The VISIONAIR Infrastructure Capabilities to Support Research

Marco Attene[1], Franca Giannini[1], Marios Pitikakis[1,2] and Michela Spagnuolo[1]

[1]Istituto di Matematica Applicata e Tecnologie Informatiche – CNR,
attene@ge.imati.cnr.it, giannini@ge.imati.cnr.it, spagnuolo@ge.imati.cnr.it
[2]mpitikak@inf.uth.gr

ABSTRACT

The development of information technologies, the increasing complexity of the information to be handled and analyzed, along with the growing capacities in scientific and engineering simulations, call for the development of powerful visualization tools and methods. Unfortunately, for many research teams the investment in visualization facilities is not always justified with respect to the actual usage. To overcome researchers' difficulties in using sophisticated visualization and interaction equipment, the European Commission is supporting the integration and the access to advanced visualization facilities around Europe through the VISIONAIR project financed in the frame of the FP7 Capacities program. In the use of the VISIONAIR's physical facilities, researchers may also be supported by the Virtual Visualization Services for sharing and retrieving shapes and related processing software tools. This paper provides an overview on the possibilities offered to researchers by the VISIONAIR project with particular focus on of the Virtual Visualization Services infrastructure.

Keywords: shape repositories, e-science infrastructure, visualization.
DOI: 10.3722/cadaps.2013.851-862

1 INTRODUCTION

The development of tools and methods for reality capturing and the astonishing improvement in computers' computation and communication capabilities have paved the way to new research outcomes in the most various fields. They range from natural phenomena forecasting to disaster and disease prevention and treatment, to product behavior simulation in multiple configurations and situations at its digital representation before its production. The great amount and variety of computed data may require not only great skill but also adequate tools for their presentation to facilitate their understanding. Since it is estimated that 50% of the brain's neurons are associated with vision, visualization is the most promising method for understanding this data to prove or disprove hypotheses, and discover new phenomena. Visualization might be seen as the binding (or mapping) of data to representations that can be perceived. The types of bindings could be visual, auditory, tactile, etc., or a combination of these.

The goal of scientific visualization is to promote a deeper level of understanding of the data under investigation and to foster new insight into the underlying processes, relying on the humans' powerful ability to visualize. In a number of instances, the tools and techniques of visualization have been used to analyze and display large volumes of, often time-varying, multidimensional data in such a way as to allow the user to extract significant features and results quickly and easily [3]. Newly available technologies allow for greater realism in the visualization perception. Unfortunately the use of such tools is still limited because they are still expensive, and their costs are not always justified with respect to the actual usage for most of researchers. To overcome these limitations and to enhance research and innovation capacities, the European Commission is supporting the integration and the access to advanced visualization facilities around Europe through the VISIONAIR (VISION Advanced Infrastructure for Research) project financed in the frame of the FP7 Capacities program. The objectives and components, with particular focus on the Virtual Visualization Service (VVS), of the VISIONAIR infrastructure are the topic of this paper, which is organized as follows. Section 2 provides an overview of the VISIONAIR project's aim and the facilities provided. Section 3 presents the architecture and components of the VVS, whose functionalities are described in section 4. The paper ends with a short summary given in Section 5.

2 THE VISIONAIR INFRASTRUCTURE

The VISIONAIR project aims at federating and providing a unique access to advanced visualization resources available at research centers and universities from Israel and other 11 countries in Europe, see

Fig. **1**. Each site has capacities in one or more specific rendering and visualization technologies including Virtual Reality, Augmented Reality, Holography, High Quality Image Processing. The involved research teams and institutes have been developing complex visualization environments for their own usage. By joining the VISIONAIR infrastructure they open the access to these environments for the research community. The 29 facilities made available by VISIONAIR have been clustered according to their main research and capabilities focus. The first clustering addresses tools and methods to navigate in huge data set issued from scientific simulations. The second cluster focuses on tools and methods that facilitate to sharing and visualization of high quality images and videos over very high bandwidth networks. The cluster on Virtual Reality provides high-end immersive facilities that allow users to experience virtual environments and to interact with them. The last cluster involves platforms that are able to propose synthetic environments mixing a large set of advanced facilities for remote collaborative works.

