

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 Shape Acquisition and Processing 2nd version

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Vers.	Issue Date	Stage	Content and changes
1	25 June 2006	35%	Initial draft for the deliverable and content structure.
2	30 June 2006	50%	First draft version.
3	30 July 2006	75%	Second draft version. Added history of a shape and first diagram for tasks and tools
4	10 August 2006	100%	Document completed

Executive Summary

This document contains a description of the deliverable **D1.2.2.1** of the IST NoE AIM@SHAPE.

The deliverable ***D1.2.2.1 – Ontology for Acquisition and Processing 2nd Version*** – is intended to provide a second version of the ontology the AIM@SHAPE partners have developed for formalizing the knowledge related to the Acquisition and Processing of Shapes. The task leader is **DISI** and has been supported by all the involved partners.

The deliverable is organized as follows: In Section 1 a short introduction to the ontology is presented, while Section 2 presents the second version of the ontology for Shape Acquisition and Processing. Section 3 draws some concluding remarks and Section 4 lists all the research publications related to the Task 1.2.2.

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1 INTRODUCTION

The first version of the ontology for Shape Acquisition and Processing (formerly the ontology for Shape Acquisition and Reconstruction Processes) has been presented in the previous Deliverable D1.2.2.1. It basically provides a starting point for the formalization of the knowledge of the creation and processing of digital shapes. The domain of the ontology has been defined as

the development, usage and sharing of hardware tools, software tools and shape data by researchers and experts in the field of acquisition and reconstruction of shapes.

The domain has not changed for the second version and the development of the ontology has been based on this domain as well as on the requirements defined in the previous deliverables and the meetings organized.

As explained in the previous deliverable D1.2.2.1, the target applications of the Ontology for **Shape Acquisition and Processing** (SAPO) are initially related to:

- *Acquisition Planning*: the process of selecting and interconnecting the most suitable acquisition devices with the purpose of obtaining a satisfactory 3D acquisition.
- *Data Validation*: Determine if data are accurate, complete, or meet specified criteria.
- *Benchmarking*: Activities related to the comparison of aspects of performance (functions or processes) with best practitioners; identifying gaps in performance.
- *Testing*: Testing the functionality and correctness of a process (algorithm, method, approach) by executing it.
- *Multi-sensor Data Fusion*: The study of the means and tools for the integration of data coming from multiple sensors.
- *Data Enhancement* (automatic recovery): the process of enhancing the quality of the data with respect to some specific constraints and requirements.

In this document we will present the second version of the ontology outlining changes and additions we made to the first version. Specifically, we will present three different usage scenarios we have more accurately specified (one of these has already been presented during the review meeting). We will also explain how our ontology is now able to answer some of the competency questions already identified (see previous Deliverable D1.2.2.1) and how we are evolving it in order to find answers to more of the outlined competency questions.

2 AN ONTOLOGY FOR SHAPE ACQUISITION AND PROCESSING (V2.0)

The ontology for Shape Acquisition and Reconstruction has been renamed to *Ontology for Shape Acquisition and Processing*. From now on we will refer to the ontology as the Shape Acquisition and Processing Ontology or SAP ontology (SAPO). **Shape models** and **tools** are treated as resources that can be uploaded and downloaded together with their metadata in the DSW.

This section presents the main changes in the SAP ontology and three usage scenarios that have been identified. These scenarios help us in the validation of the ontology, proving also that a subset of the identified competency questions can be answered at this

stage of the ontology development and outlining other competency questions that still need to be answered.

2.1.1 Identified Usage Scenarios

During the past months of research activities three different, but interrelated, template usage scenarios have been identified. We titled them as

1. Scenario n.1: "*Webby and the scanning session*",
2. Scenario n.2: "*Webby and the shape processing*" and
3. Scenario n.3: "*Webby and the shape history*".

The first two usage scenarios are related to the two different macro-aspects of the SAP ontology: the *Acquisition* and the *Processing* of a shape. The first scenario is related to the knowledge to be formalized when acquiring a real object and producing a digital shape. The second is related to the processing of existing digital shapes for producing new (or modified) ones. The third scenario instead focuses on the knowledge related to the history of a digital shape, and it outlines the case in which a researcher is interested in knowing how a given digital shape has been produced.

