AIM@SHAPE

Semantic Searching

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Information on the Web

- The Web provides a means to share information and resources among user communities (scientists, enterprises, etc.) and the wider public in general
- As such, it provides easy access to a huge amount of information
- Due to the sheer amount of information and the growing complexity of the resources being made available it has become increasingly important to:
  - Efficiently acquire, and
  - Effectively manage resources and information

Inefficient search mechanisms

- What good is it to have the information stored securely in a database server if it is so difficult to discover and access it?
- The inefficiency in discovering and accessing desired information is perhaps the most important limitation of the current state of the Web
- This inefficiency stems from the difficulty computers encounter when dealing with the analysis of user queries

Analyzing user queries

- Understanding, with relevant precision, the meaning of a query is a feat that cannot always be accomplished by human beings, let alone computer applications.
- Understanding a user query is a very complicated process and there are a lot of distinct factors that take place:
  - User background
  - Context
  - Query language
  - Complexity of the knowledge domain
  - etc.

The Semantic Web initiative

- The W3C issued the Semantic Web initiative in order to address the current limitations of the Web
- Objective:
  - "Provide an efficient way of representing content and information on the Web so that it can be used not only for display purposes, but also for automation, integration, and reuse of data across domains and applications"

Semantic Web technologies

- 2 Important elements can be identified in the scenario described:
  - A means to represent information in a structured and formal manner
  - Tools to process this knowledge and derive resulting conclusions
- The first element is realized with a logical formalism that is expressive enough to represent what we want (i.e. an ontology language)
- The second element is the primary concern of inference engines, which are tools that process knowledge structures and deduct results

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Traditional vs. Semantic searching

- Traditional search involves matching query terms in documents and retrieving relevant results
  - No attempt whatsoever is made to attribute meaning to the query
- Ontologies provide the means to map terms to concepts and associate meaning to the user query
  - Associations and axioms between concepts and terms provide the means not only to derive meaning but also to reason on the knowledge space and deduce potential implied information that is not directly associated with the query

Query example

- For example, given the query
  - "Find all Virtual Humans that can be animated"
- We need to find objects that
  - can be identified as Virtual Humans, **and**
  - have the ability of being "animatable"
- Using the traditional approach
  - we would have to explicitly associate objects that represent Virtual Humans that can be animated with an appropriate property (can-be-animated)

Searching conventionally

- In other words, we would need for each object an association like the following:

Animatable VH object → can-be-animated

- If such an association is not present for a qualified object the query cannot retrieve that object

Full text search

- In the case of full-text search
  - The association is specified in the form of keywords in the document
  - In the given example the keywords would be
    - "can be animated"
  - In this case an explicit association is searched for in the document
  - There are 2 problems with this approach
    - The keywords may be present in the document but used in a different context
    - The document might express with different keywords the fact that the object is animatable

Simple metadata search

- In this case we are using simple metadata tags to associate documents with keywords
  - The association could be specified as a metadata tag
  - An explicit association must be specified
  - If combined with full text search it can present an improvement
  - For best results a glossary of synonym terms could be used
  - This approach is still restrictive however as we are still searching for explicit associations of keywords

Searching conventionally (Cntd)

- In both cases the restrictions are important and cannot be overlooked if we want to improve search
- Several logical questions arise:
  - What if we add new objects?
    - Associations must be specified explicitly
  - What if we need to consider new kind of associations?
  - What about objects that are indirectly related to the query?

Searching semantically

- Knowledge conceptualization using ontologies provides a clearly advantageous alternative.
- The first step requires the definition of the knowledge required to answer the query
- For the example query this involves formally specifying what it "means" for a Virtual Human to be animatable.
- A simple definition could be "A Virtual Human that has joints and is associated with at least one animation that involves some of its joints"

Knowledge representation

- What is the methodology?
  - Decompose complex concepts in the query into simpler constituent parts
  - Try to define each constituent part (if not simple enough → decompose)
  - The definition of each part is done in terms of concepts and associations
  - Define rules to capture complex associations between concepts

Knowledge representation (Cntd)

- Formally specifying the concepts and associations depends on the logical formalism (i.e. ontology language) of choice as well as the design choices made
- The ontology language choice depends on
  - Expressivity
  - Reasoning support
  - Standardization
  - Usability

