	$\{x \mid \sharp\{y \mid R^{\mathcal{I}}(x,y)\} \geq n\}$
	$\leqslant n\ R$	$\{x \mid \sharp\{y \mid R^{\mathcal{I}}(x,y)\} \leq n\}$
qual. cardinality ($\mathcal{Q}$)	$\geqslant n R.C$	$\{x \mid \sharp\{y \mid R^{\mathcal{I}}(x,y) \wedge C^{\mathcal{I}}(y)\} \geq n\}$
	$\leqslant n R.C$	$\{x \mid \sharp\{y \mid R^{\mathcal{I}}(x,y) \wedge C^{\mathcal{I}}(y)\} \leq n\}$

II. METHODS AND MATERIAL

A. DL Architecture

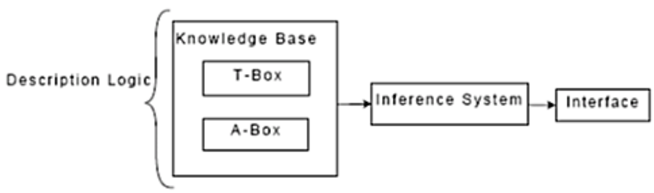


Figure 2. DL architecture

DL knowledge base consists of two components [1,3]:

1. T-Box : A set of terminological axioms.
2. A-Box : A set of assertional axioms

1. T-Box
   - Set of terminological axioms
   - Terminological axioms are of two types-
     - Inclusion axioms e.g. ⊆ D
     - Equality axioms e.g. C ≡ D

2. A-Box
   - Set of assertions
   - Two types of assertions-
     - Concept assertions: Given as C(a) i.e.a belongs to C.e.g. Book(Computer Basics)
     - Role assertions :Given as R(b,c) i.e. which states that c is the filler of role R for b.e.g. hasManager(John,Steve)

B. Conceptual Modeling

"Conceptual Models" offer more expressive facilities for modeling applications directly and naturally, and for structuring information bases. The conceptual model contains a formal description of the concepts, the relationship between concepts, and information requirements. Conceptual Models play an important role in variety of areas viz

- Artificial Intelligence It requires the conceptual models built up using some knowledge representation language to represent the human knowledge to work intelligently.
- Database System design It uses the conceptual models as its initial phase of development which determines the information needs of users and then further converted into physical implementation schema. e.g. ER models.
- Software Development In this, requirements model is used as during the initial requirements acquisition stage. This model describes the relationship of the proposed system and its environment. Here the environment is the conceptual model.
- OOMD In this, the software components(classes/objects) are viewed as models of the real world entities.

One important aspect of conceptual modeling is the identification of "Abstraction mechanisms" which allows development of large models by abstracting details initially and then introducing them in stepwise and systematic manner. The abstraction mechanisms are-

Aggregation Thinking of objects as wholes, not just a collection of their attributes.

Classification Abstracting away the detailed differences between individuals, so that a class can represent the commonalities.

Generalization Abstracting the commonalities of several classes into a superclass.

An important benefit of abstraction in conceptual modeling is that it results in structured information model which is easy to build and maintain [4].

1. Conceptual Modeling with DL

Conceptual Modeling Methodology

Main steps of modeling are-

- Identify the individuals in the desired application domain.
- Enumerate concepts that group these values.
- Distinguish independent concepts from relationship-roles.
- Develop a taxonomy of concepts.
- Identify each individual which are of interest in all states of the application domain.
- Systematically search for part-whole relationship between objects, creating roles for them.
- Identify other properties of objects and then general relationships in which they participate.
- Determine local constraints involving roles such as cardinality constraints and value restrictions.
- Determine more general constraints on relationships such as those which can be modeled by sub-roles.
- Distinguish essential from incidental properties of concepts as well as primitive from defined concepts [1,4]

2. Elementary Description Logic Modeling

Conceptual Modeling using DL uses the object centered view of the world where each real time entity is viewed as individual object, object with commanalities are grouped into classes and objects are related with each other through relationships. In DL, the classes are modeled as 'Concepts' and binary relationships are modeled as 'Roles' and 'Attributes'. For every application domain, there are some obvious classes are there. These classes are modeled as primitive or atomic Concepts in DL. Some classes are derived from base classes i.e. inherited. The inheritance is modeled using the "Subsumption Relationship" between the classes. The base class is called as 'Subsumer' and the derived class is called as 'Subsumee'. The subsumption is the basic inference on concepts in DL and is given by- C ⊑ D

