INTEGRATING BIOMEDICAL ONTOLOGIES WITH FMA REFERENCE ONTOLOGY

Vanja Luković
Technical faculty Cacak, University of Kragujevac, Serbia
E-mail: vanja@blueisp.co.yu

Danijela Milošević
Technical faculty Cacak, University of Kragujevac, Serbia
E-mail: danijela@tfc.kg.ac.yu

Goran Devedžić
Faculty of mechanical engineering, University of Kragujevac, Serbia
E-mail: devedzic@kg.ac.rs

ABSTRACT

This paper analyses a broad scope of research papers dealing with the process of integrating biomedical ontology with the FMA reference ontology. Namely, we want to investigate the capability of this process appliance in development of application ontology for the anatomy and pathology domain of spine and femur bones. Such ontology can be successfully applied in development of the application ontology in the domain of orthopedics and physical medicine.

Key words: Biomedical ontology, Formal ontology, Reference ontology, Application ontology

1. Introduction

Biomedical ontologies are being developed in ever growing numbers, but there is too little attention paid for ontology alignment and integration, in other that results already obtained by the one terminology based application ontology can be utilized in other similar application ontologies.

No scientific advance can be obtained with the horizontally integration between two application ontologies, although vertical integration between ontologies in all categories is needed [1]. In this way formal, top level ontologies should provide the validated framework for reference ontologies, which represent the domains of reality studied by the basic biomedical sciences. The latter should then in turn provide the scientifically tested framework for a variety of terminology-based ontologies developed for specific application purposes.

In this paper according to [1], we denote how the process of vertical integration of the FMA (Foundational Model of Anatomy) reference ontology [5] with the BFO (Basic Formal Ontology) top-level ontology [3] can support the process of horizontal integration of the two reference ontologies: PRO (Physiology Reference Ontology) [8] and PathRO (Pathology Reference Ontology), forming accordingly the new reference ontology OBR (Ontology of Biomedical Reality), which is therefore federation of the three independent reference ontologies which range over the domains of anatomy, physiology and pathology.

Moreover according to [9], we denote the process of vertical integration of the RadLex radiology terminology with the FMA reference ontology, forming this way FMA-RadLex application radiology ontology.

2. BFO ontology

BFO [3] is a formal, top-level ontology which is based on tested principles for ontology construction. BFO consists of the SPAN and SNAP ontologies. The SPAN ontology relates to occurrents, processing entities (events, actions, procedures, happenings) which unfold over an interval of time. The complementary SNAP ontology relates to continuants, the participants in such processes, which are entities that endure over the time, during the period of their existence. Anatomy is a science that studies biological continuants, while physiology studies biological occurrents. Pathology, on the other hand, is concerned with structural alterations of biological continuants and with perturbations of biological occurrents which together are manifested as diseases. Moreover, BFO draws distinctions also between instances and universals and specifies relations which link them.

3. FMA ontology

The FMA [5] is reference ontology for anatomy, which according independent evaluations satisfies fundamental requirements for ontological representation of human anatomy [6, 7].

Hence, the domain of the FMA is anatomy of the idealized human body. FMA uses the hierarchy of classes of anatomical entities (anatomical universals) which exist in reality through their instances. The root of the FMA's anatomy taxonomy (AT) is *Anatomical entity* and its dominant class is *Anatomical structure*. *Anatomical structure* is defined as a material entity which has its own inherent 3D shape and which has been generated by the coordinated expression of the organism's own structural genes. This class includes material objects that range in size and complexity from biological macromolecules to whole organisms. The dominant role of *Anatomical structure* is reflected by the fact that non-material physical anatomical entities (spaces, surfaces, lines and points) and body are conceptualized in the FMA, in terms of their relationship to anatomical structures.