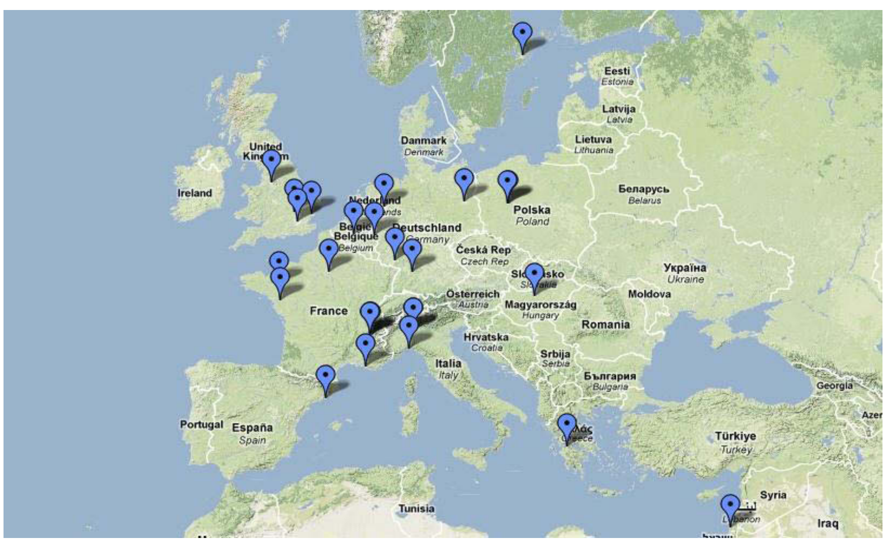

Fig. 1: Geographical distribution of the VISIONAIR visualization facilities.

The access for European and associated countries' guided researcher groups to these facilities is freely open during the duration on the European financial support. It is based upon the acceptance of the so called TNA (Trans National Activities) project proposals. Project proposal may be submitted at any time following the format and instruction available at [4], and are selected at specific evaluation cut off dates. Proposals are judged by an internal panel of experts, who analyze the scientific quality and dissemination commitment together with the added value provided by the use of advanced visualization capabilities for the proposed research. The usage of the physical facilities is supported both financially and technically by the hosting institution experts. Financial support considers the reimbursement of a daily allowance for a fixed number of days (which depends on the hosting facilities) and a return trip for one person for each selected project. Note that TNA projects can be proposed in any research area (i.e. Computer Graphics but also Earth and Material sciences), as long as one of the visualization facilities proves to be important for its advancement.

Finally, to aid the preparation of the execution of the experiments, a Virtual Visualization Service facility is provided. It acts as an e-science infrastructure enhanced with collaboration capabilities for the sharing and retrieval of shape data and related processing software tools. Within VISIONAIR the VVS is aimed at supporting the experts in several activities either for finding processing tools thus avoiding to implement already existing components and to find and store shape data necessary to run their experiments during the TNA project and to create virtual environments. The following sections describe the VVS architecture and the provided functionalities.

3 THE VIRTUAL VISUALISATION SERVICES

The VVS is based on an upgrade of the Digital Shape Workbench (DSW version 4.0, or DSW4) developed by the AIM@SHAPE Network of Excellence [5]. The main goal of the DSW4 was the formalization and sharing of knowledge about 3D digital shapes and their applications. The Computer Graphics community involved in AIM@SHAPE brought a significant contribution to the development of ontologies for 3D applications by proposing a conceptualization of a *shape*, meant as a generalization of a graphical dataset, in terms of *geometrical*, *structural* and *semantic* aspects, complemented by the knowledge pertaining to the *application domain* in which the shape is manipulated. The distinction between these levels in the conceptualization resulted in the design of two kinds of ontologies, namely the *Common* Ontologies (for both Shapes and Tools) and the *Domain* Ontologies. The Common Shape Ontology (CSO) was conceived to capture knowledge related to the geometry of 3D media: while the descriptions of a digital 3D media can vary according to the contexts, the geometry of the object remains the same and it is captured by a set of geometric, structural and topological data that define the shape.

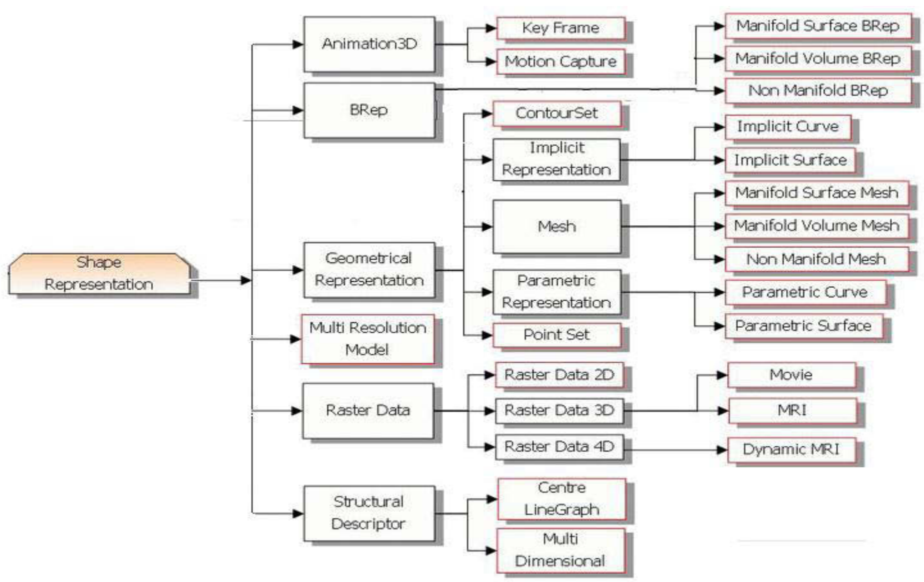

Fig. 2: The shape representation taxonomy. The user is allowed to select only the leaves of this taxonomy (red-bordered boxes).