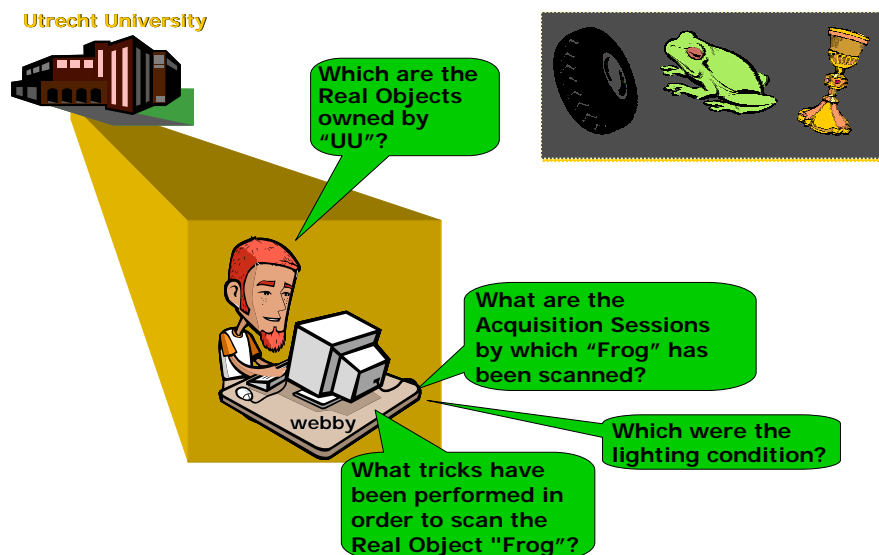


Figure 1 - The "Webby and the scanning session" usage scenario

Scenario 1. The "*Webby and the scanning session*" scenario is the following:

"Webby" works for UU in the Scanning Group. He would like to compare the quality of two different Acquisition Systems owned by AIM@SHAPE partners. So he would like to find all the objects owned by UU that could be scanned also elsewhere [CQ #1]. He finds three different real objects, among which he chooses FROG, because it is movable and its weight is reasonably low. Webby puts the FROG in his knapsack but he still does not know where to go.

He first would like to find documentation on the already performed Acquisition Session for the FROG and in particular [CQ #4 and CQ #3]. Because no trick has

ever been used to acquire FROG, and because FROG is a light absorbent real object, he poses the question [CQ #2]. He browses all the Acquisition Devices found and he discovers that one is owned by "MPII". So he plans his trip to Germany.

With this usage scenario we have been able to prove that the SAP ontology, at this stage of development, is able to answer a subset of the competency questions identified in the previous Deliverable D1.2.2.1. In particular we list here some of these CQs and the way in which we can answer them using the ontology:

- CQ #1. Which are the Real Objects owned by "UU"?
 - a. Select all the *RealObject(s)* which have *hasOwner* as UU
- CQ #2. What are the Acquisition Systems able to scan a Real Object which is light absorbent?
 - a. For each *AcquisitionSystem*, follow *hasAcquisitionDevice*.
 - b. For each *AcquisitionDevice* found, follow *hasAcquisitionDeviceType* and check if *isAbleToScanLightAbsorbentObjects* is true. In this case select the *AcquisitionSystem*
- CQ #3. What tricks have been performed in order to scan the Real Object "FROG"?
 - a. Take "FROG" follow *hasBeenAcquiredBy*, for each *AcquisitionSessions* found follow *hasTrick*
- CQ #4. Under which lighting conditions has the real object "FROG" been scanned?
 - a. Take "FROG" follow *hasBeenAcquiredBy*, for each *AcquisitionSessions* found follow *hasEnvironmentConditions* and check the value of *hasLightingConditions*

This usage scenario has been successfully presented during the AIM@SHAPE review meeting that was held in Genova, March 30-31, 2006. On that occasion it has been proven that the first version of the ontology (see previous Deliverable D1.2.2.1) correctly conceptualizes the knowledge we needed.

Scenario n.2: The second usage scenario "*Webby and the shape processing*" is the following:

Webby has acquired at MPII (using the Acquisition System of MPII) the FROG real object owned by UU. He has produced a surface mesh called "MPIIFrog.off". Webby now wants to evaluate the quality of this latest mesh compared to the one obtained at UU, but he does not have any tool to compute the *distance* between two shapes. He searches for an appropriate tool [CQ #2]. Browsing the obtained results he chooses the "*Metro*" tool since it can run on Linux (the OS he usually uses) [CQ #3]. "*Metro*" is able to load only "PLY" files [CQ #4], but the MPIIFrog mesh is in OFF format. For this reason, Webby searches for a converter from OFF to PLY [CQ #1]. He browses the results and chooses the "*Off2Ply*" tool, since it also works on Linux.