4. OBR ontology

The root of OBR is the universal *Biological entity* (*Figure 1*). A distinction is then drawn between the classes: *Biological continuant* and *Biological occurrent*, the definitions of which are inherited from BFO [3]. The class *Biological continuant* is subdivided into classes: *Organismal continuant*, which includes entities that range over single organisms and their parts and *Extra-organismal continuant*, which includes entities that range over aggregates of organisms. Accordingly, the class *Biological occurrent* is subdivided into classes: *Organismal occurent* and *Extra-organismal occurent*, which include processes associated with single organisms and their parts i.e. processes associated with aggregates of organisms.

The class *Organismal continuant* is subdivided into classes: *Independent organismal continuant* and *Dependent organismal continuant*. Extrapolating from the FMA's principles, *Independent organismal continuants* have mass and are material, whereas *Dependent organismal continuant* are immaterial and do not have mass.

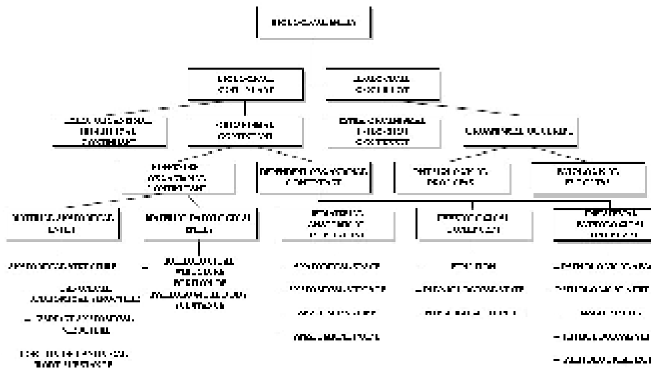

Figure 1. Ontology of Biomedical Reality OBR

OBR ontology distinguishes anatomical (normal) from pathological (abnormal) material entities. Accordingly, the class *Independent organismal continuant* is subdivided into classes: *Material anatomical entity and Material pathological entity.* The class *Material anatomical entity* is subdivided into classes: *Anatomical structure* and *Portion* *of canonical body substance*, on the basis of the possession or non-possession of inherent 3D shape. Within the class anatomical structure OBR ontology make a distinction between canonical anatomical structures, which exist in the idealized organism, and variant anatomical structures, which result from an altered expression pattern of normal structural genes, without health related consequences for the organism. The class *Material pathological entity* is subdivided into classes: *Pathological structure* and *Portion of pathological body substance*, on the basis of the possession or non-possession of inherent 3D shape, too. *Pathological structures* are result from an altered expression pattern of normal structural genes, with negative health consequences for the organism.

The class *Dependent organismal continuant* is subdivided into classes: *Immaterial anatomical continuant, Immaterial pathological continuant* and *Physiological continuant.* Although the existence of immaterial anatomical and pathological spaces and surfaces and anatomical lines and points depends on corresponding independent continuant entities, they are dependent continuants. Besides them classes: *Function, Physiological state* and *Physiological role* and classes: *Malfunction*, *Pathological state* and *Pathological role* also belongs to *Dependent organismal continuant,* because their entities do not exist without corresponding independent continuant entities.

Functions are certain sorts of potentials of independent anatomical continuants for engagement and participation in one or more processes through which the potential becomes realized. The function is a continuant, since it endures through time and exists even during those times when it is not being realized.

Whether or not a function becomes realized depends on the physiological or pathological state of the associated independent anatomical continuant. Thereat, physiological and pathological state is a certain enduring constellation of values of an independent continuant's aggregate physical properties. These physical properties are represented in the Ontology of Physical Attributes (OPA), which provides the values for the physical properties of organismal continuants. Namely, the states of these continuants can be specified in terms of specific ranges of attribute values.

The independent continuants that participate in a physiological or pathological process may play different roles in the process (e.g. as agent, co-factor, catalyst, etc.). Such a process may transform one state into another (for example a physiological into another physiological, or into a pathological state).

The class *Organismal occurent* is subdivided into classes: *Physiological process* and *Pathological process. Physiological process* courses transformations of one physiological state into another physiological state, whereas *pathological process* courses transformation of a physiological state into a pathological state or one pathological state into another pathological state. The relative balance of these processes results either in the maintenance of health or in the pathogenesis of material pathological entities, and thus in the establishment and progression of diseases. Transformation of a pathological state into a physiological, manifest as healing or recovery from a disease, comes about through physiological processes that successfully compete with and ultimately replace pathological processes, namely function is restored. Processes are extended not only in time but also in space by virtue of the nature of their participants.

