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

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Ontology for Virtual Humans 3rd version

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Document History

Vers.	Issue Date	Stage	Content and changes
1	15 December 2006	50%	Start the report
2	21 December 2006	70%	First draft
3	5 January 2007	90%	Added the sections 1.2 and Introduction
5	10 January 2007	90%	Complete draft.
6	17 January 2007	95%	Integration of modifications proposed by ITI
7	13 February 2007	100%	Final

Executive Summary

This document contains a description of the deliverable **D1.2.1.1** of the IST NoE AIM@SHAPE. The deliverable ***D1.2.1.1 – Ontology for Virtual Humans 3rd version*** – is intended to provide a third version of the ontology for Virtual Humans which is in development within the network.

The task leader is **EPFL** and is actively supported by all other AIM@SHAPE partners.

For a better comprehension of this document we recommend to read the First and Second version of the Virtual Human ontology (D1.2.1.1).

This document is structured as follows:

In the introduction we give a summary of the evolution steps in the different versions of the ontology. Section 1 presents the modifications made in the ontology during this period; section 2 presents a short overview of the ontology; section 3 presents a list of competency questions and their status; finally, section 4 presents conclusions of the document an the future work for the ontology's evolution.

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INTRODUCTION

In this document we present the Virtual Human Ontology (VHO) 3rd version. At this time, the evolution of the ontology resides in its validation using competency questions (CQs). In the previous version of this document we presented the procedure to answer CQs using the search engine and use cases. This procedure has remained the same, and the ontology has undergone some changes in order to be able to answer new CQs.

For a better understanding of the ontology's evolution we have enumerated some steps that correspond to the different versions of this document. The evolution steps made in the second version of the VHO were:

- Migration to the Common Shape Ontology classes
- Inclusion of specific classes and metadata of types of animation
- Answering of high level questions related to animation
- Consideration of standards like H-Anim in the structural descriptor of virtual humans
- Presentation of two use case scenarios using our competency questions, where we used the ontology to provide solutions.

In this third version we are going present the following evolution steps:

- Answering of high level questions related to the VH structure, which lead us in making several modifications in the ontology, as presented in section 1.1.
- The inclusion of facial animation within MPEG-4 standard, which was a joint collaboration with HUMAINE NoE, as presented in section 1.2.
- New concepts for the Virtual Human controller, where we consider the inclusion of the common tools ontology, as presented in section 1.3.

After the presentation of the evolution of the ontology in the next section, we present in section 2 an overview of the content of the ontology. In section 3 we give a list of the CQs we have answered until now. Finally in section 4, we present the conclusions and some future evolution steps.

1 ONTOLOGY EVOLUTION

In the first part of this section, we are going to present some changes made in the VHO that aim to provide better organization of the structural descriptor of VHs. In the second and third parts we present new modelling of virtual human's features, such as facial expressive animation and virtual human controllers.

To better describe the VHO we are making use of visual aids to differentiate levels and components of the ontology. In figure 1 there is the explanation of the meaning of the visual nomenclature used.

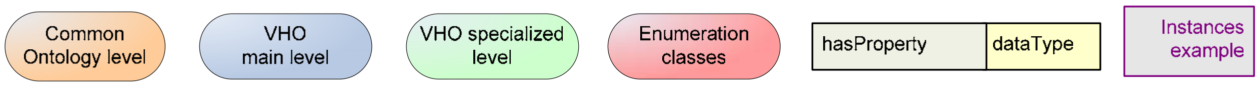

Figure 1 Nomenclature of visual aid

1.1 Modelling the Structural Descriptor

One issue that affected the extensibility of the ontology is the assumption that we could have mostly H-Anim structures, which is certainly not the case. Thus, we needed to provide generic terms and possibilities to declare any kind of structure, not only a skeletal one. In figure 2 we present the previous diagram of the structural descriptor.

