AIM@SHAPE: Research Advantages and Future Contributions

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Abstract— **Searching for multi-dimensional media is gradually becoming one of those intriguing research topics that have the potential to shape how users will access and interact with the internet in the years to come. Multi-dimensional media, however, are generally related to complex objects, and, moreover, to the different semantics that different applications and tools use while dealing with them. In the AIM@SHAPE Network of Excellence [1], one of the main objectives is to deal with the knowledge that is either explicitly or implicitly associated to digital shapes and to formalize the underlying semantics through the use of ontologies. Modelling the semantics of shape objects constitutes a concrete step in developing an effective semantics-oriented search mechanism for 3D resources. This mechanism is part of the Digital Shape Workbench infrastructure within AIM@SHAPE.**

I. Introduction

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 available 3D shapes and the growing complexity of the resources being made available, it has become increasingly important to effectively manage digital shape resources and information (i.e., multi-dimensional media characterized by a visual appearance in a space of 2, 3, or more dimensions).

This has motivated the development of the first prototypes of 3D shape retrieval mechanisms that are currently based mainly on geometric matching techniques, with rather limited results [2],[3].

Recent developments in the Semantic Web provide the means for making the shift towards a semantically enabled representation of digital shapes. Knowledge conceptualization using ontologies provides the means to map terms to concepts, and not only to associate meaning to the user query but also to reason on the knowledge space and deduce potential implied information that is not directly associated with queries. This puts an entirely new perspective on the process of modelling, accessing and retrieving digital shapes.

There are obvious advantages in semantic searching like improving the relevance of the retrieved resources and enabling us to explore resources that are indirectly related to the query.

II. The AIM@SHAPE approach

In this context, the main objective of the Network of Excellence AIM@SHAPE is twofold. On the one hand to develop tools and methods to extract morphological structures from low-level geometry and to capture the implicit semantic information of digital shapes. On the other hand to formalize the domain knowledge into context-dependent ontologies and introduce knowledge management techniques in shape modelling, with the aim of making explicit and sharable the knowledge embedded in digital shapes.

AIM@SHAPE aims to address the need of a new approach to store and retrieve shapes, tools and publications related to the field of shape modelling. The proposed framework relies on the Digital Shape Workbench (DSW) and on a conceptualization of applications domains of shape modelling techniques, providing a characterization of the relevant resources and their related knowledge in order to retrieve them with a sufficient expressiveness. The DSW consists of the resources repositories (the *Shape Repository*, the *Tools Repository and the Digital Library*), a knowledge management system that handles metadata and ontologies, and a number of different ways of discovering, searching and browsing shape resources.

The primary goal of the DSW is the formalization and sharing of knowledge about digital shapes and their applications. The main objectives of the DSW are:

1) To build the necessary framework (*Search Engine*) for reasoning, searching and interacting with the semantic content related to the context-dependent domain knowledge (ontologies).
2) To improve current content-based methods for retrieving shapes on the Web, and 3D media in particular, coupling advanced geometric techniques with semantic criteria on

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the metadata associated with shape resources (ontology-driven metadata information organized in domain ontologies).

Due to the intrinsic complexity of shapes, ontology-driven metadata are necessary in order to reach a sufficient level of expressiveness and to be able to search efficiently for shapes. These metadata represent different levels of sophistication, describing and characterizing a shape resource. For example, a search could be conducted presenting as criteria the geometric aspect of the shape, its structure or its semantics.

Some possible query categories include the following:

1) Concept based search (ontology-driven).
2) Search for a shape with specific geometric characteristics (e.g., manifold models, models without self-intersections), format (e.g. wrl or off), application context (e.g., CAD, human models, furniture), name, produced by a specific tool, history etc.
3) Search for a shape that resembles, globally or partially, a given shape.
4) Search for tools dealing with a specific application context (e.g., similarity, remeshing), name, input or output format, specific performance requirements etc.
5) Search for a methodology (e.g. similarity, remeshing). In this case both tools and scientific papers dealing with that methodology can be retrieved.
6) Range-based search e.g. "Give me the shapes having a number of polygons between 100 and 150".
7) Search for a specific user/researcher/publication.

The fundamental goal of the Search Engine framework is not simply searching for and retrieving multi-dimensional objects. Rather, we are interested in searching for every aspect of knowledge that is inherent to the representation of shapes. However, for a user to be able to take full advantage of the search facilities it should be clear how the domain knowledge has been conceptualized and structured according to some ontology specification.

III. Ontology Development in AIM@SHAPE

The motivation behind the development of ontologies in AIM@SHAPE falls into the following areas:

1) Sharing a common understanding of the information in the knowledge domains;
2) Improving interoperability among applications that use the domain knowledge;
3) Making domain assumptions explicit so that applying changes as these assumptions evolve becomes easier;
4) Enabling re-use of the domain knowledge.

Our aim is to make explicit and sharable the knowledge embedded in digital shapes. Towards this goal, our objectives are:

1) Define common metadata for shape models and shape processing tools;
2) Development and evolution of ontologies for the formalization of the various domains of knowledge;
3) Build a common conceptual framework to be used by all domain ontologies and the DSW.
4) Integrate and validate the ontologies and the corresponding metadata.

Ontology development in the network has been mainly focused on three different areas: Virtual Humans, Shape Acquisition and Processing, and Product Design.

The Virtual Humans ontology [4] aims at organizing the knowledge and data related to research and applications in the field of virtual environments and humans : the modelling and analysis of virtual human body, and their animation and interaction with virtual objects.

The Shape Acquisition and Processing ontology [5] intends to formalize the knowledge pertaining the development, usage and sharing of hardware and software tools and shape data by researchers and experts in the field of shape acquisition and processing [6].

The objective of the Product Design ontology is to guide researchers and experts in the development of tools and methods for: supporting industrial product design and engineering analysis, dealing with knowledge concerning shape processing methods and algorithms, and knowledge about processes and workflows regarding product development phases.

Concepts that are shared by all domain ontologies have lead also to the creation of two *common ontologies*, one related to shapes and one to shape processing tools, as a first attempt for a unified multi-dimensional media ontology framework. Our goal is to create higher-level ontologies which can be extended by the domain ontologies to express metadata for each domain ontology.

The common ontologies aim to capture and integrate all the metadata information from the *Shape Repository*, and the *Tool Repository*. These information are shared by all the domain ontologies because they all deal with the same kind of information (e.g., geometrical information).

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