The derived classes are modeled as defined concepts and are defined using the concept definition. The concept definition specifies the necessary and sufficient conditions for concept membership.

e.g.-Mother ≡ Woman ⊓∃ hasChild.Person

The subsumption is given as-
Mother ⊑ Woman
Besides this,there are other operators in DL which are very useful to capture the important aspects of the subclass relationships among the object in the UoD.
Those are given below:
1. Disjunction operator
2. Conjunction operator
3. Negation operator

Negation operator It is used to model the disjoint subclasses. It is useful when the superclass is specialized into its subclasses in such a way that the subclasses are totally disjoint. e.g. Superclass Person is specialized into two disjoint subclasses such as Male and Female.
Male ≡ ¬ Female

Disjunction operator It is used to model the relationship between the disjoint subclasses which fully covers the superclass. e.g. going with the same example given above, we can represent the superclass as disjunction of the two disjoint subclasses-
Person ≡ Male ⊔ Female

Conjunction operator It is used to model the combination of two expressions into single expression.e.g if we want to define the conceptWoman, we have to specify two conditions i.e. Person and Female. This is written in DL as-
Woman ⊑ Person ⊓ Female

Concept Constructors

The things,like kinds of values that can fill roles, and limit on the number of role fillers, are modeled via concept constructors in DL. The concept constructors are as follows-

- the
- all
- at-most
- at-least
- same as
- non-overlapping
- test
- counting

1. **the** specifies that the attribute has one and only one value.
   e.g. isbnNr
2. **all** specifies that all individuals should satisfy the given condition.
   e.g. Human≡ Animal ⊓ all hasParent Human
3. **at-most** specifies the maximum value allowed for the given attribute.
   e.g. Mother1≡Mother⊓ at-most 3 hasChild
4. **at-least** specifies the minimum value allowed for the given attribute.
   e.g. Borrower ≡ all hasBorrowed Book ⊓ at-least 1 hasBorrowed.
5. **same as** specifies that two roles have the same value.
   e.g same as principal univBOS
6. **test** is used to check the valid states of the world.
   e.g test(date-after(dueDate issueDate) will invoke the function date-after on the passed attributes and check that the first is after the second or not.

➢ Support for enumeration

We can define enumerated set of value for a attribute of a concept using the constructor the and one-of.
e.g. Book ⊑ (the section(one-of 'student 'reference))
Then we can define corresponding subconcepts as follows:

- ✓ ReferenceBook≡Book⊓ (fills section 'reference)
- ✓ Book1≡Book⊓ (fills section 'section)

➢ Modeling Relationships

Binary relationships are modeled using roles and attributes. There are a number of special constraints on relationships such as : cardinality constraints state the

maximum and minimum number of objects that can be related via a role, domain constraints state the kinds of objects that can be related via a role and inverse relationships between roles. These things are modeled in DL using the role constructors. Cardinality constraints are modeled using the role constructors such as the,at-most,at-least,all. Domain constraints are modeled via the role constructor the and all. Inverse relationships are modeled using the role constructor inverse.
e.g.

- Borrower ≡ (and(all hasBorrowed Book)(at-most 2 hasBorrowed))
- Mother ≡ (and Woman (at-least 1 hasChild))
- Book ≡ (and (the hasTitle String) (all hasAuthor Person))
- lentTo≡ ¬ hasBorrowed

➢ **Views**

The views can even be maintained in DL. This is done by defining a new concept
which will have some attributes to specify the view. e.g. a view MaterialOnLoan
will have the attribute such as dueDate and nrOfRenewals [1,3,4].

C. ER Modeling and Description Logic

In this section, first ER models are introduced shortly, then transformation of ER schemas into DL knowledge bases is visited.