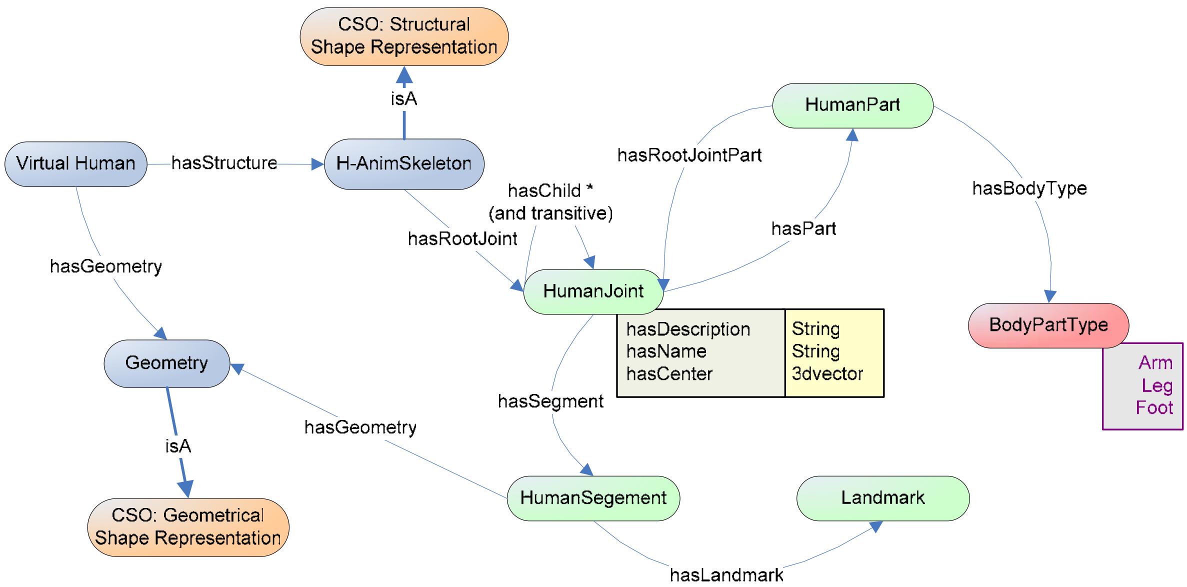

Figure 2 Previous structural definition of VHs

Therefore, we decided to group the nodes of the structure in a generic class called Node, and create subclasses to refer to specialized nodes like Joints, Landmarks, and Segments. In this way we allow the possibility of declaring other kinds of nodes that compose the structural descriptor. In figure 3 we present the diagram with the proposed new structure.

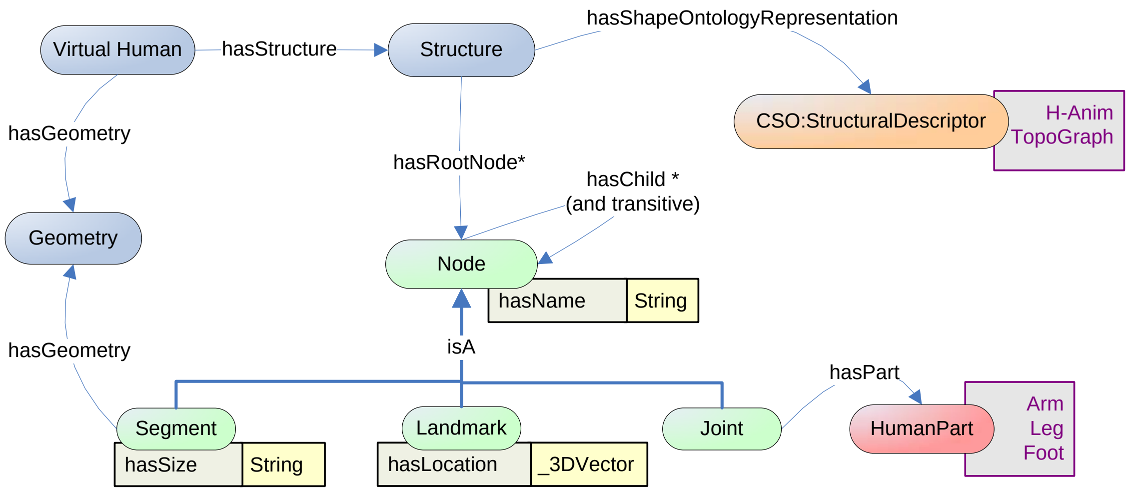

Figure 3 New structural descriptor for VHs

Joints are associated with each other using the *hasChild* relation; the transitiveness of the *hasChild* property allows exploring the hierarchical skeletal structure of the VH without the need of querying each node in the structure. For example, if we want to get a VH that has a head, we need to get a joint which is associated with the Human part head OR a joint which *hasChild* joint (transitivity) which is associated with the Human part head, and we can create the following expression to answer this question:

```
Structure ⊓ (∃ hasNode (Joint ⊓ (hasPart • HumanPart_head))))
```
OR
```
Structure ⊓ (∃ hasNode (Joint ⊓ (∃ hasChild (hasPart • HumanPart_head)))))
```

