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Pushing the FMA-OWL enveloppe further

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Abstract

Representing the Foundational Model of Anatomy (FMA) in OWL 2 W3C standard, is essential for its interoperability with other biomedical ontologies, its design, maintenance, and quality insurance. The paper describes the method and 'FMA-OWLizer' tool that moves the FMA to OWL 2. One main strength of the approach is to leverage OWL expressiveness to explicit some implicit semantics and naming conventions of the FMA, meanwhile improving its ontological model and fixing some FMA errors. Another originality is the flexibility and versatility of the conversion: many options allow for producing several FMA-OWL variants customized to users, e.g., choosing a frame or OWL source, generating an OWL DL or OWL 2, a full or reduced FMA target, configuring the classes definitions etc. Thus several new FMA-OWL ontologies are available. To the best of our knowledge, no complete representation of the entire *FMA in OWL DL or OWL 2 existed so far.*

Introduction

The Foundational Model of Anatomy (FMA) is a *reference ontology* about human anatomy, intended to be reused in *application ontologies* which calls for anatomical information [1]. The FMA models *canonical* human anatomy that is, « the ideal or prototypical anatomy to which each individual and its parts should conform » [1] [2]. It contains more than 85,000 classes 140 relationships connecting the classes, and over 120,000 terms. The FMA describes anatomical entities, most of which are anatomical structures composed of many parts interconnected in complex ways. Thus, the FMA is a very large, and also one of the most complex computer-based ontology in the biomedical sciences. Due to its sheer size and high complexity, ontology engineering - design, maintenance, quality insurance - is a real challenge for the FMA, and support by automatic tools is clearly vital. One main motivation is to leverage semantic technologies for providing assistance to detect FMA errors and help its curation.

The W3C OWL 2 Web Ontology Language[1] [9] is an ontology language for the Semantic Web. Representing ontologies in OWL 2 provides several advantages: interoperability, semantics, reasoning services. *Interoperability* is important for shared use across different biological and medical domain. Once converted to OWL 2, ontologies become easier to be connected or combined with other ontologies. *Semantics* (meaning) of terms is formally specified thanks to the underlying description logics. Another major practical benefit of converting the FMA to OWL 2 is that it allows to exploit the multitude of existing OWL tools and services, in particular *powerful reasoners* grounded on OWL logics. OWL 2 *higher expressiveness* is also of interest: OWL 2 extends OWL 1 with a small but useful set of new features [10] allowing in particular expressing qualified cardinality restrictions, annotations of annotation, properties characteristics, and metamodeling (via puning).

The main objective of the work is to provide a FMA-OWL representation of the FMA in the OWL 2 standard, in order to make it interoperable with other biomedical ontologies, and to support reasoning and automatic services, which are crucial for assisting its design, maintenance, and assuring its quality. As the FMA users are not very familiar with OWL and may prefer to continue to use existing frame language and Protégé editor, the goal is to provide them with a friendly and easy to use converter that automatically creates the OWL conversions for them. There has been several efforts since 2005 for translating the FMA into OWL [3] [4] [5]. This work extends the first 2005 conversion [3] aiming at an OWL DL ontology that DL reasoners can use for inferences. But the newer migration goes forward in the 'DL-ization' process, eliciting much further FMA underlying semantics, improving its ontological model, and meanwhile detecting and fixing some FMA errors. The first section presents the method developed to move the FMA to OWL 2. It mainly focuses on the new logical (DL) features added in the FMA-OWL 2010 ontologies. Next, the new 'FMA-OWLizer' tool is described, highlighting its options that enhance the flexibility of the conversion. The final sections report on the results obtained so far and compare the work to the existing.

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[1] http://www.w3.org/TR/owl2-overview/

Material and Method

The FMA is currently implemented in Protégé frames, the frame-based system developed by Stanford Center for Biomedical Informatics Research[2] and stored in a MySQL database backend. The FMA authors use the Protégé frames editor to enter and modify the data. Therefore, the starting point of the conversion is the Protégé frames ontology publicly available from University of Washington[3]. At the time of this writing, the input file is the FMA 3.0 version (November 2008) A different source can be selected, on a simple 'clic' the FMA-OWLizer provides the users with the up-to-date OWL conversion they want (cf.3).

1. Two-stepped conversion.

The migration to OWL 2 is processed in two steps. The first step converts the FMA from CLIPS frames into an OWL DL ontology: *FMA-OWL v1.* The (optional) second step moves it to an even more DL-ized version in OWL 2: *FMA-OWL 2.* While the former conversion sticks as closely as possible to the native frames model, the latter pushes yet further the logical formalization of the FMA. On the one hand, it elicits further the FMA underlying semantics. For example, axioms which were not expressible by frames, and that reflect FMA *implicit* assumptions, e.g. properties restrictions, disjointness or covering axioms, are added (or moved). On the other hand, *FMA-OWL 2.* leverages OWL 2 new features and increased expressiveness, e.g., metamodeling, or annotation of annotation, to better reflect the FMA model and its authors' intents.

Step1: migration to FMA-OWL v1. The starting point of step 1 is the 2005 conversion [3]. The rules of step 1 are the same except for metaclasses (see [3]). At present, it is possible to keep the metaclass level, thanks to OWL 2 metamodeling (see (d)). The program has also been much modified and improved: first, to handle the *entire* FMA, next to be more robust and overcome the changes of new (and future) FMA versions, e.g.; new slots, functions, volume etc. that led to errors otherwise.