Searching semantically (Cntd)

- The second step involves exploring all possible association paths that would satisfy (directly or indirectly, partly or fully) the required criteria as specified by the conceptualization of the query
  - Relevant objects can now be deducted by satisfying relevance of their constituent parts
  - Rules are exploited to identify implicit facts

Rules

- $Clause_1$ ^ $Clause_2$ ^ … ^ $Clause_N$ → Head
  - All clauses must be satisfied to satisfy the Head
- $Clause_1$ v $Clause_2$ v … v $Clause_N$ → Head
  - One clause must be satisfied to satisfy the Head

- Finding animatable Virtual Humans
  - isVH(x) ^ hasJoints(x) ^ hasAnimation(x) → isAnimatable(x)
  - hasRootJoint(x) → hasJoints(x)

Searching semantically (Cntd)

- In our example query this would involve exploring several sub-queries for any potential object:
  - Does the object have any joints?
  - Are there any animations associated with this object?
  - Can any animation be applied to the object (are the required joints present)?

in order to ascertain whether there is a **derived** relation between an object and the query

Searching semantically (Cntd)

- These sub-queries result from the decomposition of complex knowledge structures (an animated Virtual Human) into simpler ones
- Rules are exploited to identify all possible ways to satisfy the simpler query terms
  - Cannot find any joints defined
  - Can satisfy a rule which allows the deduction that the object has joints

Searching semantically (Cntd)

- There is an obvious benefit in semantic searching as the goal is to understand what is meant of the query.
  - improves the relevance of the retrieved documents
  - enables us to explore documents that are indirectly related to the query, therefore significantly improving recall as well.
- This, however, is not always easy or even possible

Why searching for 3D objects?

- Searching for 2D resources is still awkward and inadequate
- 3D content retrieval is overlooked in commercial search engines
- Methods for 2D content-based retrieval do not generalize directly to 3D, due to the different nature of the content
- Semantic searching is still at its infancy
- Then why targeting semantic search for 3D resources?

Motivation behind 3D Shape retrieval

- Search and retrieval of three-dimensional media
  - is expected to become a key issue in the upcoming panorama of multimedia content
  - has the potential to shape how users will interact with the internet in the years to come
- For this vision to succeed, 3D searching must be efficient and easy to use
- Current 2D and 3D search engines (Google Image Search, Princeton 3D Model Search Engine, etc.) show only a glimpse of the potential for 3D searching on the Web.

Motivation behind 3D Shape retrieval (Cntd)

- Creating a 3D model takes much time and effort.
- It would be greatly advantageous to be able to reuse and adapt existing 3D models instead of creating new ones from scratch.
- This has motivated the development of 3D shape retrieval mechanisms that are currently based mainly on 3D shape matching