1. ER Models

ER model is the most commonly used data model for pictorial representation of the databases. The basic elements of the ER model are the entities, relationships and attributes. An entity denotes a set of objects, called as instances, which have common properties. Elementary properties are modeled through attributes, whose values belong to one of the predefined domains such string, integer etc. Properties that are due to the relations to other entities are modeled through the participation of the entity in relationship. A relation denotes a set of instances, each of which represents an association among different entities.

➢ **Specialization**

An entity B is said to be a specialization of other entity A, if all instances of B are also instances of A but vice versa is not true. This situation is modeled through IS-A relationship in ER models. Relationships can be related via IS-A. This induces an inheritance of attributes of an entity to its subentities, and of roles to its subroles.

➢ **Cardinality Constraints**

Cardinality constraints are used to an ER model to specify the number of times each instance of an entity is participating in the relationship. Such constraints are used in restricted form, where the minimum cardinality is either 1 or 0 and the maximum cardinality is either 1 or ∞.

2. Formal description of ER schema

An ER schema S is constructed with disjoint sets of entity symbols, relationship symbols, ER-role symbols, attribute symbols and domain symbols. Each domain D has an associated predefined basic domain DBD. For each entity symbol, a set of attribute symbols is defined, and to each such a attribute a unique domain symbol is associated. A relationship symbol of arity n has n associated ER-role symbols, each with an associated entity symbol, and defines a relationship between these entities. The cardinality constraints are represented by two functions cmin S and cmaxS. IS-A relationship between entities and between relationships are modeled by means of binary relations ≼S. The semantics of an ER schema can be given by specifying which database states are consistent with the information structure represented by the schema. Formally a database state B corresponding to an ER Schema S is constituted by a nonempty finite set ∆B,assumed to be disjoint from all basic domains, and a function ·B that maps-

- every domain symbol D to the corresponding basic domain DBD.
- every entity E to a subset EB of ∆B
- every attribute A to a set EB ⊆ ∆B × ∪D2DS DBD.
- every relationship R to a set RB of labeled tuples over ∆B.

C. Transforming ER schemas into DL knowledge base

The transformation of ER schemas to DL knowledge base is achieved by defining a translation function Φ and then establishing correspondence between legal database states and models of the derived knowledge base. The knowledge base Φ(S) derived from ER schema S is defined as follows:

- The set of atomic concepts of Φ(S) consists of the set of entity and domain symbols in S.
- The set of atomic relation of Φ(S) is obtained from the set of relationship and attribute symbols in S. More specifically-
  – each symbol R in S, denoting a relation of arity n, is mapped into a symbol PR in Φ(S), denoting a relation of arity n.
  – each attribute symbol A in S is mapped into a symbol PA in Φ(S), denoting a relation of arity 2. Thus, each instance of the relation PA is a tuple such that its first component corresponds to an entity, while the second component denotes an element of the concept corresponding to the attribute domain.
- The set of inclusion axioms of Φ(S) consists of the following elements:
  – for each pair of entities E1, E2 such that E1 ≼S E2, the inclusion axiom E1 ⊑ E2
  – for each pair of entities R1, R2 such that R1 ≼S R2, the inclusion axiom PR1 ⊑ PR2
  – for each attribute A with domain D of entity E, the inclusion axiom E ⊑ (∀[$1](PA⊓ ($2:D)))⊓=1[$1]PA
  – for each relationship R of arity n with ER-roles U1,......,Un in which each Ui is associated with the entity Ei, the inclusion axiom PR ⊑ ($ R(U1):E1)⊓.....⊓($ R(Un):En)
  – for each ER role U of relationship R associated with entity E, with cardinality constraints m = cminS(U) and n= cmaxS(U),

∗ if m⊭ 0, the inclusion axiom E ⊑≥ m[$ R(U)]PR

∗ if n⊭ ∞, the inclusion axiom E ⊑≤ n[$ R(U)]PR [1].