The structure of the CSO is simple but broad, and it includes a large number of geometrical representation types for shapes, each documented with detailed metadata. In general, the number of properties is relatively small while the depth of the ontology is localised under the *Shape_Representation* class (see Fig. 2). Note that *Structural_Descriptor* is a sub-class of *Shape_Representation*, meaning that the concept of shape extends and includes the geometric and structural level. Other classes that have been introduced in the shape ontology concern the concept of *Shape_Groups*: frequently, indeed, it is necessary to have a mechanism for linking shape models under a common framework, for example, to capture a series of models that correspond to the various stages of an acquisition and reconstruction process or for capturing a series of models that correspond to different representations of the same geometry.

Besides knowledge related to 3D media and content, it is also important to capture knowledge embedded in the software *tools* used to process shapes. For example, imagine that one wishes to prepare a 3D point cloud for a high-quality visualization infrastructure which accepts as input only triangle meshes. There may exists a variety of different algorithms that implement the triangulation of the dataset and the choice of one or another depends on the properties that the resulting triangular mesh should possess. For example, there are methods producing equiangular triangles that are more suited for finite element analysis or methods that produce triangles that are positioned adaptively along creases of the surface. The know-how of an expert is usually needed to decide for one or another method. A clear classification of available tools for processing the geometry and manipulating 3D models might be an important building block for supporting the composition and creation of new easy-to-use tools for 3D content, whose use and selection can be made available also to professional users of 3D but not expert in the specific domain of Computer Graphics. The common ontology for the description of tools, Common Tool Ontology (CTO), is less complex than the SCO in terms of depth, but it contains more concepts. However, the properties that define relations between concepts are localized at the first level of the hierarchy only. The tool ontology reflects a taxonomy of a variety of processing tasks that are used in the Computer Graphics domain, such as for example modeling, parameterization or distance computation. Intuitively, each software tool may implement one or more basic functionalities, which in turn may be modeled by one or more algorithms. The *Functionality* hierarchy, shown in Fig. 3, has the main role to capture type information for the respective concepts and this means that there are no additional attributes defined and only a specific amount of instances will be created, that is those that represent the most specific types for each concept. More details can be found in [6].

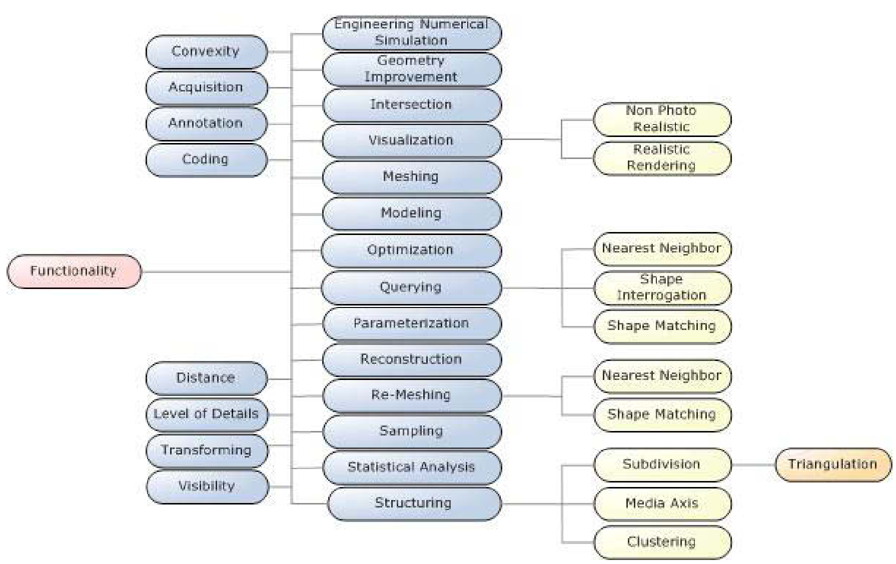

Fig. 3: Taxonomy of tool functionalities within the Common Tool Ontology.

In this new version, i.e. the Digital Shape Workbench version 5 (DSW5), the original architecture was re-visited and several of its key software components were re-implemented. The motivation behind this work was to improve the existing framework for storing, searching and interacting with resources (content) and their context-dependent domain knowledge (ontologies and metadata), as well as to extend it to better support collaboration activities in the view of the TNA experiment preparation.

DSW5 integrates resources and knowledge into a unified interface, providing the following main functionalities:

(a) insertion of resources (shape models, such as n-D images, video, n-D geometric models, software tools and users);

(b) advanced searching, browsing and downloading of resources;

(c) management of resource metadata and related ontologies.

The DSW5 consists of the data repositories (Shape Repository and Tool Repository), the knowledge management system (Ontology & Metadata Repository), the Authentication & Authorization mechanism and a number of different ways of discovering, searching and browsing for resources. An overview of the architecture of DSW5 is shown in Fig. 4.

