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Tooth Positional Ontology Represented in OWL

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Abstract

In the practice of dentistry, few biomedical ontologies exist that support dentists' decisions or meet their clinical needs. Unlike other medical domains, a dental concept requires specific identification in terms of position. In order to assist with dentists' clinical tasks, we created a tooth ontology in Web Ontology Language (OWL) with embedded spatial relations. In this paper, we share our experiences in building and maintaining this tooth ontology.

Keywords:

tooth ontology, OWL, biomedical ontology

Introduction

Representing knowledge in a medical domain is advantageous for supporting decisions based on clinical judgment and reusing patient information for clinical research or quality assessment. An ontology provides a way to compile medical knowledge in a reusable, sharable, machine-understandable way. In medicine, research on biomedical ontologies is a response to the need of handling large volumes of patient data in a more comprehensible and effective way [1].

Although the current ontologies are designed to minimize ambiguities and redundancy, none of these ontologies have been used in dentistry. The main reason for generally accepted mereological relations, such as **part-of** and its inverse **has-part**, are complex in *classes* between material and nonmaterial entities, parthood over time, parthood and spatial location, and parthood between occurrents [2]. Ontologies built in a given domain must be foundational and robust with regard to interpretation, to prevent human-dependent semantic bias.

We do not argue that **part-of** and **has-part** are the most important roles in a biomedical ontology, but we must address the necessity of identifying more specific spatial relations. A more detailed expression may be needed to define the positional relationships among the anatomical structures in the oral and maxillofacial region, compared to other body structures.

Materials and methods

Each adult human has 32 teeth distributed evenly, with eight teeth in each quadrant: the central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar, and wisdom tooth. Incisors and canines are front teeth that are essential to one's appearance. Premolars and molars are located in the back of the oral cavity and play an important role in chewing and digesting food. In other words, we can divide teeth into two categories: anterior (front) teeth and posterior (back) teeth.

There are four central incisors, which are classified by position as left, right, upper, and lower. When we refer to a tooth as a *Central_Incisor*, we do not know which is being indicated. To identify whether a specific tooth is positioned on the left or right, three different dental notation systems are commonly used: the universal numbering system, the Palmer Notation Method, and the two-digit World Dental Federation (FDI) notation. In this paper, we adopt the two-digit FDI notation, which is also known as the ISO-3950 notation. We insert this notation in the *ToothNumber* class.

There are three different relations connecting a physical entity to the positional quality. These properties take their ranges with their positional quale from the *Positional_Value_Partition,* which has six leaf subclasses: *Anterior, Posterior, Right, Left, Upper*, and *Lower.* The value of **hasAP_Position** is either *Anterior* or *Posterior*, the value of **hasRL_Position** is either *Right* or *Left*, and the value of **hasUL_Position** is either *Upper* or *Lower.*

In order to use the *Anterior* class as the only representation of "Anterior" value, we made **hasAP_Position** as a functional property with the restricted domain such as *Anterior* and *Posterior*. A functional property is a property that every individual to which the property applies has at most one image along the relation [3].

The class *ToothNumber* has 32 subclasses, which have the three properties listed above: **hasAP_Position, hasRL_Position,** and **hasUL_Position**.

To build and share our ontology more consistently and unambiguously, we adopted formal relationships in biomedical ontologies [4]. Since we can select symmetry as a characteristic of **co-adjacent_to** in OWL, we use it as a

vehicle to connect neighbors. For example, *W11,* one of the subclasses of *ToothNumber,* is a neighbor to *W12* and *W21.*

We defined *AnteriorTooth* that has only the **hasAP_Position** property linking to the class *Anterior* using a closure axiom [5]. Similarly, we made the classes *PosteriorTooth, LeftTooth, RightTooth, UpperTooth,* and *LowerTooth*, for the purpose of identifying position.

We can infer a class as part of another class based on this definition, which is strength of description logic. The following shows the results after classification.

Results

Given the definition of our tooth position ontology written in OWL, we expect that any tooth located anteriorly to be in the appropriate subclass of the *AnteriorTooth* class. **has_Position** relations tie the positional concept to all relevant classes. There is no inconsistency. From this result, we easily recognize which the *ToothNumber* class is in a subsumptive relation to the class *AnteriorTooth.*

Discussion

In light of the above results, we can observe the arbitrary classification of the classes *ToothName* and *ToothNumber* into the expected positional classes depending on the user's intention (*e.g., AnteriorTooth, LowerTooth*). This positional concept of teeth helps to build a dental decision support system that lets the computer know where a tooth is positioned [6].

In addition, one can modularize the other tooth-related concepts such as dental materials and dental treatments using our pre-defined positional ontology, so that the maintainability, reusability, and interoperability are easy to obtain. They are crucial features in ontology development written with OWL.

Smith et al. [4] showed that consensus was recently reached concerning the foundational relationships in biomedical ontologies. However, the real application of temporal relations has a weakness in weaving binary ontological plots with OWL. Interestingly, the temporal concept requires more than two arity, which is impossible in OWL. Although there are several approaches to enable OWL with n-arity relations, we cannot find a formal methodology to incorporate temporal concept to our ontology within OWL. Because of that, we just employ spatial relations of the several proposed relations of *Smith et al.* [4] into our tooth positional ontology written with OWL. Above practice, the application of temporal relations leaves some issues unanswered, even though temporal perspective can be a fundamental role in dentistry in order to define a missing tooth and a milk tooth sufficiently.

Conclusion

This paper shows how spatial relations are specified using a special property (**has_Position**). Well designed properties help the ontology engineer to grasp clear definitions and usage. Here, the powerful interdependent concept classification in OWL-DL allows us to build our modularized ontology.

Identifying the position of a tooth is crucial in a dental ontology since ontology users must identify a specific tooth in order to make a correct decision. For example, a tooth colored restoration should be used for a decayed anterior tooth. The main limitation of our approach is due to simplification, for which well-designed relations in OWL-DL are still necessary.

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