D. Example

Following is the transformation of the ER model in fig.4.1 into equivalent knowledge base :

worksFor ⊑ ($1:Employee) ⊓ ($2:Dept)
manages ⊑ ($1: Employee) ⊓ ($2:Dept)
Sales ⊑ Dept

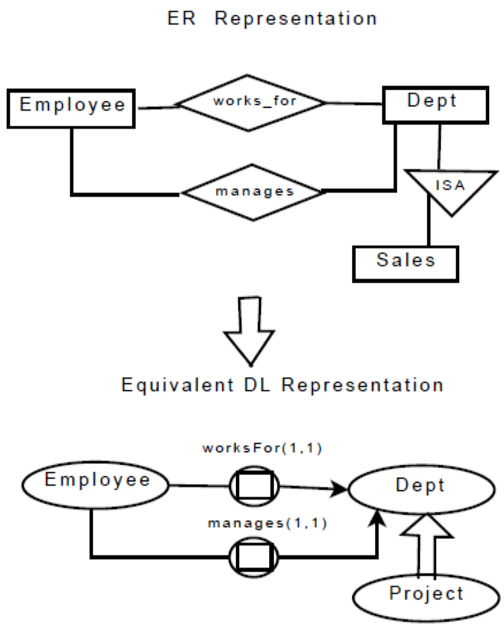


Figure 3. Transformation of ER model to DL model

D. Conceptual Model For Library System

1. Knowledge Base

Table 1. Knowledge base for library system

Primitive Concepts	Concrete Concepts	Roles
Person	staff student teaching non-teaching	hasAdmitted hasAppointed hasBorrowed belongsTo
Material	Book CDs Journals	purchasedBy hasAttribute isIssued hasName hasType
Organization	College	hasPurchased hasDepartment hasPrincipal hasLocation
Department	Computer Engineering Information Technology Electronics and Telecommunication Mechanical	hasHOD hasLab
Laboratory	Computer Center IT Microprocessor and Hardware Power Electronics	hasInstrument belongsTo hasIncharge
Library	–	hasIncharge belongsTo hasMaterial

2. T-Box for library system

Book⊑Material
CDs⊑Material
Journals⊑Material
Book ⊑(the section(one-of 'student 'reference))
student≡Person⊓∀hasAdmitted·⊤
staff≡Person⊓∀hasAppointed·⊤
Lecturer ≡ staff ⊓∃ hasType.Teaching
NonTeachingStaff ≡ staff ⊓∃ hasType.¬ Teaching
lentTo≡ ¬ hasBorrowed
Lecturer≡ ¬NonTeachingStaff
Borrower ≡ Person ⊓∃ hasBorrowed ·Book
Borrower ≡ (staff ⊔ student) ⊓ (∀ hasBorrowed·⊤)
ReferenceBooks ⊑ Book

ReferenceBooks ≡ Book ⊓(∀ hasBorrowed.⊥)
issuedate⊑Date
returndate⊑Date
currentdate⊑Date
BookOnLoan≡ Book ⊓Book.returndate > currentdate
$student_1$ ≡ student ⊓∀hasBorrowed .⊥
CN-Books ≡Book⊓∀ (fills Name 'Computer Network)
ReferenceBook≡Book⊓ (fills section 'reference)

3. ER model for library system

Schema (TRC) or relation (RA and RDBMS)

1. person (pid,lib-id,pname,address,phone-no)
2. staff (pid,type, join-date, salary)
3. teaching (pid, designation, department,workload)
4. nonteaching (pid, designation, department)
5. material (sr-no,type,price,purchase-date)
6. book (sr-no,book-id,ISBN-NO,title,author,section)
7. student (pid,PRN,branch,class)

Relational Schema (TRC) or relation(RA and RDBMS)

1. Purchased-by(sr-no,purchase-date,material-type,quantity,amount,supplier)
2. Work-for(pid, workload, joining-date, designation, department)
3. admitted-in(pid, date-of-admission)
4. issue(issue-date, lib-id, return-date, book-id, due)
5. teaches(pid, class, subject)