Thanks to the second usage scenario, we have been able to identify a subset of competency questions we are addressing now regarding the tasks and tools that can use/manipulate shapes. We list here some examples strictly related to the usage scenario above:

- CQ #1. Is there a Converter tool able to convert an OFF file into a PLY file?

- CQ #2. Which are the tools that are able to compute the distance between two shapes?
- CQ #3. Which is the compilation platform for this tool?
- CQ #4. Which format type does this tool support?

Scenario n.3: The third usage scenario "*Webby and the history of a shape*" is the following:

Webby wants to learn more on the acquisition process and surface meshes in general. He searches for all the surface meshes with a given characteristic (for example "no self-intersections"...). He browses the obtained results and chooses the shape "bimbaConNastrino.ply". He asks for the history of this shape, discovering all the operations made in order to obtain the chosen digital shape.

The third usage scenario basically identifies an important competency question regarding the history of a digital shape: Which is the History of this shape? In Section 2.1.2 we present our proposed evolution of the ontology in order to model the knowledge related to the history.

2.1.2 Modeling the History of a Digital Shape

In the previous Deliverable D.1.2.2.1 we have presented *ShapeData* as a concept in our ontology, with some properties, such as its format or its URL, its Description, but also the information on the source from which it has been generated (through the slot *hasSource*) or the information on the owner of the particular shape (through the slot *hasOwner*): the owner can be identified via an *Institution* or a *Person*.

A *ShapeData* can be obtained by modifying another *ShapeData* (also more than one) or a *ShapeData* can be used to generate a new one. The relation *isDerivedFrom* initially formalized the knowledge related to the **History** of a given shape in the Ontology version 1.0 (see previous Deliverable D1.2.2.1). Since the property was not sufficient to find answers to the competency questions we had identified, we modified the ontology.

First of all we need to define the history of a shape in the SAP ontology. The history of a shape *X* is basically the set of operations (with all the details) that have been performed in order to obtain *X*. These operations can be related to the acquisition of a real object or the processing of different shapes. We have created the concept *ProcessingSession*, transforming the *AcquisitionSession* as a sub-concept of it. We have also created the subconcept *ToolSession* which identifies a session in which a shape is processed via a tool in order to produce another shape. **Figure 2** shows the diagram of this new part of the ontology.

The concept *ProcessingSession* has a property called *hasPreviousSession* which links a *ProcessingSession* to the previous one. The transitive closure of the property *hasPreviousSession*, called *hasHistory*, is exactly the relation which produces the history of a given shape. In this way the history of a shape is the set of *ProcessingSessions* that contributed to its creation (if the shape is derived from a real object the first *ProcessingSession* will be an *AcquisitionSession*). For a *ProcessingSession* we have also identified and defined other properties, in particular:

- *hasInput* (with domain on *ShapeData* and *RealObject*), which identifies the input *ShapeData* for a *ToolSession* or the input *RealObject* for an *AcquisitionSession*.

- *hasOutput* (with domain in *ShapeData*), which identifies the output *ShapeData(s)* of a *ToolSession* or an *AcquisitionSession*.
- *hasProcessingSystem* (with domain in *ProcessingSystem*), which identifies the *ProcessingSystem* used in the processing session.

ProcessingSystem is again a new concept defined in the SAP ontology. It has two sub-concepts: one is the *AcquisitionSystem* (already defined in the ontology, see previous Deliverable D1.2.2.1) used when a *ProcessingSession* is an *AcquisitionSession* and the other is *Tool*, which identifies the tool used in a particular *ProcessingSession* (a *ToolSession*).