4. RadLex terminology

The Radiological Society of North America (RSNA) developed a publicly available terminology, RadLex [12], to provide a uniform standard for all radiology-related information. RadLex terminology is organized into a hierarchy (Figure 2) and subsumes over 7400 terms organized in 9 main categories or types with *RadLex term* as the root. However *RadLex* terminology does not yet have a principled ontological framework [14] for these three reasons:

1) being term-oriented, RadLex currently ignores the entities to which its terms project;
2) the lack of a taxonomy grounded in biomedical reality;
3) the ambiguity and mixing of relations (such as *is_a*, *part_of*, *contained_in*) represented by the links between the nodes of the term hierarchy (Figure 2).

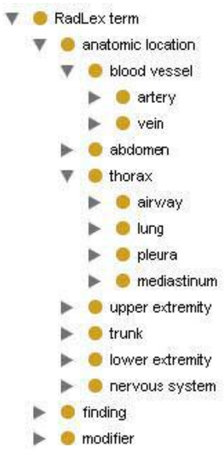

Figure 2. RadLex hierarchy in Protégé

In the next section, according [9] is described how a portion of reference ontology, such as the FMA, can be adopted to lend application ontology in which all challenges mentioned above are resolved.

5. Derivation of FMA-RadLex application ontology

Terms relating to anatomy are represented in the RadLex terminology category *Anatomic location*, which corresponds to the category *Anatomical entity*, used by other disciplines of biomedicine. This is not radiology image entity, yet the entity that exists in the reality. *Anatomic location* is therefore renamed as the FMA root term *Anatomical entity* (Figure 3). For the image findings representing radiology images entities the separate ontology should be created.

Application ontology from the FMA can be derived either by:

1. Obtaining an entire copy of the FMA and pruning the ontology down to the required specifications - *de novo* construction.
2. Mapping the existing terminology project to the FMA, carving out the ontology around the mappings and finally incorporating the derivatives into the existing terminology project project.

The latter method was applied in constructing the anatomy application ontology for RadLex [9]. Hence, high level RadLex terms are first mapped to the corresponding FMA terms, and then their corresponding FMA super-types are imported into the RadLex taxonomy. After that, other terms at different levels of the RadLex tree are mapped to the corresponding FMA terms, and then their corresponding FMA super-types are imported into the RadLex taxonomy super-types. In RadLex anatomy taxonomy the highest level parents of the imported super-types of the FMA are incorporating, as well: *Anatomical structure* which subsumes 3-D objects that have inherent shape, e.g. body, organ system, and organ, and *Immaterial anatomical entity* which encompasses types that have no mass property, such as: anatomical space, anatomical surface, anatomical line and anatomical point.

Hence, this conclusion can be divided: the operation of construction the same ontology via the *de novo* approach, would involve a series of deletion and addition of links (Figure 3, left) from the FMA reference ontology. For example, the *is_a* link of the class *Anatomical structure* is deleted from *Material anatomical entity* and then added directly to *Anatomical entity*. Both *Physical anatomical entity* and *Material anatomical entity* are then deleted from the FMA taxonomy. Beside that, FMA types representing microscopic entities which are not relevant to radiology such as *Cell, Cardinal cell part, Biological macromolecule, Cardinal tissue part,* are also deleted from *Anatomical structure.* These operations can be carried out in all levels of the hierarchical tree.