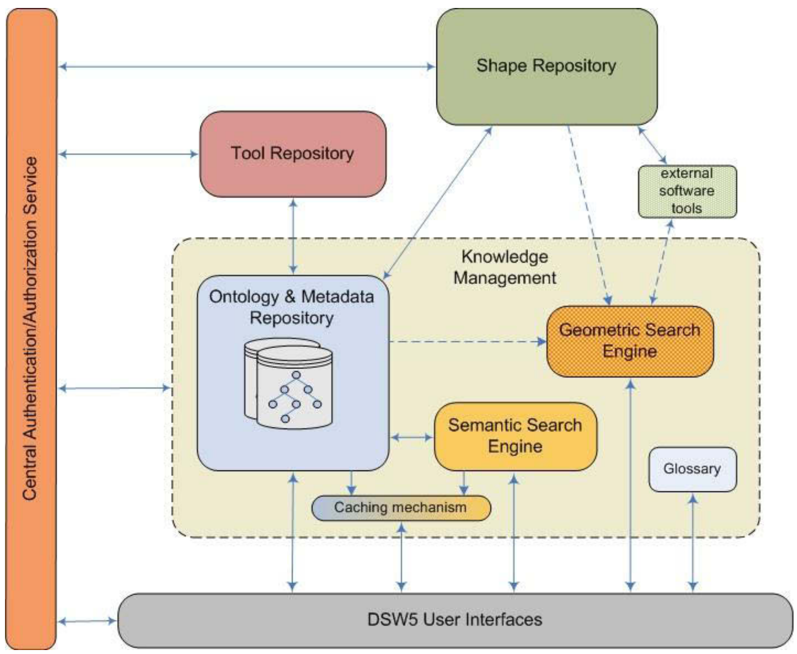

Fig. 4: The DSW5 architectural schema.

The **Shape Repository** is a repository open to the research community, populated with a collection of high quality shape models. It also includes a variety of standard test cases and benchmarks, enabling efficient prototyping as well as practical evaluation on real-world or large-scale models. The repository has rapidly grown the last few years and at this moment contains around twelve hundred (1200) models.

The data (uploaded files of models) are stored in a file system-based storage solution, categorized and documented through ontology-driven metadata according to the leaf classes of the CSO, that is according to the category of each shape. During the model upload procedure, it is required to classify the shape according to the CSO and fill in the appropriate ontology-driven metadata information, which are stored in the Ontology & Metadata Repository.

The Shape Repository has several unique features that differentiate it from other existing repositories. First of all, it integrates a number of tools that make the upload procedure, and later on, the browsing and searching of the models easier. For some types of shapes (e.g. meshes) it is possible to automatically extract useful metadata (e.g. number of vertices, number of faces etc.) by using the Trimeshinfo software [7]. The multi-resolution (MTF) representation computed at upload time by the TriMesh2MT software [8] allows more efficient download functionality and the model pre-view through the creation of a 3D thumbnail. In addition, for each mesh model some post-processing are performed to compute the various signatures exploited by the Geometric Search Engine. All the above software is invoked automatically by the system and its depicted as "external software tools" in Fig. 4.

Other unique features of the DSW5 Shape Repository include the following:

- Possibility for the uploader of choosing the level of accessibility of the stored data. By default all the stored resources can be visible and downloadable by all the DSW5 visitors, but the owner, i.e. the uploader, can decide to let it private or to set visibility/modifiability/download ability rights public or restricted to only specific groups of users.
- When a model is downloaded, upon agreement to the applicable licenses, its thumbnails and metadata are automatically bundled into a package. Currently the majority of the models are free to download by everyone.
- For some 3D models it is possible to choose the quality (resolution) of the downloaded model, view a simplified version model online or choose the desired file format.
- Models logically related to each other can be bound as a "group of models" with a single model acting as a representative shape. Each group is accompanied by a group description.
- Each model can have a thumbnail image as a preview of the model. The thumbnail image is usually uploaded along with the model but it can be also uploaded at a later time or even changed by selecting one of the available gallery images of the model.

The **Tool Repository** is an inventory of software tools that can be used in different stages of digital shape processing. It currently contains tools developed by the AIM@SHAPE project partners and third party developers (either free or commercial). The tools in the Tool Repository are organized based on their functionality as defined by the CTO. For every tool a brief specification of its usage, limits and capabilities are provided as metadata. It was decided that the Tool Repository will not host any of the tool software but will only provide information and links to the official download sites of the tools. Currently, there are around a hundred (100) software tools and libraries in the repository.

The DSW5 also provides a common vocabulary/glossary of terms concerning digital shapes. It contains a selected set of over three hundred seventy (370) terms and their definitions which are distinctive in the domain of shape modeling.

The goal of the search mechanisms provided is to aid in the discovery of shape resources and tools. The fundamental components of the DSW5 search mechanisms are: a simple keyword search enriched with several filtering options, an inference mechanism for semantic-based searching and a geometry-based search mechanism.

The aim of the inference engine is not to restrict the user in searching only for shape resources (i.e. models, tools) but also to be able to acquire other metadata information relevant to the resource as well as using semantic criteria. This information may be either explicitly or implicitly described. Implicit information can be inferred from explicit information (metadata) about a resource.

