Introduction/summary

AIM@SHAPE aims at coordinating research on representing, modelling and processing knowledge related to digital shapes, where by **shape** it is meant any object having a visual appearance and which exists in some (two-, three- or higher- dimensional) space (e.g., lines, sketches, images, 3D objects, videos, 3D animations, etc.). **Digital shapes** are digital representations of either physically existing objects or virtual objects that can be processed by computer applications.

The Partners are research or academic institutions with background expertise in Computer Graphics and Computer Vision.

AIM@SHAPE focuses on the development of ontologies for the description of resources relevant in the context of Computer Graphics and Vision through metadata derived by the ontologies. Within the broader and vast context of Computer Graphics and Vision (CG&V), the ontology development has considered three more focused domains of application of CG&V techniques:

- Virtual Humans
- Product Design
- Acquisition and Reconstruction processes.

The development on each ontology advances independently from that on other, but all share some common knowledge related to shape **models** (e.g., 2D or 3D images, 3D meshes, implicit surfaces, lines, 3D animations, video,..), shape **structures** (e.g., segmentation of a shape into meaningful components, skeletons, ..) and **tools** (e.g., code for processing shapes, libraries of routines, plug-ins). So the shape models and tools constitute **common** knowledge which has to be represented and accessed in all domain ontologies. For example, in a file representing a shape, there is some metadata information which is common to any kind of shape regardless of the domain and should be shared in all domain ontologies because all deal with this kind of information (e.g. geometrical information). In a specific domain, a shape has this common metadata information plus some extra metadata information which is specific to that specific domain only. This common metadata information is represented and captured by a **common ontology** which describes the concepts that will be shared by all domain ontologies. Therefore, in the analysis of the requirements for the “minimum set” we have considered the requirements with respect to this AIM@SHAPE “common ontology”.

For what application are you using/plan to use a multimedia ontology (e.g. annotation, retrieval, media production, summarisation etc)?

Main application: description of resources according to metadata derived by domain ontologies (within the context of CG&V) finalized to the retrieval and sharing of resources. Retrieval and sharing are used to support the creation of an e-science platform for algorithm benchmarking, re-usability of tools, documentation, media production.

Reference to your web site and/or publications describing the applications

AIM@SHAPE web site: http://www.aimatshape.net
Relevant Publications:

Falcidieno, Bianca; Spagnuolo, Michela; Alliez, Pierre; Quak, Ewald; Houstis, Catherine; Vavalis, Emmanuel. *Towards the semantics of digital shapes: the AIM@SHAPE approach*. In: European Workshop on the Integration of Knowledge, Semantic and Digital Media Technologies, IEE Royal Statistical Society, London (2004)

Abaci, Tolga; Mortara, Michela; Patanè, Giuseppe; Spagnuolo, Michela; Vexo, Frederic; Thalmann, Daniel. *Bridging Geometry and Semantics for Object Manipulation and Grasping.* In: Proceedings of the Workshop towards Semantic Virtual Environments Villars, Switzerland pp.110-119 (2005)

Albertoni, Riccardo; Papaleo, Laura; Pitikakis, Marios; Robbiano, Francesco; Spagnuolo, Michela; Vasilakis, George. *Ontology-based Searching Framework for Digital Shapes*. In: Lecture Notes in Computer Science - Applications of Semantic Web II (SWWS), Springer-Verlag GmbH pp.896-905 (2005)

Gutierrez, Mario; Thalmann, Daniel; Vexo, Frederic; Moccozet, Laurent; Magnenat-Thalmann, Nadia; Spagnuolo, Michela. *An Ontology of Virtual Humans: incorporating semantics into human shapes*. In:

Proceedings of Workshop towards Semantic Virtual Environments (SVE05), pp.57-67 (2005)

A.Garcia-Rojas, D. Thalmann, F. Vexo, L. Moccozet, N. Magnenat-Thalmann, M. Mortara, M. Spagnuolo, M. Gutierrez. *An Ontology of Virtual Humans: Incorporating Semantics into Human Shapes*, 2nd European Workshop on the Integration of Knowledge, Semantic and Digital Media Technologies (EWIMT05). November 30-December 1,2005

