Building Views with Description Logics in ADE: Application Development Environment

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Abstract

Any of views is formally defined within description logics that were established as a family of logics for modeling complex hereditary structures and have a suitable expressive power. This paper considers the Application Development Environment (ADE) over generalized variable concepts that are used to build database applications involving the supporting views. The front-end user interacts the database via separate ADE access mechanism intermediated by view support. The variety of applications may be generated that communicate with different and distinct desktop databases in a data warehouse. The advanced techniques allows to involve remote or stored procedures retrieval and call.

Introduction

Recent research activity generated not only the valuable advance in the area of supporting views [BLR97] but stimulated the experimental efforts in developing the views supporting mechanisms over the generalized object-oriented structures, e.g., BACK, CLASSIC, CRACK, FLEX, K-REP, KL-ONE, KRIS, LOOM, YAK. Here is briefly discussed the Application Development Environment (ADE) that is used to build database applications involving the generalized views. They are encircled within the description logics that are a family of logics being developed for modeling a diversity of hierarchical structures. The main units in a description logic (DL) are the unary predicates, called concepts or, more generalized, variable concepts [Wol96]. Other kind of units is represented by the binary predicates called roles, or cases. Variable concepts represent the sets of generalized objects (called individuals) and cases or roles represent their states.

The generic concepts and roles are used as initial primitive units while the additional concepts and roles are defined using constructors giving rise to derived units. Thus, the concepts indicate the associated classes of individual instances in the domain and the constructors over the concepts indicate the appropriate necessary and sufficient conditions on individuals of the classes.

The restricted types of DL’s with (ordinary) concepts have the semantics based on the first order logic with equality while the DL in use here manipulates the variable concepts, thus, involving the higher order logics and structures. This is more general assumption than usually, e.g., the known result for DL’s with ordinary (not variable) concepts is that it can be translated into a special kind of first order logic [Bor96].

To solve the possible inconveniences, ADE computes separately the database access and the user interaction with this computational environment. The variety of applications may be generated that communicate with different and distinct desktop databases. The advanced techniques allows to involve remote or stored procedures retrieval and call.

According to an object-oriented traditions [Gro91], ADE include some basic features of inheritance, encapsu-
lution, and polymorphism. They are used to derive an actual object from possible, or potential objects to cover the needed information resources.

The potential object (PO) is composed with the menu (M), data access (DA), and modular counterparts (MC). The Ancestor Potential Objects (APO) contain the menus, events, event evolver, attributes and functions (that are encapsulated). The Descendant Potential Objects (DPO) are inherited from APO.

The aim of the current contribution is to give a brief profile of the ADE project in general and yet without any detailed mathematical or implementation consideration. Nevertheless, some mathematical background corresponds to the references [Gro91], [He95], [And96]. Other less traditional for the database area ideas are due to [Wol96] to conform the object computation strategies. The main ADE building blocks have the relative uniformity to resolve the modular linkages. ADE enables the host computational environment to extend the properties of the distinct MC.

To support this, we develop a well-modularized architecture for DL that is implemented using the “normalize-compare” approach (see Section 3). This architecture expects a set of procedures to be filled in for each new concept constructor extending the original language. In addition, the methodological heuristics could be proposed to specifying what these procedures need to do.

The outline of the rest of the paper is as follows. Section 1 outlines the basic notions in use. Section 2 provides an introduction to DLs, their syntax and semantic description, and the services provided by the reasoning with concepts, especially the “subsumption” relationship. Section 3 provides the basics from event-driven technics in use. Section 4 gives a brief outline of data integrating facilities. It introduces the architecture of the proposed approach to DL support, provides an overview of the methodology for extending it. Section 5 describes the general features of supporting technologies. It terminates by discussing successes and limitations of the proposed ADE approach to extension, an its relationship to one particular other approach that is directly relevant.

We conclude by summarizing the contributions and limitations of the approach.

1 Basic notions and architectures for database interoperations

In this paper the term ‘view’ is used in a rather general sense. For instance, the SQL statement ‘CREATE VIEW’ results in a single and virtual relation with a content being specified using a query over pre-specified relations. Here the term ‘view’ means a database schema, where the contents of the schema elements (relations, classes, etc.) are specified using queries against one or more already-specified schemas. A view may be virtual or actual (materialized), or supported using a combination of the two.

There are several known architectures for database interoperation: mediation, federation, mediation with updates, workflow.