The geometry-based search mechanism is able to search the Shape Repository according to different similarity criteria and matching mechanisms (e.g. global and partial matching, sub-part correspondence, part-in-whole) and according to different perspectives (e.g. geometry-based or structure-based). Geometric similarity between shapes is evaluated as a distance between shape descriptors that capture relevant properties of the shape. Tools for computing shape descriptors and for computing distances between shape descriptors are implemented as stand-alone tools that can be plugged into the Geometric Search Engine (GSE). The GSE works with different matching criteria depending on the shape descriptors and the comparison methodologies available (see Section 4.2).

Moreover, the system can be easily extended providing capabilities to plug-in procedures for additional descriptors exploitation.

The central authentication/authorization service (CAAS) is implemented using a LDAP server and is integrated in every DSW5 component user interface. Browsing and searching for resources is available to everyone but only registered users can upload new model/tool resources. An online form allows a new user to request an account registration. Our user access policy is based on UNIX-like categories of users. We have defined four categories for accessing and managing content (Everyone, Registered users, Group and Owner) while each resource can have specific restrictions related to its visibility, who can download or change it. Registered users can also create groups of models or groups of users.

3.1 The Knowledge Infrastructure

The Ontology and Metadata Repository (OMR) constitutes the knowledge base back-end of the whole system and is responsible for effectively integrating all other components. The OMR in essence is an ontology management system that allows storing, editing and accessing ontologies and ontology-driven metadata for all the resources.
The knowledge-base was designed in a layered manner, dividing the responsibilities into various inter-dependent but loosely-coupled components. The architectural elements that comprise the software components of the OMR are identified in Fig. 5.

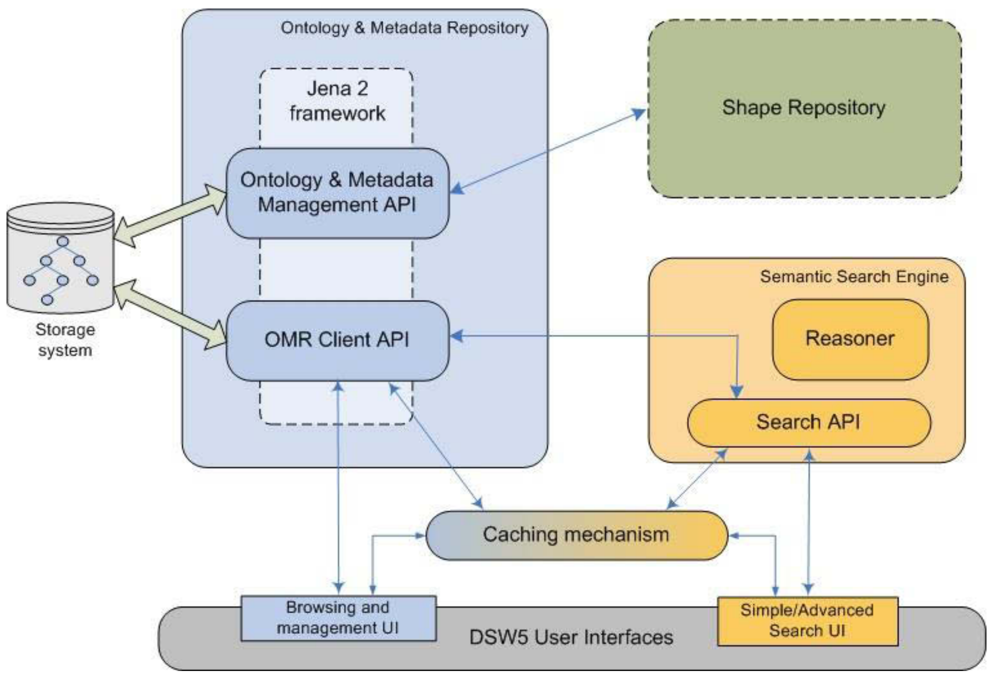

Fig. 5: The Ontology & Metadata Repository general architectural design.

As shown in the above picture there are two APIs for accessing knowledge base functionality: the OMR client API and the Management API. The search engine interfaces with the knowledge base through the Search API while the Management API provides functionality for managing both the ontology schema and the metadata. A caching mechanism is used mainly for performance reasons (to minimize the response time) when browsing and displaying through the Shape and Tool Repository web pages.

The ontology and metadata Management Module provides the basic persistence/storage services. More specifically, it provides a set of ontology & metadata management and maintenance activities and is capable of storing and handling multiple ontologies.

The Management module, which is the core part of the repository, was developed on top of the Jena 2 framework. Jena is an open source Java software under a BSD license and contains a rich set of features for dealing with RDF (Resource Description Framework) and OWL (Web Ontology Language), including OWL-based ontology processing. Jena provides a semantic layer which abstracts a lot of the underlying knowledge that is required to work with the OWL syntax. The ontology models are created from OWL files and are stored to a RDBMS (Relational Data Base Management System) using the appropriate API. In the current implementation we used PostgreSQL as the underlying RDBMS.