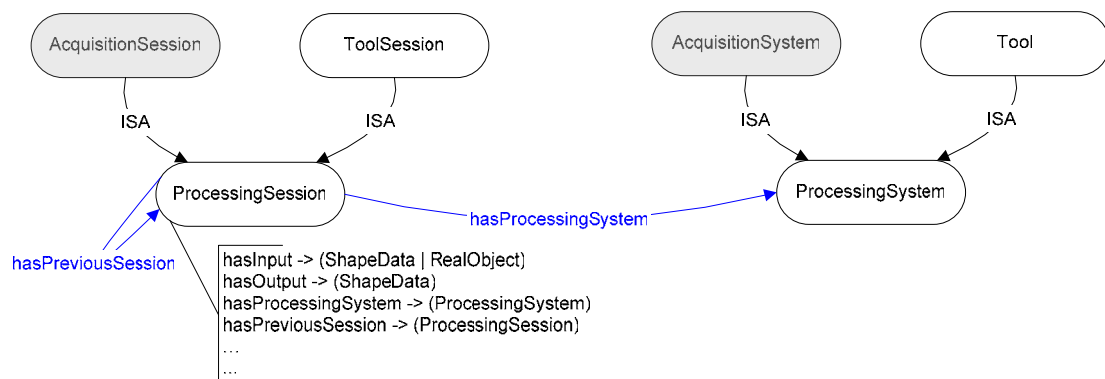


Figure 2 – the concepts *ProcessingSession* and *ProcessingSystem* have been added to the SAP ontology in order to reach the desired level of expressiveness and to model the knowledge related to the history of a digital shape.

The following is a specification of the rules to define the relation *hasPreviousSession(h,z)* with integrity constraints, meaning that the session *z* has a predecessor in *h*.

$$\text{hasInput} (?z, ?x) \wedge \text{hasOutput} (?z, ?y) \wedge \text{ProcessingSession} (?z) \wedge \text{ProcessingSession} (?h) \wedge \text{hasOutput} (?h, ?x) \Rightarrow \text{hasPreviousSession} (?h, ?z)$$

and also

$$\text{hasPreviousSession} (?h, ?z) \Rightarrow \text{hasHistory} (?h, ?z)$$

These rules are derived from the Semantic Web Rule Language (SWRL) which is the latest emerging standard from the W3C. Each predicate of the form `predicate-name (list-of-variables)` denotes a logical association between the variables listed in parentheses. If a single variable is specified, a property of the variable is being referred to. Each variable is preceded by a question mark "?". In a rule of this form we can identify the body of the rule on the left of the implication symbol (" \Rightarrow ") and the head of the rule on the right of the implication symbol. If the body of the rule can be satisfied, we can deduce that the head is also satisfied

We now list a subset of competency questions we have recognized which deal with the history of a shape and we produce the general idea of how to navigate the ontology in order to find the related answers. This proves that the new structure of the ontology is expressive enough.

CQ #1. What is the History related to the *SurfaceMesh* "ItalianWorldCup.wrl"?

- Find the *ProcessingSession*, let's say PS_{start} , with *ItalianWorldsCup.wrl* as output (via the relation *hasOutput*)
- Browse the relation *hasHistory* from PS_{start} relying on the transitivity closure with respect to *hasHistory* such that all *ProcessingSession(s)* which have contributed to obtain the shape are retrieved.

CQ #2. Who are the owners of the *RealObjects* source of the *SurfaceMesh* "flyingPotamo.ply"?

- Find all the *AcquisitionSession* in the history (found as before) of "flyingPotamo.ply"
- Browse the relation *hasInput* to find out the *RealObject* source for "flyingPotamo.ply"

To conclude this section we like to note that the properties *hasHistory* and *hasSource* could be useful in general to both the other domain ontologies we are developing within the network, namely the Virtual Humans and the Product Design. For this reason we have proposed to move the two properties to the common shape ontology and to attach them to the general concept *ShapeRepresentation*. All the partners involved are actually working and evaluating these proposed changes.

2.1.3 Modeling the knowledge related to tasks, tools and shapes

Some of the competency questions identified by the involved partners suggest that a formalization of the relations among tasks, tools and shapes is necessary and helped in the definition of the second usage scenario presented in Section 2.1.1. Here we list some of them as examples:

- What are the possible steps to perform when starting with a points cloud?
- Through which steps is it possible to reach a surface mesh?
- Through which sequence of steps is it possible to reach a surface mesh starting from a points cloud?