Therefore, the fact that a VH can have a complete body can be automatically inferred by the reasoning in the ontology. We define a subclass of *VirtualHuman* class called *VHwithCompleteBody*, and add the following necessary and sufficient condition:

```
∃ hasStructure (Structure ⊓
(∃ hasNode (Joint ⊓ (hasPart • HumanPart_Pelvis))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_head))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_Trunk))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_RightLeg))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_LeftLeg))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_RightHand))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_LeftHand))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_LeftFoot))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_RightFoot))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_RightArm))))) ⊓
(∃ hasNode (Joint ⊓ (∃ hasChild (Joint ⊓ (hasPart • HumanPart_LeftArm ))))))
```

This means that *VHwithCompleteBody* are all *VirtualHuman* that have a Structure that has all *HumanParts*. With this condition, the ontology will automatically classify as *VHwithCompleteBody* all virtual humans that accomplish this restriction. This class helps to answer some CQs presented in section 3.

Concurrently with validations, we have also added new semantics to some concepts in order to complete the ontology; they are presented in the next subsections.

1.2 Modelling a Virtual Human's Facial Animation

As part of the evolution steps, we have considered to include components in the ontology that describe facial animation, specifically emotion expressive animation. In [1], we have presented an ontology that describes some research in facial animation. This ontology aims to represent the research of Raouzaiou et al. [2], who have used the MPEG-4 framework to synthesize facial expressions based on discrete and dimensional emotion representation models.

The goal of including these features in the VHO is to be able to provide specific (expressive) information of this kind of animation. Then, the competency question of our ontology can be extended with this kind of questions:

- What are the facial animations for expressing the emotion of sadness?
- What kinds of anger expressions do we have?

MPEG-4 specific questions are:

- What is the range of FAP values for the following emotions: worried, terrified?
- Given a set of FAP values, what is the emotion that can be produced?

In MPEG-4 [3], a face shape is defined by the facial definition parameters (FDP) and facial deformation tables (FDT) nodes. FDPs contain the feature points in the face shape and the FDT contains the deformation of the model face as a function of its animation. A VH face specifies 84 feature points on a neutral face as presented in figure 4. They provide spatial reference for the Facial Animation Parameters (FAPs). For animating a face, a FAP node has the translations of feature points, expressed in FAP Units; they can produce high quality facial expressions and speech pronunciation.

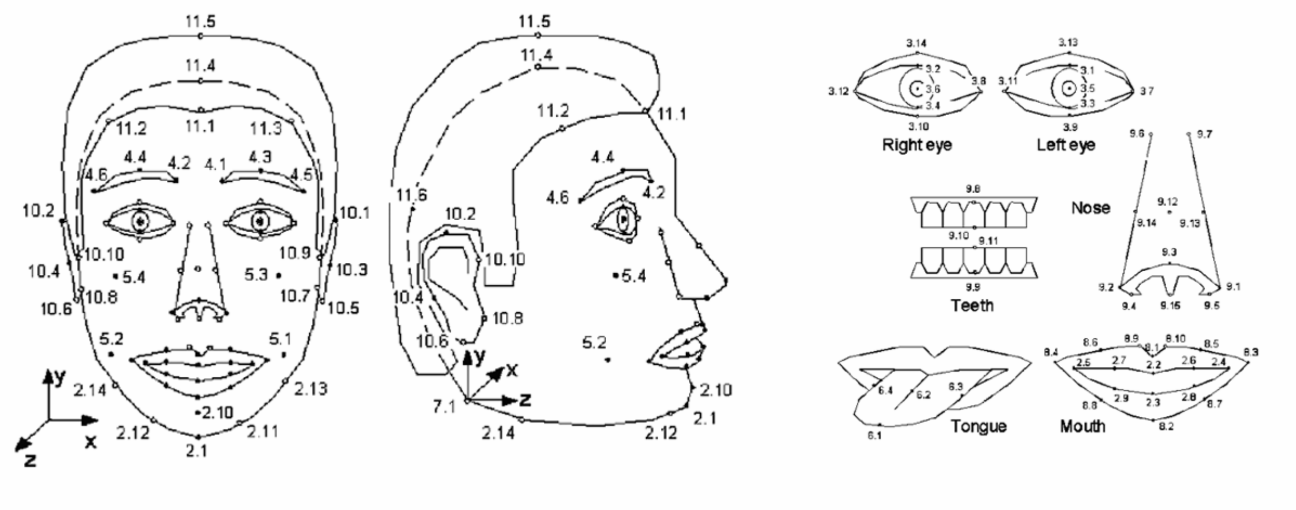

Figure 4 Face Feature Points

Depending on the context of interaction, one might prefer to choose a discrete emotion representation model, such as Ekman's, over a dimensional one. Ekman's model of emotion [4] has been widely accepted to describe the six archetypal emotions: sadness, anger, joy, fear, disgust and surprise. In general, archetypal expressions can be uniformly recognized across cultures, and they are therefore invaluable when trying to analyze the user's conditional state. In MPEG-4, for each one of these emotions, a list of FAPs can be associated to it (those FAPs that are animated to produce the specified emotion). These expressions occur rather infrequently, and in most cases emotions are expressed though a variation of a few discrete facial features related with particular FAPs. Moreover, each one of the described emotions can have more than one expression.