The management module extents the Jena API (Application Programming Interface) and provides the following:

a) An API capable of storing multiple ontologies in the repository and providing a set of ontology management and maintenance activities like: inserting an ontology (from an OWL file or URL) in the repository; deleting a selected ontology from the repository; cleaning the RDBMS i.e. removing everything (ontologies and metadata) from the persistent storage; export/download stored ontologies and metadata to OWL files.

b) A Metadata Editing API, providing a set of metadata management and maintenance activities as follows: insertion of instances (individuals) to a specific class of a selected ontology after filling in the required metadata; deletion of existing instances from a selected ontology model; editing/updating metadata values of a selected instance.

c) An API for browsing/listing all the stored ontology structures (schemas) as well as all the instances (individuals).

Currently the system integrates the above described two core ontologies (tools and shape ontology) plus three domain ontologies, namely the Shape Acquisition and Reconstruction, the Virtual Human [10] and the CAD/CAE process integration [11]. Further ontologies can be easily plugged-in without any programming extension need. New ontologies for providing a manufacturing view of the stored resources and for guiding the process of data preparation form CAD/PLM system to VR environment are under development and will be included to better support the physical facilities use within the VISIONAIR project. Since ontologies (domain ontologies and common ontologies) were developed by different groups of people and continuously evolved over time, we needed a way to keep track of ontology changes. A basic set of functionalities to store and manage different versions of the same ontology (updates) have been integrated. Some additional information about the ontologies is also maintained like: imported ontologies (e.g. the Common Shape Ontology and Common Tool Ontology), version number, date of insertion and ontology model name. Moreover, a tracking mechanism has also been implemented for logging changes to resource metadata through the DSW user interface. All changes are kept for backup and security purposes.

The OMR is also dependent on the selection of the inference engine and the most important considerations involve the level of support for OWL DL (which is the chosen logical formalism for describing resources) and performance. For DSW5 we chose the Pellet [11] open source inference engine.

4 FUNCTIONALITIES OF THE VVS

The VVS implements a number of functionalities that are foreseen to support researchers setting up their experiments and visualization workflows. These range from basic functionalities (e.g., access and usage) to more complex ones (e.g., searching using content-based and semantic search) and their development and implementation is still continuing. The general principle followed is to try to make 3D resources visible, accessible and re-usable to an as-large-as-possible context of users and usages. This goal be achieved either by exploiting a rich set of metadata (either automatically computed or by forcing users to upload them) or by setting up advanced indexing and querying that can help finding resources to reuse. The functionalities offered by the VVS is a trade-off between the two: on the one side we tried to ensure that a rich set of metadata is provided, even if the number of mandatory metadata is relatively small, and on the other side we implemented advanced query mechanisms that allow for content-based retrieval of 3D resources. In the following, we will describe the functionalities that we consider as the most interesting for perspective users.

4.1 Resource Management

Resource management includes uploading new resources and editing/removing existing ones. These are available to registered users only, to avoid unwanted content to be easily uploaded. The VVS provide access to unregistered users for visualizing and downloading resources, while for their management and upload an authentication is required. As an additional security measure, a specific committee is alerted by email upon any new user registration request and at every new upload.
Besides managing resources, registered users are allowed to create groups of users to enable a collaborative work on common resources.

4.1.1 Shapes

Registered users can upload new shape models either individually or as elements of *shape groups*. After the selection of the type of shape being uploaded (see Fig. 2), the user can enter metadata values to describe the shape itself. Finally, the shape model can be uploaded, possibly with a thumbnail image and additional accompanying material that might be useful to further describe the model.
If a user wishes to upload a fully-documented shape model, the whole process may take a while as the number of metadata values to be entered might be significant. For this reason, the system provides the possibility to store incomplete upload sessions that can be recovered and completed in a second time.

As mentioned in Section 3, when the selected shape category is *surface mesh*, the system activates a number of additional functionalities (thumbnail generation, MTF representation, GSE indexing, etc.). Since these functionalities proved to be particularly useful in DSW4, in this new version 5 it is possible to upload an accompanying mesh representation when the original model being uploaded is of another type (e.g. CAD parametric surfaces of boundary models). This makes it possible to enable the aforementioned additional functionalities for all the shape types for which a mesh representation makes sense.

4.1.2 Tools

As for shape models, software tools can be uploaded, updated and deleted by registered users through a similar procedure. The first step amounts to selecting the *category* of the tool being uploaded, which can be: *Web Service, Independent Application, PlugIn, Macro, Library*. After this first step, the user may upload a thumbnail image and enter metadata values. Differently from the shape repository, the tool repository stores metadata only, while the core data (i.e. the software tool itself) is stored remotely and linked to the repository through a URL. Note that linking a software's official Web page instead of replicating its contents guarantees a pointer to the most up-to-date version.