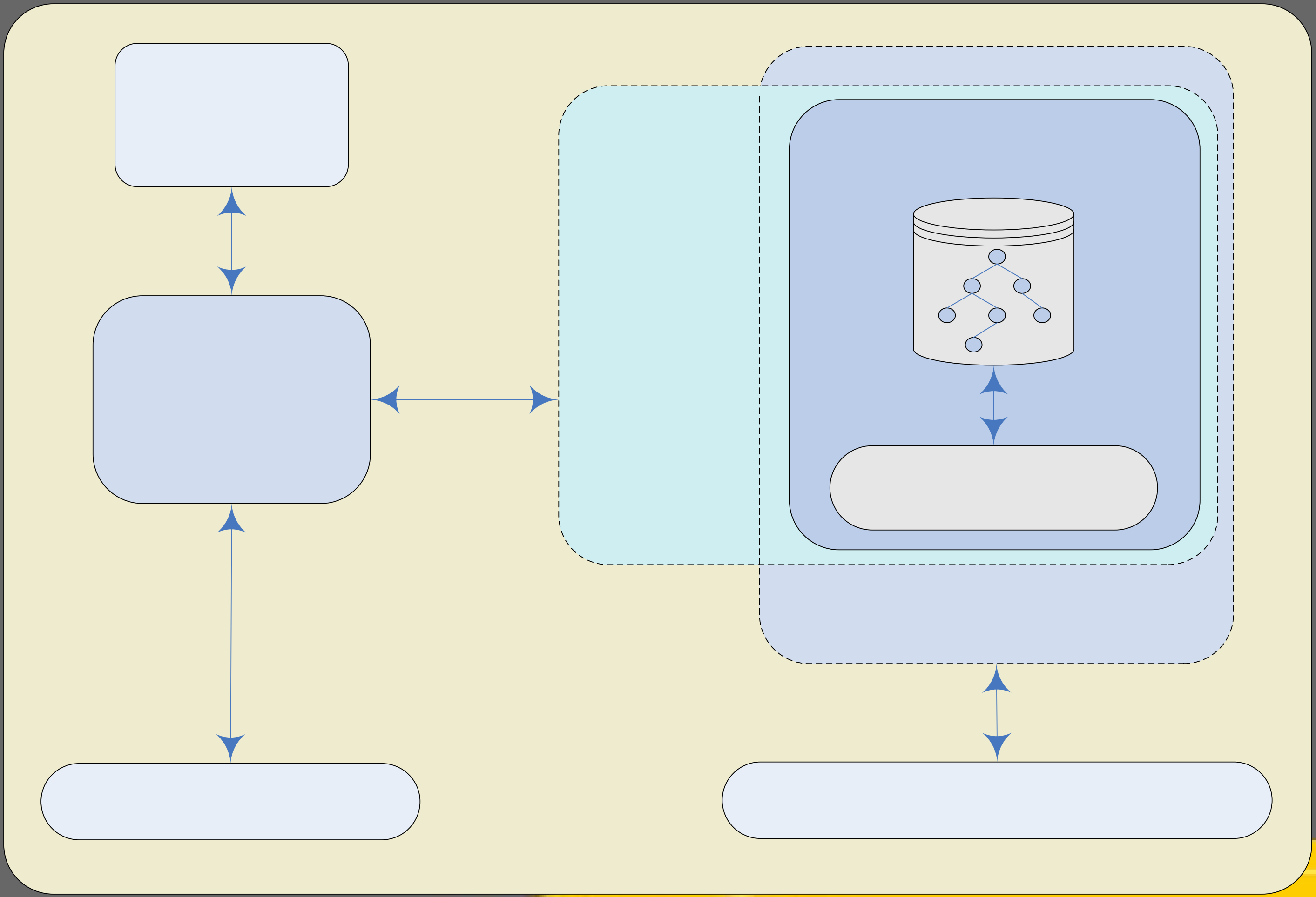
3D Shapes in AIM@SHAPE

- AIM@SHAPE objectives with regards to searching
  - not just 3D Shape retrieval
  - formalization of knowledge elements (concepts, associations and rules) that contribute to the conceptualization of the various domains in which queries about 3D Shapes can be expressed
  - modelling the semantics of shape objects constitutes by itself a concrete step in developing an effective search mechanism for 3D resources
  - ontology-driven metadata are structured according to different conceptual views, capturing different aspects of the shape information (e.g. geometry, structure, semantics)
  - metadata also take into account the different contexts in which the shape can be used

Objectives for the Search Engine framework

- To make explicit and sharable the knowledge embedded in digital shapes
- To build the necessary framework for reasoning, searching and interacting with the semantic content related to the context-dependent domain knowledge (ontologies).
- To improve current content-based methods for retrieving 3D objects on the Web through the implementation of a semantic-based search engine
- The two fundamental components of the search mechanism are the inference engine and the interface for discovering shape resources.

Architectural elements



Basic components interaction

- The Query API is the *protocol* that binds the Search Engine interface to the inference engine (RACER). The system is truly agnostic of the actual reasoner implementation that is being used.
- We have selected nRQL as the ontology query language for the knowledge base.
  - Other available choices
    - DIG – minimal expressivity
    - OWL QL – not fully supported at the time
- With this Query API design we ensure that the functionality of the API is independent of reasoner specific functionality.

GUI front-end

- One of the most important aspects of searching is *knowing how to search*.
  - involves the user’s comprehension of the domain that is being conceptualized
  - depends on the user’s comprehension of the way that domain knowledge has been structured according to some ontology.
- To help the user in making efficient and appropriate queries, a GUI front-end has been implemented that abstracts the underlying reasoner logic.

The AIM@SHAPE Search Engine Interface