Based on elements from psychological studies and from statistical analysis using FAPs, we can describe 25 archetypal facial expressions grouped into the six emotions. In table 1 we present an example of the profiles created for expressing sadness and fear with their ranges of FAP values. The FAPs are represented by the letter "F" and the number that belongs to it, for example, F1 is the FAP one: close_t_l_eyelid, witch represents a vertical displacement of top left eyelid. Sadness has only one profile and fear has nine (nine ways to represent the emotion of fear). In [2], Raouzaiou et al. present the complete list of all archetypal expression profiles and the associated FAP range values.

Profiles	FAPs and range of variation
Sadness (P_S^0)	$F_{19} \in [-265, -41]$, $F_{20} \in [-270, -52]$, $F_{21} \in [-265, -41]$, $F_{22} \in [-270, -52]$, $F_{31} \in [30,140]$, $F_{32} \in [26,134]$
Fear ($P_F^{(0)}$)	$F_3 \in [102,480]$, $F_5 \in [83,353]$, $F_{19} \in [118,370]$, $F_{20} \in [121,377]$, $F_{21} \in [118,370]$, $F_{22} \in [121,377]$, $F_{31} \in [35,173]$, $F_{32} \in [39,183]$, $F_{33} \in [14,130]$, $F_{34} \in [15,135]$
...	...
Fear ($P_F^{(4)}$)	$F_3 \in [400,560]$, $F_5 \in [-240, -160]$, $F_{19} \in [-630, -570]$, $F_{20} \in [-630, -570]$, $F_{21} \in [-630, -570]$, $F_{22} \in [-630, -570]$, $F_{31} \in [460,540]$, $F_{32} \in [460,540]$, $F_{33} \in [360,440]$, $F_{34} \in [360,440]$, $F_{35} \in [260,340]$, $F_{36} \in [260,340]$, $F_{37} \in [60,140]$, $F_{38} \in [60,140]$
...	...

Table 1 Archetypal emotions and FAP values

To represent this information in the ontology, we have created classes for MPEG-4 concepts. Moreover, we create the FAP ranges that are related with facial expressions. In figure 5 we present a diagram of these classes integrated in the VHO. The classes in the rectangle are the already existing classes of the ontology, and the others are the new ones.