4.1.3 Ontology, metadata and glossary terms

The knowledge base represented by the ontologies and their individuals can also be managed. In particular, after having selected one of the available ontologies, registered users may modify or delete an existing individual, or can create a new individual along with its associated metadata. It is also possible to delete or add new ontologies to the repository, either by uploading an OWL file or by referring to the URI (Uniform Resource Identifier) of a published ontology. Through the same approach, ontologies which are already stored in the repository can be modified or updated. As for any other resource, existing glossary terms can be removed or modified, and new glossary terms can be added.

4.2 Resource Access and Retrieval

While ontologies, metadata and the glossary can be consulted by anybody, for shapes and tools some restrictions may take place depending on their specific access level (see Section 3).

4.2.1 Shapes

At the most abstract level, access to shape records can take place through *browsing*, *searching* and *downloading*. While browsing the repository, each shape's thumbnail is displayed in a small box along with few metadata and a brief description, while the full record is displayed by clicking on the box.

Specific shapes may be searched within the repository using different approaches. Through a *keyword-based* search, the user may look for specific keywords within the metadata. So, if meshes stored in OFF format are searched, the "OFF" keyword can be used to retrieve them. The results of the search may be sorted and filtered according to various criteria.

The VVS introduces an advanced query mechanism which allows users to retrieve models which are similar in shape to a given query model. This is particularly useful when the users have to set up different virtual scenes for which models are sought which resemble a given one. For this type of search, the user may exploit the *geometric search engine* introduced in section 3. In the GSE, the query model can be either uploaded or selected from the repository, and the user can choose among different approaches to compute the shape similarity. The GSE has been indeed designed to host various signature types, it can be incrementally modified, and accounts for a relevance feedback mechanism to refine the search. Note that content-based retrieval for 3D shapes is a very lively research area and the GSE provided by the VVS is actually a very promising service for testing and experimenting various alternatives to shape-based similarity.

Shape models can be also searched using the *semantic search engine* (see section 4.2.3) to focus on desired properties of the shapes within specific contexts (i.e. the domain ontologies).

4.2.2 Tools

With the exception of the GSE, the shape access functionalities described in section 4.2.1 are also implemented for the tools, though in this latter case there are more filtering options. While browsing, indeed, the user may filter based on the *tool category*, on the *functionality* provided, on the execution platform or on the physical infrastructure (i.e. VISIONAIR Institution or Lab) that provides the tool itself.

4.2.3 Ontology and metadata

Ontologies can be browsed in different ways, though any approach should allow the user to understand the domain being conceptualized. With this in mind, the VVS include a *hyperbolic tree viewer* which provides an intuitive interaction with the ontology (see Fig. 6).

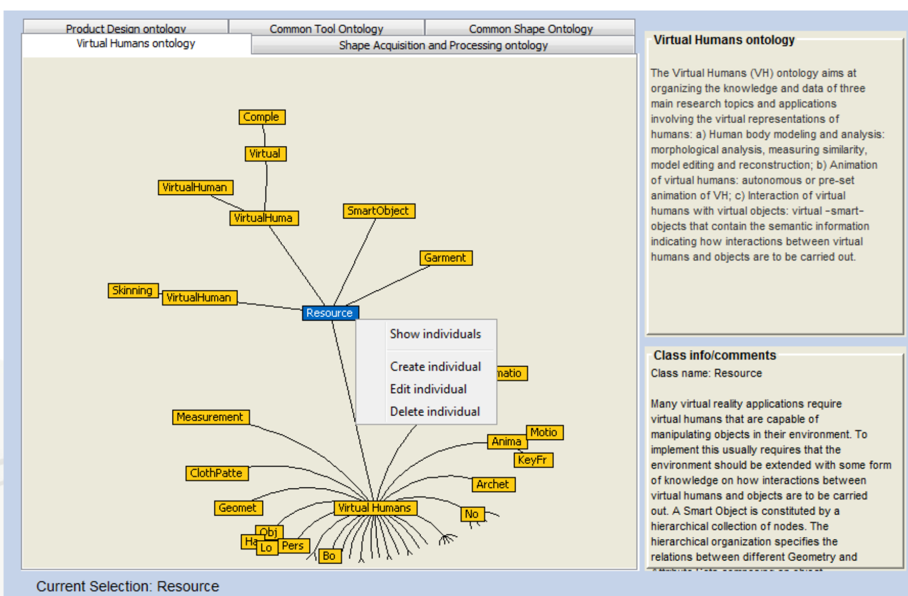

Fig. 6: Ontology navigation within the VVS hyperbolic tree viewer.

A *semantic search engine* (SSE) makes it possible to formulate very specific queries to retrieve individuals whose attributes meet a combination of requirements. For example, it is possible to ask the SSE to retrieve all the individuals within the Common Shape Ontology which are *manifold surface* meshes, and whose attribute **hasNumberOfConnectedComponents** equals 1. Note that individuals of the Common Shape Ontology are linked to the Shape repository through an attribute called **hasModelURL**, and this makes it possible to exploit the SSE to actually search shape models to be downloaded based on their semantics. Furthermore, a *reasoner* enables the SSE to retrieve also individuals whose semantic characteristics are not explicitly encoded but can be deduced.