Requirements of the "minimum set" involving the analysis of:

Scope and Usage including

Building up on the requirements of the common ontology in AIM@SHAPE, the "minimum set" should be used for the :

- *Annotation of shape models, structures and tools*, finalized to storing the resources in a shared repository and to completely document :
    - the *models*, with information regarding the different properties of the different types of digital models (e.g., triangle mesh, B-rep, image, algebraic surface and so on);
    - the *tools*, with information regarding the task solved by the tool, the input/output types (e.g., meshing implicit surfaces, mesh reconstruction from point clouds, and so on);
    - the *structures*, with information regarding the process of creation/definition of the structure and its relation to the original shape;

- *Analysis of shape models,* finalized to the classification and understanding of shapes (semantic analysis of the shape, where the semantic context varies from the geometric/mathematical one to any specific domain such as Virtual Humans)

- *Reasoning on shapes, tools and structures*
- *Retrieval of shapes, tools and structures*
- *Comparison and similarity evaluation between shape models*

Resources/Concepts including information on what concepts you need to describe, for example:

- images (2D and 3D, range images as well as intensity images)
- videos
- 3D models of shapes
  Examples of 3D models are triangle meshes, NURBS, point clouds, implicit surfaces, virtual humans, and many more. Each of these models has specific characteristics/properties that have to be described.
- animation of 3D objects (i.e, a cynematic/dynamic model is associated to a 3D shape)

- segmentation of 3D models into meaningful parts, or features (e.g., a virtual human is decomposed into its main body parts); note that the same 3D model can be decomposed in different parts according to the related domain of knowledge
- skeletonization of 3D shapes (e.g., a 3D "volumetric" shape is associated to a graph-like structure composed of lines only, as for example the medial axis transform represents a polygon in 2D)
- tools, which vary from single-task programmes (*atomic* tools) to libraries or plug-ins; tools may be compund in workflows
- workflows of interest for a researcher working in the CG&V field (e.g., how to reconstruct a 3D shape from a set of range images obtained scanning a physical object)
- acquisition devices for the digitalization of 3D shapes

Links to domain models - vocabularies;

- AIM@SHAPE makes use of a glossary developed by the Partners, which defines the most relevant terms in the domains addressed;

Requirements for cross-domain linking, if applicable

- the three domain ontologies in AIM@SHAPE are linked via the so-called AIM@SHAPE common-ontology which describes the common knowledges and resources; further, other domain ontologies could be linked within CG&V as well as from different application fields such as CAD, cultural heritage, medicine, entertainment, and in general any other application field which requires the description of 3D shapes.

Tools (e.g. annotation, reasoning)

- Annotation tools, for the automatic extraction of shape model metadata are being developed by AIM@SHAPE, for example, the plugin called TriMeshInfo for the ontology editor Protege which automatically computes attributes for 2D and 3D triangle-based shape representations (e.g., manifoldness, number of vertices, edges, triangles, and so on);

Languages - standards

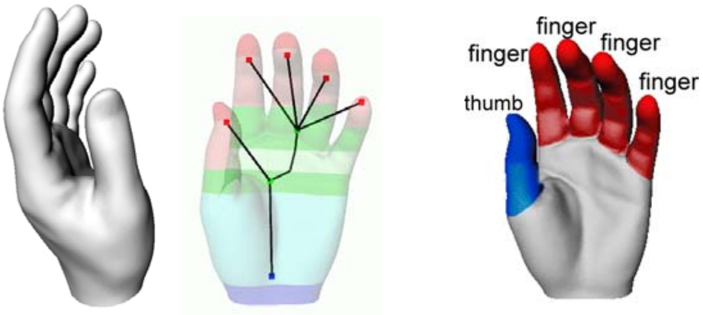
- the semantic web standards, languages, and technologies as the ones we are using in AIM@SHAPE: OWL, Racer or other reasoner, JENA etc.
- MPEG-7, and H-ANIM in particular for the description of virtual humans;