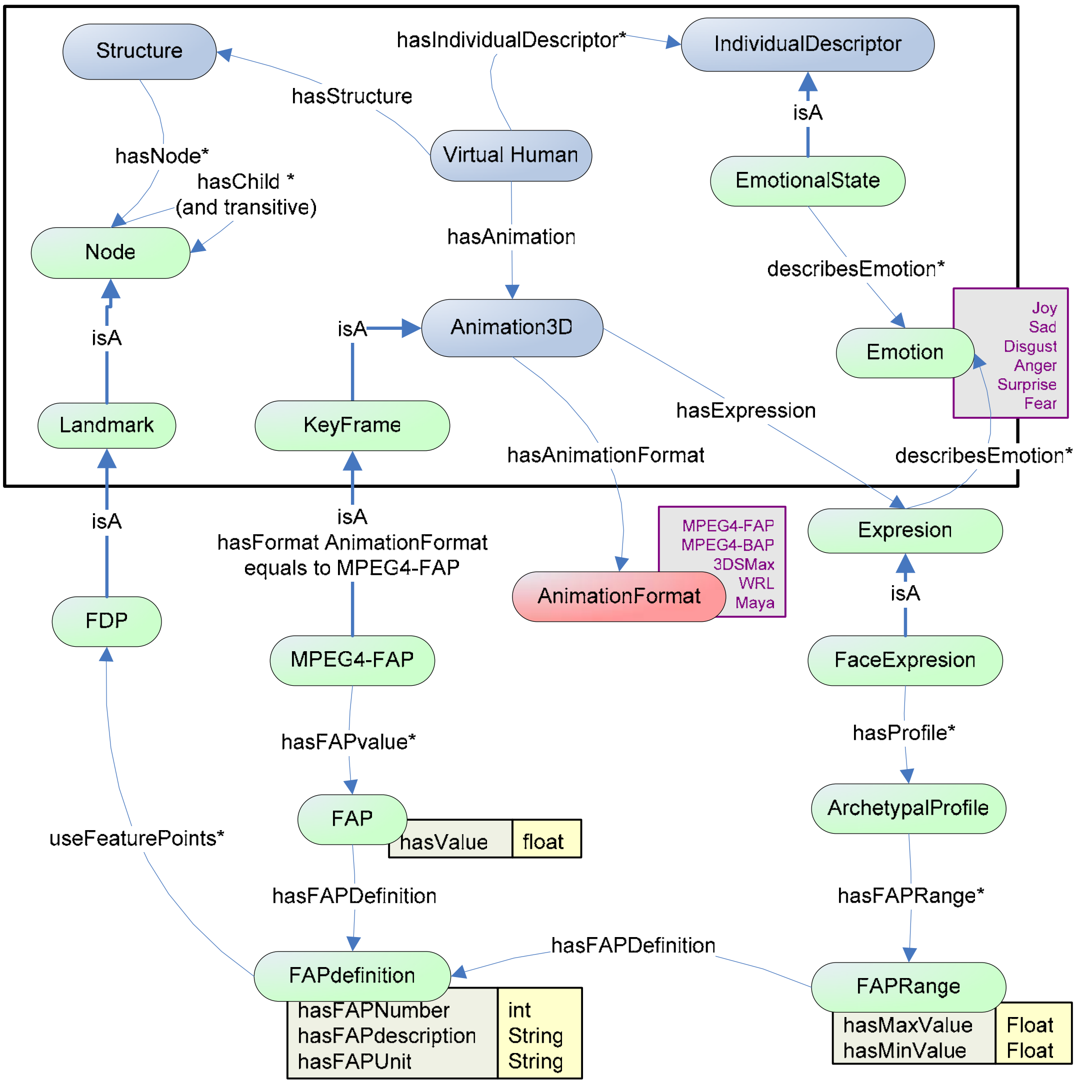

Figure 5 Modeling MPEG-4 facial animation

The *MPEG4-FAP* class is a *KeyFrame* animation that has a property value of *hasAnimationFormat* equal to *MPEG4-FAP_AnimationFormat*, expressed in the form of a restriction like:

```
MPEG4-FAP isA KeyFrame • hasAnimationFormat MPEG4-FAP_AnimationFormat
```

The classes for MPEG-4 *FAP*, *FDP* and *FAPdefinition*, describe the content of the facial animation key frame type. The *Expression*, *FaceExpression* and *FAPRange* classes describe the type of expression that describes an emotion through FAP values.

It is possible to make an automatic classification of FAP files onto a Facial expression. We need to add rules that evaluate if the animation uses FAP and FAP ranges that are contained in an Archetypal profile, in which case the animation expresses the same emotion as the Archetypal profile.

The actual structure of the ontology allows for integrating more different descriptions of animation formats for Face and Body. Some research has been done in [5] to include body expressions as well, however this is still work in progress.

1.3 Modelling Virtual Human's Controllers

In the previous versions of the ontology, we have considered *BehaviourController* like classes that contain algorithms used to produce behavioural animation. In that class we specified inputs that are required for the algorithm to work and outputs that the algorithm is capable to produce, which are usually animation sequences or specific joint values. With the future integration of the tools ontology, this kind of algorithm can be extended to any kind of implementation used to animate virtual humans, not only behavioural animations. Therefore, to be more generic, we have changed the *BehaviorController* class name to *VirtualHumanController*. Controllers can be any kind of tool as specified in the Common Tools Ontology. We have specified that a *VirtualHumanController* has a property called *hasControllerPurpose* which domain is a ControllerPurpose enumeration. This enumeration has the following instances: Cinematic, Physical, Cognitive, Path Planning, Skinning, Sensorial, Gesture, and so on. Also this class can have some requirements such as a specific definition of a virtual human, another controller, or some animations. A diagram of the *VirtualHumanController* is presented in figure 6.

Considering the generalization of controllers, we have removed the *Sensor* class from the ontology, because it is now encapsulated by the *VitualHumanController*. As presented in [6], the virtual human controllers can be used for different purposes and one may serve as input for another; such purposes can be: Kinematic, Gesture, Cognitive, Behaviour, Skinning, etc.