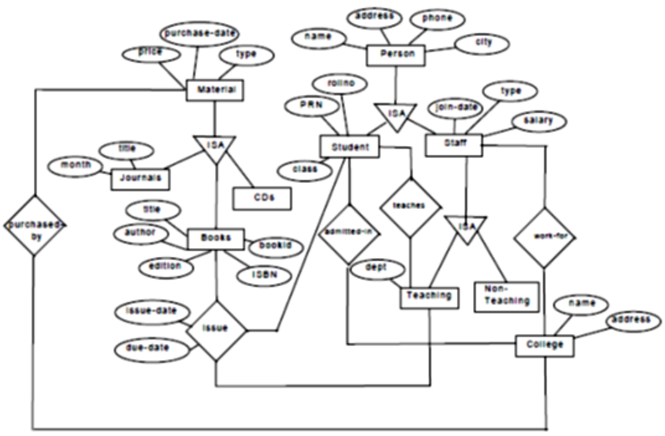


Figure 4. ER model for library system

4. DL Model for Library System

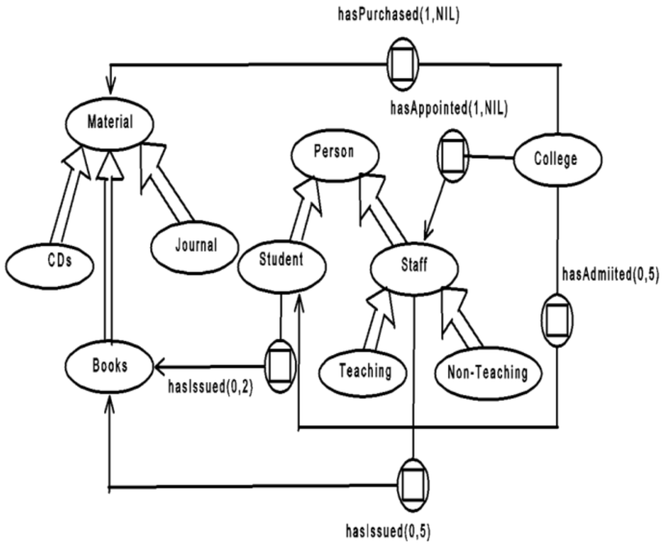


Figure 5. DL model for library system

5. Query Representation

Query 1 List out all the books written by John Uffenbeck.

Language	Query
RA	$\sigma_{author='JohnUffenbeck'}(Book)$
TRC	{b|∃b∈Book(b|author|='John Uffenbeck')}
SQL	select * from book where author='John Uffenbeck'
DL	$Book_1$ ≡Book⊓∃hasAuthor.John Uffenbeck

Query 2 Find out the books which belong to reference section.

Language	Query
RA	$\sigma_{section='reference'}(Book)$
TRC	{b|∃b∈Book(b|section|='reference')}
SQL	select * from book where section='reference'
DL	ReferenceBook≡Book⊓ (fills section 'reference)

III. CONCLUSION

In this paper, basically I have concentrated on the several modeling issues and the ways in which they can modeled in DLs. During the whole process, I proceeded step by step. Initially I have taken a brief overview of the concepts like databases, conceptual modeling, DL basics etc. Then I have studied in detail what are the various possible situations of the real world and solution to each of them. Some of these are not easily supported in DL but can be modeled in other way. Finally, I have gone through an application of Library system, For this, I have first represented it using the conventional language such as ER model along with the database schema. Then I have modeled it with the DL representation along with knowledge base. Then queries are represented for each application using RA, TRC and SQL. Then these representations are compared with the query representation in DL. From the examples it is clear that DL provides much clear and easy to learn syntax as compared to conventional languages. As well as DL also supports reasoning facilities which are required to test correctness of the conceptual model.

IV. REFERENCES

[1] Franz Baader, Diego Calvanese , Deborah L. McGuinness , Daniele Nardi, Peter F. Patel-Schneider, " The Description Logic Handbook: Theory, Implementation and Applications", Cambridge University Press; 2 edition (June 28, 2010), ISBN-13: 978-0521150118.

[2] Vandana Mohan Patil, "Description Logic: A Knowledge Representation Language", IJCA Proceedings on National Conference on Emerging Trends in Information Technology NCETIT(2):1-5, 22 December 2014. (NCETIT/Number 2 (ISBN: 973-93-80884-61-3))

[3] Calvanese, Diego, and Giuseppe De Giacomo. Expressive description logics. Cambridge University Press, 2003.

[4] Borgida, Alexander, and Ronald J. Brachman. "Conceptual Modeling with Description Logics." In Description logic handbook, pp. 349-372. 2003.