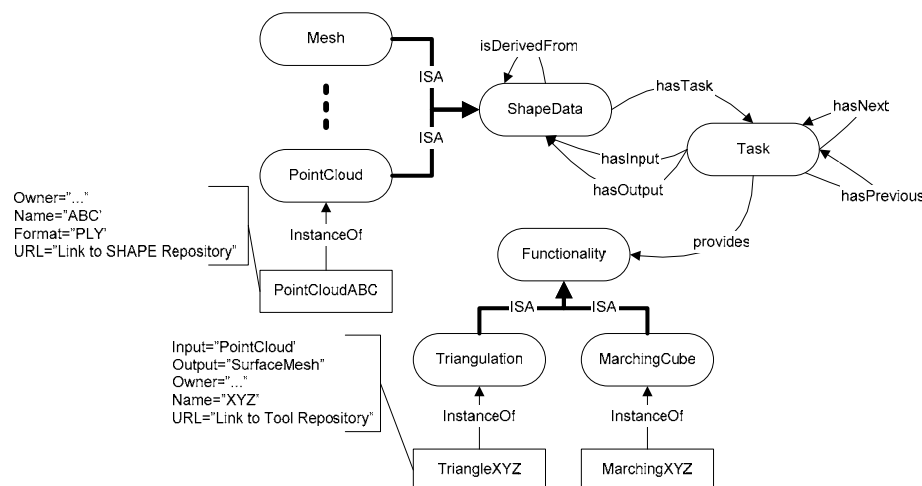


Figure 3 - A diagram showing the initial tentative solution to formalize the knowledge related to shapes and tools.

The basic idea is that the ontology should maintain and provide all the possible “*template set of actions (template workflows)*” we can activate when considering a given input and/or output type. An initial solution to formalize this knowledge was already proposed in the initial version of the ontology (see the previous deliverable D1.2.2.1 and **Figure 3**) but it was insufficient.

One general problem is that the meta-level at which we should find the correct conceptualization is different from the level at which we have developed the ontology so far. For the first competency question listed above, a “point cloud” should not be a concept but an instance of another concept (e.g. *ShapeType*). We have developed a new diagram (in some sense a new little ontology) that we will explain in the following.

Part of our conceptualization uses the concepts already defined in the common tool ontology that will link directly to the AIM@SHAPE tool repository (namely, *SoftwareTool*, *Algorithm*, *Functionality*, *ShapeType* and all the related properties). We defined the concept *Step* modeling the knowledge related to a step in the shape processing pipeline. A given *Step* can use a specified tool (via the relation *usesTool*) and/or can have a precise functionality (via the relation *hasFunctionality*). A given *Step* is performed taking a *ShapeType* as input (via the relation *hasInput*) and produces a certain *ShapeType* as output (via the relation *hasOutput*). The relation (a), (b) and (c) in Figure 4 are modeled in order to ensure consistency among the instances.

With the proposed conceptualization we are now able to answer some of the identified competency questions, as for example: *What are the possible steps to perform when starting with a points cloud?* The answer will be a set of steps which have a *PointCloud* as input.