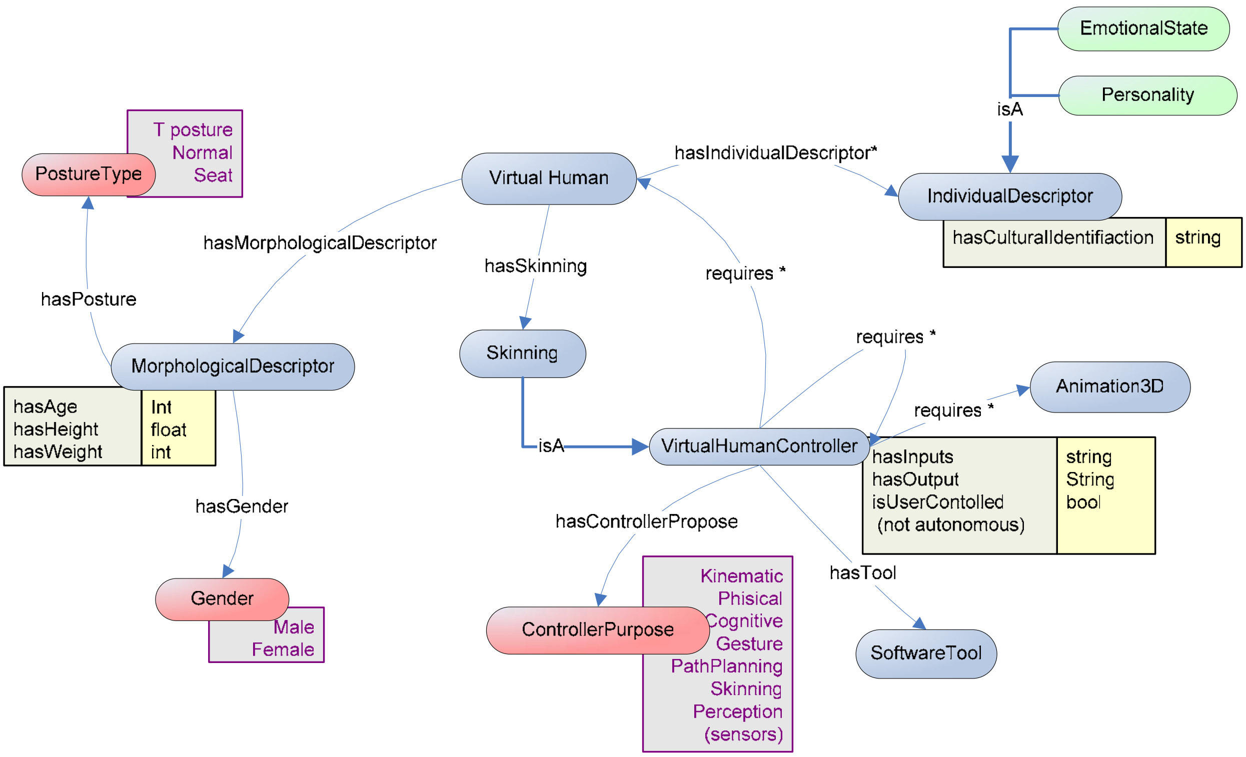

Figure 6 Diagram for the Virtual Human Controller

2 Ontology Overview

In the previous version of this document, we presented the concept of Resource to describe those VH features that share properties like version, author, fileInfo and description. That is the case for a *VirtualHuman*, a *SmartObject* and a *VirtualHumanController* class, as presented in figure 7.