User preferences, policies, constraints

- the resources shared in AIM@SHAPE are covered by a licensing scheme that is inspired to the Creative Common (http://creativecommons.org/licenses/by-nc-sa/2.0/); some of the models are covered by copyrights and industrial constraints and can be shared only within the consortium
- a user policy is adopted to give different privileges to the participants wrt uploading,downloading, editing, creating and deleting ontology instances and the related *physical* resources (e.g., shape models and tools)

Identification of the characteristics to be represented: this will probably include characteristics such as:

The approach of AIM@SHAPE focuses on the distinction of three basic levels of representation of the knowledge embedded in digital shapes: geometric, structural and semantic. A purely geometry-based representation of a digital shape can be used for example to view the shape, rotate it, zoom in and out (a); a structural view gives hints on how relevant shape segments are linked together (b); a semantic view is able to propose an interpretation or meaning of the digital shape (c). The characteristics to be represented in the "minimum set" include all characteristics relevant at least at the geometric and structural level.



(a) (b) (c)

At the geometric level, different types of geometric models can be used to represent the same object's form. As examples we can list, polygons, surface models (splines, NURBS,..), solid models (3D mesh, Brep, CSG, …), 4D models (animations, multi-dimensional scalar fields, ..). In a geometric model, topological and geometric information are coded in a computer processable structure.

AIM@SHAPE has already produced an ontology of the geometric representation of shapes, which can be used as a basis for the 3D part of the "minimum set".

The structural level is reached by organising the geometric model in order to reflect and/or make explicit the association between parts/components of shape geometric models or shape data. If the organisation is geometry-oriented we can cite as examples: multi-resolution models, multi-scale models, curvature based surface decompositions, networks of critical points and lines, etc. If the approach is oriented towards shape understanding, we can list: shape segmentations, pattern or cluster based structuring, form features (e.g., protrusion, depressions, holes, ..), topological and morphological decompositions etc. There are different possible structures for describing a shape model (see (b) for an example).

AIM@SHAPE is planning to develop a conceptualization of the structural level of shape representation, and this will surely include the modelling of the spatial relationships between shape parts/segments.

At the semantic level, there is the association of a specific semantics to structured and/or geometric models through annotation of shapes, or shape parts, according to the concepts formalised by the domain ontology. For example, in the manufacturing domain, the association of the semantics to a product model is done through the detection of all the shape features which have a specific definition in the manufacturing ontology (e.g., slots, steps or notches). Therefore, a semantic model is the representation of a shape embedded into a specific context (see (c)).

A challenging aspect of the expected reasoning capabilities based on the AIM@SHAPE ontologies is related to the possibility of answering competency questions related to the expert knowledge needed to process shape models, in typical scientific workflows such as acquiring a shape from the real world, defining a digital model from the acquired data, interactively modifying the digital shape, adding/substituting parts using existing models, and so on.

It is therefore important to be able to describes characteristics of the *tools* for shape processing.

Harmonisation approaches :

(Extracted from section 1 of the D1.2.2 AIM@SHAPE deliverable)
Ontology development does not constitute a new approach to knowledge representation and management. Nevertheless, its popularity has recently grown and more and more new technologies seem to revolve around it. The motivation behind the development of an ontology for a particular domain of interest falls in the following areas:

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

Ontology development still remains a not well understood process. This is due to the sheer size of the knowledge we are usually faced with, for a specific scientific domain, and the complexity of the problem of storing and managing this knowledge in a flexible and efficient way. During the ontology creation process we have to bring together different perspectives on the domain and reach a consensus within a group with different backgrounds. Also, because of the nature of the problem ontology development is a rather subjective matter. The last observation means that there is not a single correct ontology for a specific domain. The resulting ontology structure depends on usage, scope, anticipated extensions, etc. If for example we foresee it to change rapidly we should put emphasis on following a basic and general approach so that changes can be easily applied.

Much like in the design of object-oriented software, there is not a single correct methodology for designing and building an ontology. There are, however, a few methodologies that are well established and seem to perform better than others. In AIM@SHAPE we will be using the OntoKnowledge methodology[1], shown in Figure 1.