4.2.4 Glossary

The glossary makes it possible to disambiguate the meaning of terms used within the VVS, and the functionalities provided are rather simple. A keyword-based search makes it possible to find the definition of a specific term in the glossary or, alternatively, the user may browse the repository based on the term's initials. To enable offline inspection, it is also possible to download the whole glossary as a single pdf document.

4.3 Automated Analysis and Inspection of Shapes

When accessing surface meshes, a user can exploit some additional features provided by the VVS, see Fig. 7. Besides downloading the original model, for example, it is possible to download a simpler version by specifying a *quality* value in the range 0-10. It is also possible to visualize a 3D thumbnail to have a quick preview of the model before downloading it, and the user may download a multi-resolution representation of the shape (i.e. a multi-triangulation as computed by the *TriMesh2MT* tool [8]).

Fig. 7: A snapshot of the shape repository displaying a shape's record along with its 2D and 3D thumbnails.

5 SUMMARY

The present paper illustrates the aim and the constituting facilities of the VISIONAIR infrastructure with particular focus on the Visualization Virtual Service. Within VISIONAIR, important European universities and research centers open the access to their laboratories to research groups who can benefit from advanced multisensorial visualization capabilities for checking and rendering their research outcomes or to better understand the underlying principles of the analyzed data. The access to the Physical facilities is supported both financially and technically based on the evaluation and acceptance of activity proposals in response to the VISIONAIR continuous call for Transnational Activities. The usage of the physical facilities is also supported by the Virtual Visualization Service. The VVS offers access to useful shape resources for either algorithm testing or scene preparation. In addition it offers a good means for all the research community and commercial systems developers for disseminating and re-using research results on shape-related data visualization and processing by making available software tools.

AKNOWLEDGMENTS

This work has been partially supported by the European Commission under grant agreement 262044 VISIONAIR. The author wants to thank Prof. Bianca Falcidieno and all the participants to the AIM@SHAPE NoE for making possible the initial version of the Digital Shape Workbench and Ing. Lino Ferrentino and Dr. Daniela Giorgi for the implementation and design of the Geometric Search Engine capabilities.

REFERENCES

[1] Senay, H.; Ignatius, E.: A Knowledge-Based System for Visualization Design, IEEE Computer Graphics and Applications, November 1994, 36-47.

[2] Foley, J.; Ribarsky, B.: Next-generation Data Visualization Tools, in Scientific Visualization, 1994, Advances and Challenges, Academic Press.

[3] Brodlie, K.W.; Carpenter, L.A.; Earnshaw, R.A.; Gallop, J.R.; Hubbard, R.J.; Mumford, A.M.; Osland, C.D.; Quarendon, P.: Scientific Visualization, Techniques and Applications, Springer-Verlag, 1992.

[4] VISIONAIR: VISION Advanced Infrastructure for Research, http://www.infra-visionair.eu/

[5] AIM@SHAPE Advanced and Innovative Models And Tools for the development of Semantic-based systems for Handling, Acquiring, and Processing knowledge Embedded in multidimensional digital objects, ContractFP6 IST NoE 506766, www.aimatshape.net

[6] Vasilakis G., Garcia-Rojas A., Papaleo L., Catalano C. E., Robbiano F., Spagnuolo M., Vavalis M., Pitikakis M. Knowledge-Based Representation of 3D Media. In: International Journal of Software Engineering and Knowledge Engineering, vol. 20 (5) pp. 739 - 760. World Scientific Publishing Company, 2010. DOI: 10.1142/S0218194010004773

[7] Borgo, R.; Dellepiane, M.; Cignoni, P.; Papaleo, L.; Spagnuolo, M.: Extracting meta-information from 3-dimensional shapes with protégé, in 8th International Protégé Conference Proceedings (July 2005). Madrid, July 18-21 2005.

[8] Danovaro, E.; Papaleo, L.; Sobrero, D.; Attene, M.; Saleem, W.: Advanced Remote Inspection and Download of 3D Shapes, in Proceedings of Web3D'07, 15-18 April 2007, Perugia, Italy, ACM Press, pp. 57-60, 2007.

[9] Albertoni, R.; Papaleo, L.; Robbiano, F.: Preserving Information from Real Objects to Digital Shapes, In: Eurographics Italian Chapter Conference (Trento, Italy, 14-16 February 2007). Proceedings, pp. 75 - 87. R. De Amicis, G. Conti (eds.). The Eurographics Association, 2007.

[10] Gutierrez, M.; Garcia-Rojas, A.; Thalmann D.; Magnenat-Thalmann N.; Mortara M.; Spagnuolo M.; Moccozet L.; Vexo, F.: An ontology of virtual humans, Visual Computer, 23(3) 2007, 207 - 218. **DOI:** 10.1007/s00371-006-0093-4

[11] Catalano, C.E.; Camossi, E.; Ferrandes, R.; Cheutet, V.; Sevilmis, N.: A product design ontology for enhancing shape processing in design workflows, Journal of Intelligent Manufacturing, 2009, 20(5), 553-567 **DOI:** 10.1007/s10845-008-0151-z

[12] Pellet, http://clarkparsia.com