In our approach the computational environment identifies three main layers to supporting data integration. The first of them holds wrappers supporting common query interface. The second one holds mediators and provides semantic data integration. At last, the third layer holds coordinators providing support for relevant information sources.

2 Preliminaries with concepts

Description logics are knowledge representation languages tailored for expressing knowledge about concepts and concept hierarchies. They are usually given a Tarski style declarative semantics, which allows them to be seen as sub-languages of predicate logic. They are considered an important formalism unifying and giving a logical basis to the well known traditions of frame-based systems, semantic networks and KL-ONE-like languages, object-oriented representations, semantic data models, and type systems. The basic building blocks are concepts, roles and individuals.

Concepts describe the common properties of a collection of individuals and can be considered as unary predicates which are interpreted as sets of individuals.

Roles are interpreted as binary relations between individuals. Each description logic defines also a number of language constructs (such as intersection, union, role quantification, etc.) that can be used to define new concepts and roles. The main reasoning tasks are classification and satisfiability, subsumption and instance checking. Subsumption represents the is-a relation. Classification is the computation of a concept hierarchy based on subsumption. A whole family of knowledge representation systems have been built using these languages and for most of them complexity results for the main reasoning tasks are known. Description logic systems have been used for building a variety of applications including conceptual modeling, information integration, query mechanisms, view maintenance, software management systems, planning systems, configuration systems, and natural language understanding.

2.1 Example

Consider an example with the primitive concepts person, technical and Information Technologies, and paper is a primitive role. The new derived concepts can be defined by the various constructors. This is a way to imposing some restrictions on the number of fillers of a certain role have to be associated. E.g., \( \leq 6 \) paper is a derived concept determined by applying a number restriction on the role paper. Namely, it determines the set of objects that have at most 6 fillers for the case (role) paper.
The same way, (∀ paper.technical) is a description that derives the concept, – an *intension*, – by imposing the *universal quantifier* constructor ∀, and the associated class – an *extension*, – returns the class of objects with the property that all the fillers of the case paper are within the class technical. (∃ paper.InformationTechnologies) contains the *existential quantifier* and determines the set of objects, – *individuals*, – among which there exists at least one filler of the case paper belonging to the class InformationTechnologies. The following concept description describes the complex concept C1. This concept includes a set of persons such that all of their papers are technical, have at most 6 published papers, and have a paper that is on Information Technologies area:

\[
C1 := \text{person} \cap (\forall \text{paper.technical}) \cap (\leq 6 \text{paper}) \cap (\exists \text{paper}.\text{InformationTechnologies})
\]

If we want to fix the set of *primary facts*, then the assertions like

\[
\text{Concept(Instance), Role(Owner,Member)}
\]

are to be used, where *Instance*, *Owner* and *Member* are the *individuals*.

For instance, paper(Rick, ‘Logics in Humanities’) means that *Logics in Humanities* is Rick’s paper. (∀ paper.technical)(Rick) means that all the Rick’s papers are technical, i.e. belong to the class technical.

2.2 Syntax and semantics

Now we determine the outline for syntax and semantics of description logic used in this paper.

2.2.1 Syntax

In the definition below A denotes a primitive concept, P;’s are used for indicating the roles, C, C1 and C2 denote concept descriptions, and R indicates a case (role) description. Descriptions are determined using the syntax as in Figure 4.

2.2.2 Semantics

Semantics of the constructions is given by the *assignments I* that is, in the context of this subsection, the same as *interpretations*. We assume that I is being associated a non-empty domain H(I). Note, that best of all think of the term ‘domain’ in a sense of the theory of computations. This interpretation assigns a unary relation A(I) over H(I) to each atomic (primitive) concept A as well as a binary relation R(I) over H(I) × H(I) to every atomic (primitive) case R.

In the following card{S} means the cardinality of a set S, binary relation θ is one of \{<, ≤, =, ≥, >\}, Ci ⊆ H(I), and the informal ideas are determined by the equations shown in Figure 2.

3 Event driven objects

A description logic system provides some services that are connected to the computational features of the event-driven environment.