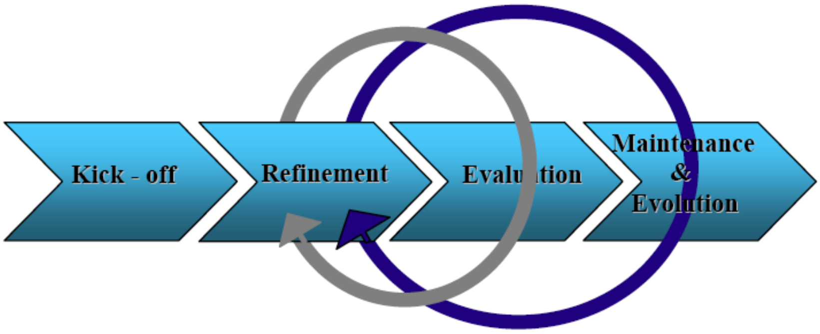


Figure 1. The OntoKnowledge methodology

The OntoKnowledge methodology defines an iterative process comprised of four phases:

Kick-off phase: Capturing the ontology

[1] http://www.ontoknowledge.org

The kick-off phase is probably the most important phase because as a result of this phase we formulate a first concrete idea of how the ontology structure is going to be. This can be seen in Figure 1, where the kick-off phase is the only one where iteration does not take place. There are two steps in this phase. During the first step the concepts that will structure the ontology will be identified as well as how they are related to one another. This step identifies the domain of the ontology, some usage scenarios, knowledge sources (domain experts, glossaries and dictionaries, etc.), potential users and applications and basic questions the ontology should be able to answer. These basic questions are called Competency Questions (CQs) and essentially constitute expressiveness requirements for the ontology. CQs indicate the scope of the ontology and are also used as reference during the evaluation phase. Ideally, CQs should be defined in a modular manner, so that higher level (more complex) questions are comprised of lower level questions (less complex).In the second step we build a semi-formal hierarchy of the concepts and relations in the ontology structure. Three different approaches exist for this stage. The top-down approach models the most general concepts first and then produces more refined concepts. This approach produces a high-quality, fine-grained ontology but may not cover all domain information. The bottom-up approach identifies the most specific concepts first and produces generalizations to obtain the higher level concepts. This approach produces an ontology that is less-detailed than that produced by the top-down approach, but is more complete and addresses all available domain information. The middle-out approach identifies the most important concepts and obtains the rest either by specialization or generalization. This is the most natural approach, concentrating on what is important and better controlling the desired level of detail.

Refinement phase

In the refinement phase a representation language is chosen and the ontology is recorded in a formal manner. The result of this phase is a formal representation of the ontology described in the previous phase. Possible representation languages include RDFS, DAML+OIL, OWL and others. What makes a representation language appropriate or not is its expressive power and its support for reasoning.

Evaluation phase

During the evaluation phase the ontology is constantly checked to evaluate its compliance with the expectations/requirements. Usage scenarios, requirements specifications and competency questions are used as reference for the evaluation.

Maintenance and Evolution phase

During this phase several maintenance tasks are performed as the ontology changes and evolves. The ontology development process as described is shown in Figure 2.

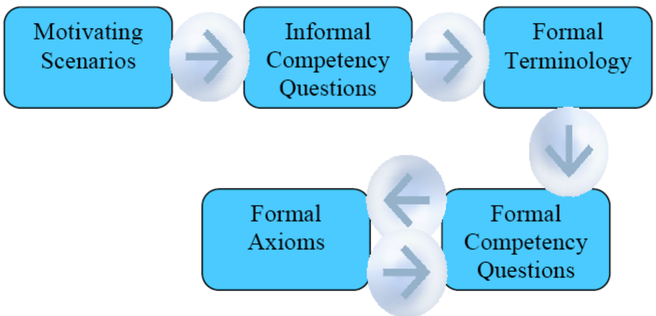


Figure 2. The ontology development process