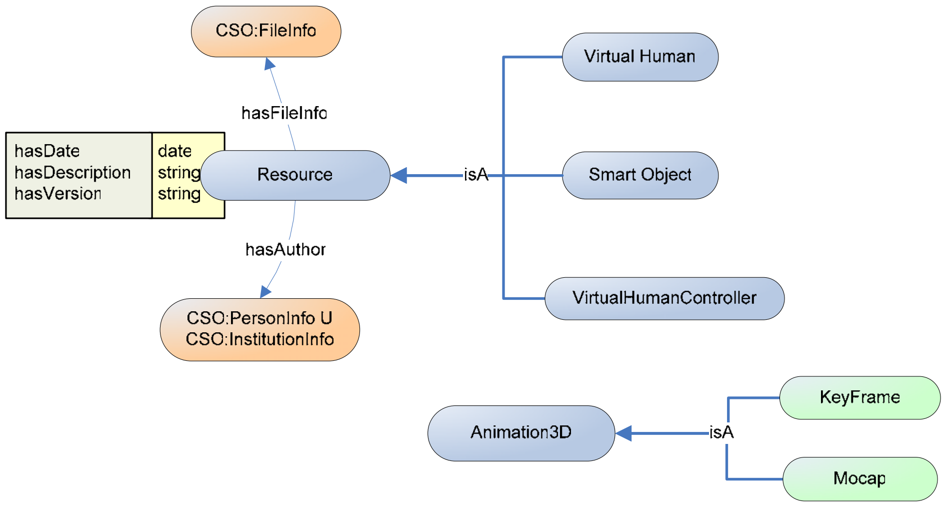

Figure 7 Ontology main Components

The animation3D class is also a main component in the ontology, but in this case it does not have properties like version or author, and as it has a direct representation on the CSO. In figure 8 we present the *VirtualHuman* class with the main properties, and its relationship with the CSO and the CTO taking into account the changes of this period.

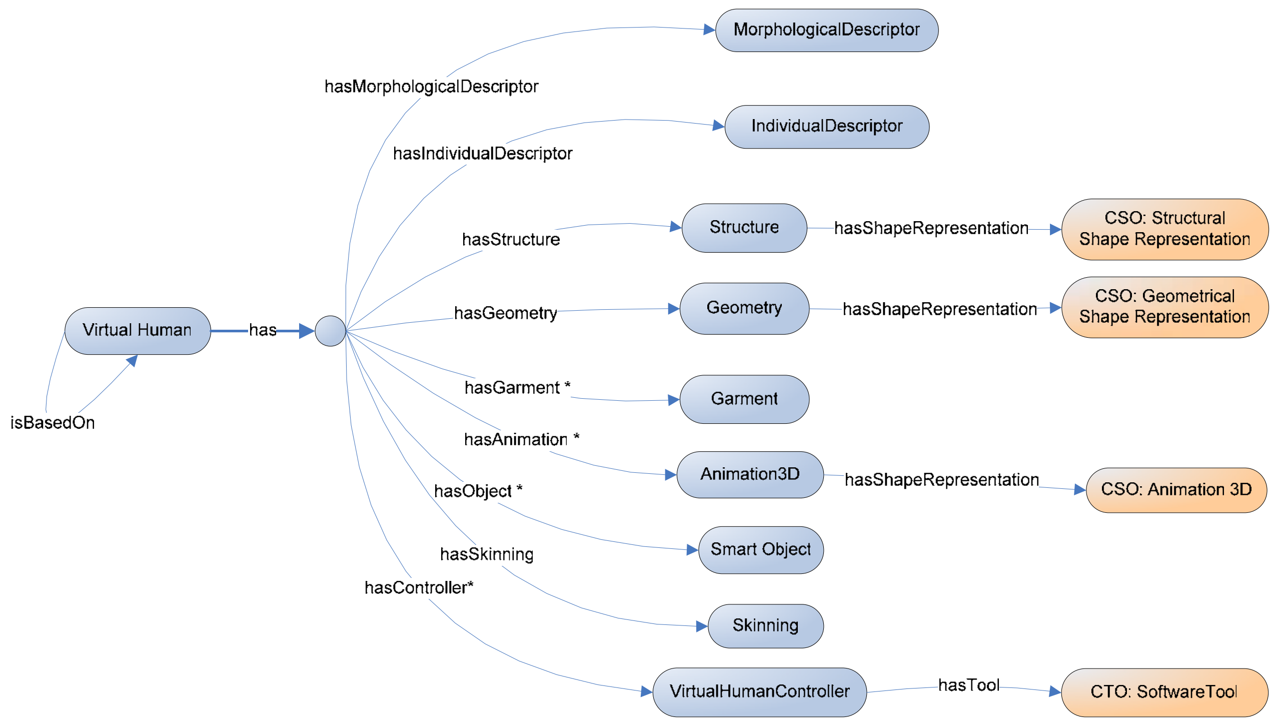

Figure 8 Ontology of VH

3 CQ STATUS

The CQs are an important means to validate that the ontology fulfils its objectives. In [7], we have presented one scenario where people are able to create their own VH based on a set of questions formulated and posed to the ontology using the tools provided within the network [8]. This procedure has also been presented in the previous deliverable.

During the validation of the ontology, we have identified that the history of a virtual human has been considered in a very simple way through the property *isBasedOn* another virtual human. This approach to history information is very limited in the sense that it does not provide any information about a process of creation, nor the tools used for that. However, this kind of history is closely related with the other cluster ontologies. On one hand, the ontology of Shape Acquisition and Reconstruction (SAPO) can store all the information of a human shape when it has been acquired from a scanning session. On the other hand, the Product Design ontology (PDO) refers to the process when a human shape has been created form scratch by designers.