First of all it provides the procedures for validating the subsumptions between concepts. For any two concept descriptions it can validate whether one of the descriptions for all assignments I, i.e. always, determines a superset of the *individuals* for the other. Say, the derived concept C1 is subsumed by the concept author as follows:

\[
\text{author} := \text{person} \cap (\geq 0 \text{paper}), \text{and}
\]

\[
\forall I. \text{author}(I) := \text{person}(I) \cap (\geq 0 \text{paper})(I)
\]

The term ‘event driven object’ means that the *script* is executed in response to the *event* being recognized by the object. Every event has the associated script. To enable the event-driven computations, the Modular Counterpart (MC) is implemented as a holder of all the controls to communicate with the user. The event – and corresponding *assignment*, or interpretation, – is assigned by the user call (for instance, clicking) or selection. Thus, when the activity is initiated, the following main events may be triggered: respond to a request from the user application, database retrieval or updating. The possible order of the events is prescribed by *evolver* and is determined by the *scripts*. A fragment of the event driven procedure is shown in Figure 4.

Semantic heterogeneity is the result of representing the same or overlapping data in two or more ways. The ways to compare the ability of different data models and database schemas to hold the same information, possibly restructured, could be derived.

As usually, events could be triggered using *menu* in the user GUI, initiating the associated particular application. Menu gives more flexibility to the attribute selection. Usually the lists of possible attributes are supported to give the developer or user more freedom. Menus are established to be encapsulated in *Ancestor Potential Objects* (APO) and are inherited from *Descendant Potential Objects* (DPO)

The particular application is derived from Potential Object Library (POL) giving rise to Actual Object Libraries (AOL).

3.1 The starting assumptions

The represented domain is assumed inhabited by the (atomic) entities, or *individuals*. A safety reason is to set up individual as a primary concept that is not assumed to be definable. In fact, the observer operates with the *constructs*
primitive concept \( C_1, C_2 \rightarrow A \)
conjunction, disjunction \( C_1 \cap C_2 | C_1 \cup C_2 \)
repetition \( \neg C \)
universal quantifier \( \forall R.C \)
existential quantifier \( \exists R.C \)
number restrictions \( (\leq nR) | (\geq nR) | (\leq nR) | (\geq nR) \)
case conjunction \( R \rightarrow P_1 \cap \ldots \cap P_m \)

Figure 1: Syntax of descriptions.

\[
\begin{align*}
(C_1 \cap C_2)(I) & = C_1(I) \cap C_2(I), \\
(C_1 \cup C_2)(I) & = C_1(I) \cup C_2(I), \\
(\forall R.C)(I) & = \{ h \in H(I) | \forall d : (h, d) \in R(I) \Rightarrow d \in C(I) \}, \\
(\exists R.C)(I) & = \{ h \in H(I) | \exists d : (h, d) \in R(I) \land d \in C(I) \}, \\
(\theta n R)(I) & = \{ h \in H(I) | \text{card}\{d : (h, d) \in R(I)\} \theta n \}, \\
(P_1 \cap \ldots \cap P_m)(I) & = P_1(I) \cap \ldots \cap P_m(I).
\end{align*}
\]

Figure 2: Semantics of descriptions.

**Actual Objects**

| Potential Objects | Events |
|-------------------|-------|
|                   | i     |
|                   | h(i)  |

**Event Driven Objects.** Here: possible object \( h \) is the mapping from the event (assignment) \( i \) into the actual object \( h(i) \). Note that a set of all the possible objects \( \{ h | h : I \rightarrow T \} = H_T(I) \) represents an idea of functor-as-object for \( I \) is a category of events, \( T \) is a (sub)category of the actual objects - type.
that represent the individuals that can be located into a single domain $D$.

The advanced studies in a theory of computations prescribe $D$ as a domain of potential (or schematic) individuals. Those individuals are possible with respect to some theory (of individuals).

The individuals enter the domain and leave it cancelling out their own existence. Such a ‘flow of events’ may be based on a time flow.

The additional virtual individuals are completely ideal objects. They are used to increase the structure regularity of the (initial) domain $D$.

As a result, clear distinction between actual, possible and virtual individuals induces the inclusion:

$$ A \subseteq D \subseteq V, $$

where $A$ is a set of actual individuals, $D$ is a set of possible individuals, and $V$ is a set of virtual individuals. The central computational proposal is to generate actual individuals as the different families of $D$,

$$ A_i \subseteq D \text{ for } i \in I. $$

### 3.2 Other generic notions

A user actually needs a (logical) language, even overcoming his own initial desire. These logics is not homogeneous and do not suit the amorphous idea of a thing and property. The regular and working logics are the logics of the descriptions. The descriptions directly illustrate the differences of the individuals and tend to general operators.

The logical formula $\Phi(x)$ gives the property, but the direct assignment of the property $\Phi(\cdot)$ to the individual $x$ is given by the description:

$$ \mathcal{I} x . \Phi(x), $$

with a sense ‘the (unique) $x$ that $\Phi(x)$’.