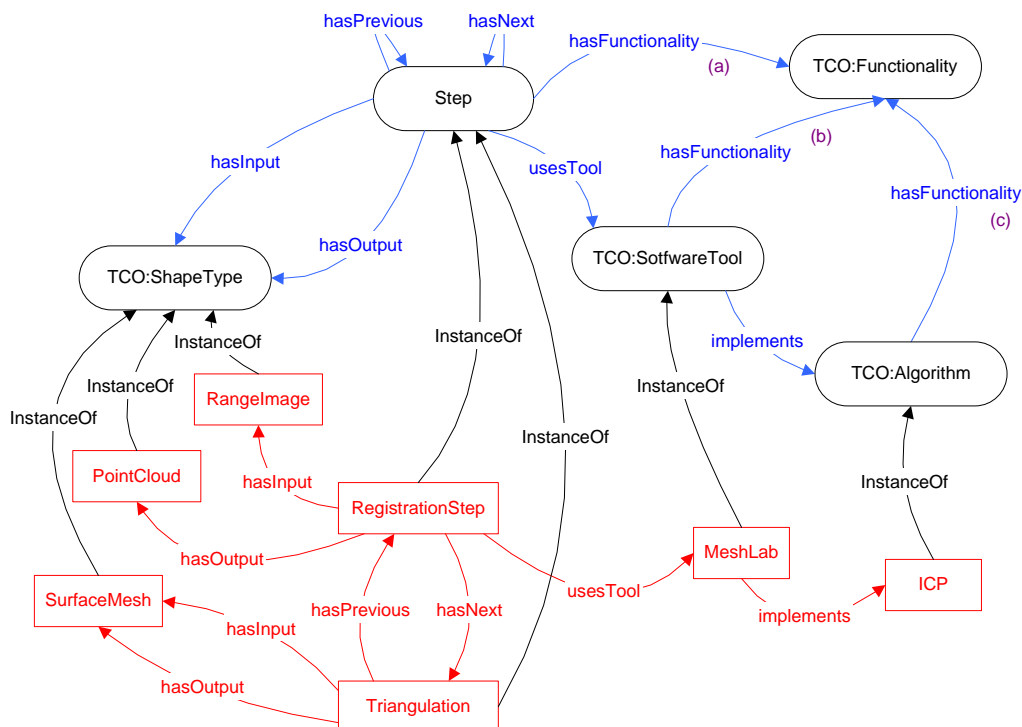


Figure 4 - our proposed schema for modeling tasks and tools in the SAP ontology. The concepts in TCO are concepts already present in the Common Tool Ontology.

2.1.4 Integration with the Common Shape Ontology

In the first version of the SAP ontology, we mainly concentrated on modeling the knowledge related to the acquisition of a real object and the successful creation of a digital shape. We had identified three different main concepts: *ShapeData*, *RealObjectForAcquisition*, *AcquisitionSession*. During these months of activity we worked a lot in order to validate the common shape and tool ontologies, trying to define which concepts could remain in the SAP ontology and which could be inherited from the two common ontologies.

For the common shape ontology (SCO) we have realized that the concept of *ShapeRepresentation* in the SCO can substitute almost entirely the concept *ShapeData* we have in our ontology. The exceptions are the two properties *hasSource* and *hasHistory* we have defined for *ShapeData* that are not properties of *ShapeRepresentation*. For this reason we have proposed to add these properties in the common shape ontology.

For the common tool ontology, we have validated it, proposing little changes (as for example the concept *Functionality*, or the property *hasParameters* for a *SoftwareTool*) and we have used part of it in our first conceptualization for tasks, steps and tools, related to the processing of digital shapes.

We are actually working in order to completely integrate our ontology with the two common ones (for tools and shapes). We believe that some of the solutions we have adopted in the SAP ontology can be useful also to other clusters (i.e. the *hasHistory* relation), the exact mapping among concepts then depends both on the results of the validation process and the needs other clusters have with respect to our extension.

3 CONCLUDING REMARKS

In this deliverable we have presented the second version of the Ontology Shape Acquisition and Processing. It is intended to produce knowledge support for the researchers who have to face the lifecycle of the shape in general. We have identified that the acquisition of a shape is fundamental in this sense but also that further processing has to be done to fulfil the users' needs, and documentation has to be produced in order to enrich the semantic impact of the shape.

The first version of the ontology already supports the requirements related to the Acquisition Session. In this second version we have formalized the knowledge related to shapes, tools and tasks proposing a schema that we will be validated in the future months.

Here, we briefly outline the major changes and improvements with respect to the first version of the ontology presented in the previous Deliverable D1.2.2.1:

1. **Identification of three template usage scenarios**, "Webby and the scanning session", "Webby and the shape processing", "Webby and the shape history".
2. **Identification of the answered competency questions also wrt the identified usage scenarios.**
3. **Formalization of the history of digital shapes.** New concepts have been identified: *ProcessingSession* and *ProcessingSystem*. The relation *hasHistory*, the transitive closure of the property *hasPreviousSession*, actually models the history of a shape.
4. **Formalization of the knowledge related to steps, tasks and tools**

processing digital shapes: the draft diagram presented in the first version of the ontology has been modified in order to obtain an ontology structure that is able to answer the identified competency questions. The concept *Step* has been introduced and part of the common tool ontology has been used to reach the correct level of expressiveness.

5. **Validation and first Integration of the common shape and tool ontologies:** The validation of the two common ontologies has been performed, proposing little changes and improvements.

We want to remark again that, looking at some requests from the involved partners (e.g. questions regarding MRI volumes, such as "*which anatomical region of interest (e.g., hip, knee, liver etc.) is this?*" or "*find more examples of a selected body part*", or "*Is this a healthy organ?*"), it is clear that a formalization of the knowledge related to the **shape analysis** could be useful in order to "*close*" the digital shape lifecycle. We still need to understand how to integrate this knowledge in this cluster or maybe if another cluster (or sub-cluster) could be necessary. We are planning to discuss this within the network in order to understand possible interests and to plan future activities.

4 REFERENCES AND PUBLICATIONS RELATED TO THE SHAPE ACQUISITION AND PROCESSING ONTOLOGY

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