Title:
Combining 3D Models and Functions through Ontologies to Describe Man-made Products and Virtual Humans: toward a Common Framework

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Introduction:
Modeling 3D complex products using functional information has been an initial target for CAD to support the design process. More recently, 3D technologies have brought new capabilities to describe virtual humans and perform various simulations using these models. In the latter case, functional information related to 3D models has been barely addressed and it is part of the purpose of this work to show how recent advances in this field [4] can take advantage of 3D models and functional information through ontologies to develop new browsing and simulation capabilities. In the former case, processing functional information has been essentially addressed in a top-down manner where it loosely connects to 3D geometry. Recent advances showed that using geometric interfaces between components [3] and qualitative reasoning connected to ontologies [7] could bring new means to interact with Digital Mock-Ups (DMUs) [1].

Based on both advances, it is the purpose of the proposed contribution to analyze the main features of each of them to look for possible commonalities to define a more global infrastructure that can be useful for each category of 3D models as well as applications involving both 3D products and virtual humans.

Toward a common ontology framework for 3D products and virtual humans:
The proposed analysis focuses on two frequent tasks addressed by products and virtual humans both: browsing and simulation preparation. Indeed, these tasks are frequent and can become very tedious in both cases. Navigating and selecting a component in either category of 3D models (product or virtual human) is tedious if performed classically with the (move + click) principle as well as other geometry-based selection principle [2]. Simulation preparation, as needed for products to study their structural behavior using Finite Element (FE) models or biomechanical simulations as needed to evaluate the mechanical behavior of virtual humans, also use FE-based or similar mechanical models to simulate movements. There, identifying the set of components needed for a given simulation, setting up the boundary conditions and adapting the components' shapes is a common denominator for both categories of models and these tasks are time consuming. Using functional information appeared to be an efficient means to speed up this preparation process for products [1] as well as virtual humans [4].
Having a function-based selection process has already proved its interest [1, 4] but each category of 3D models differs in the type of 3D model used for their description. 3D products are commonly described with B-Rep NURBS CAD models whereas virtual humans are based on 3D mesh models, which significantly differ in terms of geometry processing but they stay rather similar when a selection process matters.

Not only differences exist in terms of geometric models but product's components and anatomical entities are not identified in the same way. Where a precise and standardized taxonomy exists for anatomical entities through FMA (Foundational Model of Anatomy) [5], no such reference is available for product's components. However, describing a human body anatomy and a product structure has some common features that can be used to set up a common framework.

From a complementary point of view, the concept of function is addressed rather similarly in the product design context and in the human anatomy, though the function designations differ significantly between a product and a virtual human. Again, this commonality can be exploited to contribute to a common framework that applies to browsing and simulation preparation needs. Browsing processes are improved through the use of functional information because it is a new means to characterize a group of 3D entities sharing a common concept that is meaningful from the user's point of view. Similarly, biomechanical simulation preparation is improved with functional information because the simulation objectives focus on groups of anatomical entities that are meaningful wrt to a given body function. Consequently, selecting the appropriate entities helps preserving the consistency of the simulation and setting up the correct simulation parameters and boundary conditions.

In order to connect 3D entities to functional information, both contexts use ontologies and reasoning processes. In the case of virtual humans, the knowledge base devoted to anatomy: MyCorporisFabrica [5], has been equipped with a procedural approach [4] that connects anatomical entities to their functions through linked taxonomies. All facts and inference rules are expressed using an RDF/RDFS framework accessed using SPARQL query and update engines. Ontologies can be edited using the Protégé editor. Within this framework, inference rules can be used to propagate new facts to all the relevant entities of the knowledge base so that it is always saturated and is ready for querying any entity without requiring careful and complex update processes.

Because of the procedural approach set up, the knowledge base can be easily updated to incorporate new facts and new rules. Based on the commonalities and differences reported above for 3D products and virtual humans, it is the purpose of the paper to analyze how this framework can be adapted to both of them and into which extent this framework meets their requirements.

As a result, it appears that the set of inference rules used for human anatomy that express the structure of anatomical entities can be applied also to the structure of a product. When connecting anatomical structures to their functions, inference rules set up can be transposed to products with an appropriate designation to convey a correct meaning from the user's point of view. As mentioned previously, the designation of components in a product is not robust information compared to the standardized designation of anatomical entities and functions. This is one among the differences between digital product models and virtual humans and complementary reasoning processes are mandatory to use DMU models as input as they are available from CAD or PDM systems.

Anyhow, the framework is able to process 3D digital models of components as well as 3D anatomical entities with their corresponding functional information. In both cases, these new capabilities contribute to the improvement of browsing and simulation preparation processes. Refining the requirements for biomechanical simulations, the consistency of geometric models of anatomical entities appears as critical as it is in the case of digital products where geometric interfaces between components contribute to the definition of boundary conditions and other mechanical parameters. Other observations, similar to this one, confirm the commonalities between biomechanical simulations of virtual humans and structural simulations of 3D digital products.

<u>Conclusion:</u>

Given the digital description of products with DMUs and of virtual humans, these two categories of models face similar issues among which, browsing and simulation preparation have been addressed to improve the efficiency of these tasks using functional information. The ontology-based framework set up for virtual human anatomy appears to be versatile enough to be adapted to digital products as described. The commonalities observed between 3D products and virtual humans in the context of browsing and simulation preparation and their adequacy with ontology-based framework validates the interest of this approach to process symbolic information, like functional data, connected to 3D models.

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