The connection between syntax and semantics is given by the evaluation map:

$$ \| \cdot \| : \text{descriptions} \times \text{assignments} \to \text{individuals}. $$

(Here: an assignment is temporary viewed as an index ranging the families.) The abridged concepts are an attribute $a$ and property $\Phi(\cdot)$ (via the description):

$$ a = \| \mathcal{I} x . \Phi(x) \|, \text{ for } i \in I \quad (\text{Attr}) $$

An attribute thus defined indicates the set of individuals with a property $\Phi(\cdot)$. In usual terms the functional representation of attribute is established (attribute is a mapping from a set of things and a set of ‘observation points’ into a set of values). Note that a ‘thing’ is represented by the ‘description’.

**Principle adopted:** The attribute is defined by (Attr).

The addition of the uniqueness

$$ \{ a \} = \{ d \in D \mid \| \Phi(\bar{d}) \|_i = \text{true} \} \quad (\text{Singleton}) $$

as necessary and sufficient condition

$$ \| \mathcal{I} x . \Phi(x) \| = a \iff \{ a \} = \{ d \in D \mid \| \Phi(\bar{d}) \|_i = \text{true} \} \quad (\text{Unique}) $$

enforces the observer to conclude: fixing the family $i \in I$ and evaluating $\| \Phi(\bar{d}) \|_i$, relatively to every $d \in D$, he verifies the uniqueness of $d$.

In above the individual is called as $a$ and is adopted as an evaluation of the description relatively to $i$.

### 3.3 Functional scheme

A general solution for attributes attracts the set of attribute functions (Attr) that is called as a functional scheme.

Equation (Attr) is to be revised as follows:

$$ \mathcal{I} x . \Phi(x) = \bar{h} \quad \text{in a language of observer} $$

$$ \| \bar{h} \| = h \quad \text{this is an individual} $$

$$ h(i) = a \quad \text{this is an individual} $$

Thus, if $h$ is an individual, then $a$ is its state under the forcing condition $i$.

Hence, the generalized individuals (or: concepts) are schematic:

$$ h : I \to C, $$

where $h$ is a mapping from the ‘observation points’ into the (subset of) attribute $C$. The latter undoubtedly is the set of individuals.

There is a clear reason to call the collection of $h$ as a concept. Thus a concept really represent the functional scheme. The (individual) functional schemes are to be gathered into a greater stock:

$$ \{ h \mid h : I \to C \} = H_C(I) \quad (\text{VDom}). $$

Certainly, $H_C(I)$ is and idealized object. This object $H_C(I)$ is a representation, and what is specific the feature of a variable domain is captured. The possibilities and the advantages of a notion of variable domain are applied mostly to the dynamics.
3.4 Dynamics of objects

The state in an object-oriented approach is viewed as the value of the functions in the functional scheme at a given point among the ‘observation points’. This agrees with the computational framework where a set of individuals is generated by:

\[ H_C(\{i\}) \subseteq C \text{ for } i \in I. \]

This set is a state of a variable domain \( H_C(I) \), where \( C \) gives the local universe of possible individuals. The pointer \( i \) marks the family of individuals that is ‘observed’ from \( i \).

As can be shown in addition, the commonly used in object studies are encapsulation, composition, classification, and communication/transaction have the computational representation as well.

4 Integrating data

The desired aim for data integration could be applied to constructing a global schema from the source database schemas. In the project under discussion there are two ways to supported read-only integrated access via views: virtual and actual.

The virtual approach. This way is based on decomposing the initial query to subqueries being addressed to particular source databases.

The actual approach. The main feature is that a view is updated every time when given an update in terms of particular databases. This is important for commercial applications when data warehouse provide support to actual integrated view.

ADE has under research the idea of a concept as the variable entity to possess the creation of the variable concepts and associated transition effects. In their turn the variable concepts lead to parameterized type system. The approach developed in ADE is based on the reasons stated.

The usage of the method of embedding typed system (including the apparatus of variable concepts) into untyped system based on the apparatus of Applicative Computational Systems (ACS) is the distinctive feature of the approach being developed.

Combining the ideas of variable concepts will make possible development of a wide range of applied information systems, particularly in the field of data base management systems, knowledge based systems and programming systems.

ADE is viewed to be a comprehensive computational environment from a formal point of view based on the notion of ‘variable concept’. This notion gives rise to an approach to integrating the far distant concepts, means and models in use.