In the following table we present our CQs separated by category, and with the actual status. This status indicates if the CQ has been answered or not. If the CQ has not been answered we comment on the considerations we have to take into account to be able to answer it.

Model history	
Is this model obtained by editing another model?	Question related to PDO and SAPO.
What features have been changed on model X?	Question related to PDO and SAPO.
What tools where involved in the synthesis/modification of this VH?	Question related to PDO and SAPO.
Who performed the task T on the model X?	Question related to PDO and SAPO.
Features listing	
What is the height of the model?	answered
Is the model male or female?	answered
Is the model has cultural identification?	answered
What are the features of this model?	All has property?
Is this model obtained artificially or does it represent a real person?	We need to add a property that will be filled at the time of uploading the model, but at what level? VH or Geometry?
Which VH have a landmark description?	answered
Which are the available structural descriptors for a particular VH?	answered
Which aspects of the shape are described by the structural descriptor related to a particular VH?	Question not clear.
Which are the standing (seating, walking, etc.) VH?	answered
How is the body model represented? (a mesh, a point set, etc.)	answered
Is the VH complete (does it have a skeleton, a hierarchy of body parts)?	answered
Questions whose answer is a function of low/high level features	
Which are the VH that are fat/slim/short?	Answered partially. We propose a tool to give the answer.
Is this VH a child or an adult?	Answered, but reformulated to: is this VH > 18 years?
Does it have a long nose?	Removed. We cannot answer this question directly, but a tool can be provided.
Does it miss any body part?	Answered
Does this VH match another VH (or how much do they	Answered. Here we can list the few

match)? In particular: are they in the same posture?	properties we can check to match TWO VHs, e.g. number of polygons, skeletal structure, body parts, morphology, posture.
Do they have the same structure?	Answered
Do they have similar parts (same arm length, same fatness, similar nose?)?	Answered. We propose a tool to give the answer.
Do they have similar anthropomorphic measures (in terms of landmarks)?	Answered partially. We propose a tool to give the answer.
Is the model suitable for animation?	Answered
How will this VH look like after 20 years?	Removed, it is very high level to be able to answer it with the ontology.
With 20 kg more? With another nose?	Answered partially. We propose a tool to give the answer.
Does this model fit these clothes?	Answered partially. We can compare until some point. For example if the VH has the landmarks needed to try the clothes.
What VH do I get if I put the head of VH1 on the body of VH2?	Answered partially. We propose a tool to give the answer.
Animation sequences	
What model does this animation use?	Answered
What are the joints affected by this animation sequence?	Answered
Are there any animation sequences lasting more than 1 minute that are suitable for this VH?	Answered
Are there any running/football playing animation sequences for this kind of VH?	Answered
Can the animation sequence X be applied to the VH Y (in the case of key-frames for skeleton-based animation this would basically depend on the possibility to match the key-frame data to the skeleton of the VH)?	Answered
Animation algorithms	
What are the input and output channels of a particular Behavior controller (animation algorithm)?	Answered
Does this VH have a vision sensor attached?	Answered, but reformulated to: is there a controller to implement sensorial vision to this VH?
Can this VH react to sound events in its virtual environment?	Answered, but reformulated to: is there a controller that can make react this VH to sound in the VE?
Interaction with objects	
What capabilities does an object provide?	Answered
What are the actions the human can execute on the object?	Answered
What are the characteristics of an object (structure, physical properties, etc.)?	Answered
How can the object be grasped?	Answered

4 CONCLUSIONS AND FUTURE WORK

In this deliverable we have presented some modifications to the representation of the structural descriptor in the ontology in order to provide generic concepts for different kinds of structures. Furthermore, we have extended the ontology to provide semantics on the facial animation and virtual human controllers. With the current structure of the ontology we have explored its usage in research specific domains, such as the expressional animation of face and body, where more specific ontologies have been built on top of the VHO with the goal to provide an organized structure of the knowledge.

Considering that the actual structure of the ontology clusters and the CSO allows seeing one shape from different points of view: one is the shape as a Virtual Human with features ready to populate a virtual world; another is the human shape with its creation process pipeline; we need to explore how we can exploit these relations to extract more information about a shape in different domains and not only in one specific cluster.

The validation of the VHO has been carried out by answering the competency questions formulated in the beginning on the project. However, there is still some work to be done in this area.

As part of the future work we present the next evolution steps that will be considered:

- Define the history of VH creation in cooperation with the other cluster ontologies.
- Integrate the Common Tools Ontology with the VHO.
- Finalize answering the CQs.
- Test the ontology with a larger population of instances using the automatic metadata extraction tools.

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