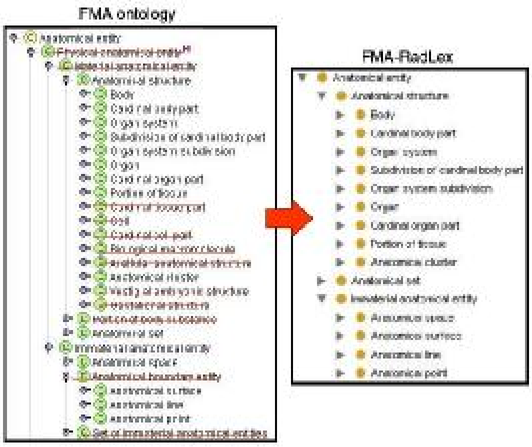

Figure 3: FMA-RadLex (right) derived from the FMA (left)

6. Conclusion

By vertical integration of the FMA reference ontology with the BFO top-level ontology the process of horizontal integration of the two reference ontologies: PRO and PathRO is supported, forming accordingly the new reference ontology OBR, which range over the domains of anatomy, physiology and pathology. This ontology can be successfully applied in development of the application ontology in the anatomy and pathology domain of spine and femur bones, which is one of the many objectives in the realization of the project named: "Ontological modeling in bioengineering[1]" in the domain of orthopedics and physical medicine.

Moreover, described process of vertical integration of the RadLex radiology terminology with the FMA reference ontology, forming this way FMA-RadLex application radiology ontology can also be applied in development of the application ontology in the anatomy and pathology domain of spine and femur from the OBR reference ontology.

[1] "Ontological modeling in bioengineering", Project funded by national Ministry of science, Faculty of mechanical engineering, University of Kragujevac, Serbia (2008-2010)

References

[1] Cornelius Rosse, MD, DSc, Anand Kumar, MD,PhD, Jose LV Mejino Jr, MD, Daniel L Cook, MD, PhD, Landon T Detwiler, Barry Smith, PhD, "A Strategy for Improving and Integrating Biomedical Ontologies." AMIA Annu Symp Proc. (2005), pp. 639-643.

[2] *http://www.loucnr.it/DOLCE.html*

[3] Grenon P, Smith B, Goldberg L. "Biodynamic ontology: applying BFO in the biomedical domain." In DM Pisanelli (ed.), Ontologies in Medicine, Amsterdam: IOS Press, 2004,20-38.

[4] Open Biomedical Ontologies: http://obo.sourceforge.net/

[5] Rosse C, Mejino JLV Jr. "A reference ontology for biomedical informatics: the Foundational Model of Anatomy." J Biomed Inform, 2003 Dec; 36(6):478-500.

[6] Smith B, Köhler J, Kumar A. "On the application of formal principles to life science data: A case study in the Gene Ontology." DILS 2004: Data Integration in the Life Sciences. 2004; 124-139.

[7] Zhang S, Bodenreider O. "Law and order: Assessing and enforcing compliance with ontological modelling principles." Computers in Biology and Medicine 2005: in press.

[8] Cook DL, Mejino JLV, Rosse C. "Evolution of a Foundational Model of Physiology: Symbolic representation for functional bioinformatics." Medinfo 2004; 2004:336-340.

[9] Jose L.V. Mejino Jr, Daniel L. Rubin, and James F. Brinkley. "FMA-RadLex: An Application Ontology of Radiological Anatomy derived from the Foundational Model of Anatomy Reference Ontology."

Proceedings AMIA Symposium 2008: Page 465-469.

[10] Rosse C, Mejino JLV 2007. “The Foundational Model of Anatomy Ontology” in: Burger A, Davidson D, Baldock R. (eds.), Anatomy Ontologies for Bioinformatics: Principles and Practice, pp 59-117, New York: Springer.

[11] Online available at: http://www.rsna.org/radlex.

[12] Langlotz CP: “RadLex 2006. a new method for indexing online educational materials.” Radiographics 26:1595–1597.

[13] Rubin DL 2007. “Creating and curating a terminology for Radiology: Ontology Modeling and Analysis.” J Digit Imaging.

[14] Marwede D, Fielding M and Kahn T. 2007 RadiO: “A Prototype Application Ontology for Radiology Reporting Tasks.” Proc AMIA 2007, Chicago. IL, pp 513-517.

[15] FMA Online available at: http://fma.biostr.washington.edu.