The target prototype system Application Development Environment (ADE) is involves the idea of a variable, or switching concept and covers the vital mechanisms of encapsulation, inheritance and polymorphism. Variable concepts naturally generate families of similar types that are derived from the generic types. Concepts in ADE are equipped with the evolvents that manage the transitions, or switching between the types.

In particular, the identity evolvent supports the constant concepts and types (statical concepts). To achieve the needed flexibility a general ADE layout consists of the uniform modular units, as shown in Figure 4.

In ADE Data Object Definition Language (DODL) contains the construction of data objects’ base schema as a relation between concepts. Concepts are included into the type system with the interpretation over the variable domains. A coherent set of variable domains generates the data objects’ base. Basis to maintain the data objects in use and their bases is generated by computational models with applicative structures.

The developer obtains the set of the means that establish, support and modify the linkages between the data objects’ base schemes, data objects’ base and computational models. DODL declares: type system as a set of metadata objects; em linkages between the types; system of domains; linkages between the domains; extensions of domains and types; computational tools of applicative pre-structures and structures.

The third part of the implementation supports two level of interfaces. The first is the Intentional Management System (IMS) to support concepts (metadata objects) of different kinds, and the second is associated Extensional Management System (EMS) to support the appropriated extensions (data objects) generated by the intentions.

EMS is embedded into the unified computational model. It is object-oriented extensible programming system Basic Relational Tool System (BRTS). BRTS has the fixed architecture with the one level comprehension, separate self-contained components, interfaces and languages. It is the First Order Tool (FOT) and generates ‘fast prototypes’. D(M)ODL and D(M)OML of BRTS contain the SQL-based relational complete languages that cooperate with ADE. BRTS mainly supports relatively large number of low cardinality relations (extensions) and supports Data (Metadata) Object Model D(M)OM with retrieval, modifications and definitions of a storable information.

IMS is also embedded into the computational model and supports a numerous metadata objects. Their amount is almost the same as for data objects. IMS is based on D(M)OM with a simple comprehension to manage metadata base and is supported by MetaRelational Tool System (MRTS). MRTS manipulates with the metaobjects (concepts) and metarelations (frames) and is embedded into ADE.
Figure 4: Application Development Environment: ADE. Abbreviations: GUI - Graphical User Interface; POL - Potential Object Library; PO - Potential Object; AOL - Actual Object Library; AO - Actual Object; DPO - Descendent Potential Object; R-level - Representation level; S-level - Storage level
5 Supporting technologies

A main result is the experimental verification of variable concepts approach. This would be applied to develop the variety of applied information systems.

Computations with variable concepts and appropriated programming system allows to built a system especially to manipulate the objects.

The experimental research and verification of the obtained model is based on prototypes – CS, ADE, BRTS, BMRS. The difficulties to implement full scale prototype are resolved by the high level object-oriented programming language. Some candidate programming systems are tested to enable the needed computational properties. After that the main programming tool kit is selected. Preliminary candidate tools were C++ or Modula-2. An attention is paid to select an appropriate database management system. If needed the original DBMS is attached. At the preliminary tests the attention was paid to OLE-2 techniques.

Some ready made original systems were tested and expanded to achieve the prototype system with the properties mentioned.

Conclusions: interpretation of the results

Note that our goal is to obtain close to the same efficiency as would have been offered by a custom-built DL reasoner. Of course, the approach presented here is not a perfect.

1) To the extent that normalizecompare algorithms are unable to reason in a complete manner with DL constructors involving incomplete knowledge such as disjunction, the present system is also likely to suffer the same deficiencies.

2) The present work has not yet addressed DL notions such as role constructors, recursive concepts, and general constraints.

3) There are many other notions in knowledge representation, such as the full spectrum of epistemic and other nonmonotonic reasoning, abduction, casebased reasoning, etc., which are likely to require a thorough overhaul of the entire reasoning architecture, and hence are likely not to be accommodated properly by the present approach.

The resulting two level comprehension model and computational environment verify the feasibility of the approach. The adequate, neutral and semantical representation of data is the target in the sphere of extensible systems and their moderations and modifications. The relational solutions are the criteria in database technology. Therefore, the variable concepts generate the power and sound representation of data objects, have the boundary conditions as the known results in information systems (both in a theory and applications) and capture the additional effects of dynamics to simulate, in particular, the encapsulation, polymorphism and inheritance.

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