Step 2: migration to FMA-OWL 2. One main challenge of the migration is to enrich the FMA with formal definitions and axioms having a sound *anatomical* meaning. At the second step, new rules and methods are defined to that end. While the first rules were mainly based on the analysis of the frames syntax, the new rules mainly rely on a lexical analysis of the FMA vocabulary, and the inference power of OWL. They allow eliciting knowledge that was still encrypted in the vocabulary at the first conversion. Also at this second step, the FMA vocabulary is standardized as much as possible with W3C norms, e.g. using '`label`', '`date`'. The structure and the ontological model of the FMA are improved. Finally, all the changes, e.g., removing/creating new entities (classes, properties) or axioms are achieved.

2. Bringing semantics.

The semantics of the FMA ontology is elicited and enriched in several ways: (**a**) new classes definitions are automatically generated for entities having a particular pattern; (**b**) numerous axioms are automatically created or moved, (**c**) OWL 2 properties characteristics are added; (**d**) some annotation properties are reformatted, new ones are created; More importantly, OWL 2 annotations of annotation are generated to annotate the FMA entities (e) metaclasses may (optionally) be used to reflect the notion of "anatomical templates" of FMA's authors.

(a) Classes definitions. One main challenge in converting the FMA to OWL is certainly to specify precise and correct formal definitions of the classes. To avoid risking errors, the definitions introduced here, rely only on *safe* assumptions about the meaning of the names of the anatomical entities. For example, though it is not stated, it is *very* likely that the FMA entity *Left* denotes all the objects having some 'left' laterality, that *Left_Hand* denotes all the hands having left laterality, *Left_superior_cervical_ganglion* all the left and superior cervical_ganglion, that *Region_of_cytoplasm* denotes all the regional parts of cytoplasm etc. Based on such assumptions and a careful analysis of the FMA naming conventions and hierarchical organization, the semantics of numerous FMA entities encrypted in their name is stepwise decoded and formalized using an OWL 2 equivalent classes axiom `EquivalentClasses(A Exp)`, which states that the class `A` is equivalent to the expression `Exp`, thereafter written: `A ≡ Exp`.

Classes are incrementally formalized as follows.

- **Anatomical coordinate**. First, all the subclasses of `Primary_Anatomical_coordinate` are defined. For instance, `Left` (resp. `Superior` etc.) is specified by the equivalent class axiom `Left ≡ laterality value individual_Left`. Next, the subclasses of `Binary_Anatomical_coordinate`, are interpreted as the conjunction of two modalities, e.g; `Left_superior` is supposed to denote all objects having *left* and *superior* anatomical_coordinate, hence, is represented by the axiom `Left_superior ≡ Left and Superior`. Likewise, `Left_Hand` (resp. `Right_Hand`) is represented by the axiom

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[2] bmir.stanford.edu/

[3] sig.biostr.washington.edu/projects/fm/AboutFM.html#accessing

Left_Hand ≡ *Left* and *Hand*, which states that `Left_Hand` is semantically equivalent to the class expression `Left and Hand`.

- **Lexical patterns.** Other definitions are drawn from lexical patterns. At the moment, two categories of patterns are supported: (a) symmetrical siblings with an opposite anatomical_coordinate, e.g., *Left_A/Right_A, Anterior_A/Posterior_A, Inferior_A/Superior_A* etc., or an opposite gender, e.g.; *MaleA/FemaleA*; (b) pattern A_of_B, e.g., *Lobe_of_Lung*. It is very likely that the FMA entity A_of_B is a contraction formed from the entities A and B that omits a property *p_of* relating them, for example, the term *Lobe_of_Lung* refers to all *Anatomical lobe* that are a *regional_part_of* some *lung*. Thus, *Lobe_of_Lung* is represented by the equivalent class axiom *Lobe_of_Lung* ≡ *Anatomical_Lobe* and *regional_part_of* some *Lung*. At the moment, the `p_of` handled are only the `part_of` properties and subproperties (e.g.; `regional_part_of`).

A special process is defined for A_of_B when A is *Region, Zone, Segment, Subdivision*. Indeed, all region classes of the FMA denote *regional parts.* They are further distinguished on the types of boundary used to define the region, for example *Organ segment* is an *Organ region* with one or more anchored fiat boundaries, *Organ zone* is an *Organ region* with one or more floating fiat boundaries (private note from FMA authors). They are all formalized by an axiom asserting that they denote some regional_part of B. For example, *Region_of_cytoplasm* is represented by *Region_of_cytoplasm* ≡ *Region_of_cell_component* and *regional_part_of* some *Cytoplasm*.

The method takes advantage of the lexical patterns and naming conventions not only to automatically generate classes definitions, but also to perform other actions at the same time, that is to handle (create/remove/move) axioms as explained below.

(b) Axioms generation

- **Disjointness and subclass axioms.** Thus, the sibling symetrization process operates several tasks in the same pass: 1° it explicits the implicit semantics of the classes of a given pattern, *Male_A/Female_A, Left_A/Right_A, Inferior_A/Superior_A* etc. 2° it adds relevant subclasses and disjointness axioms. 3° meanwhile, it detects and repairs errors or omission in the native FMA (see Algo 1). For example, 1° the meaning of *Left_Hand* is made explicit by an axiom *Left_Hand* ≡ *Left and Hand*. 2° Several OWL subclass axioms (noted <) are added, for example

(a) the axiom *Hand* < `laterality exactly 1` {*individual_Left*, *individual_Right*} asserts that any hand has necessary exactly one left or right laterality

(b) Disjointness axiom states that left and right hands are exclusive. In fact, for each modality, a single disjointness axiom is defined asserting that nothing can be left and right, e.g., `DisjointClasses(`*Left Right*`)`. Thus all `Left_A` and `Right_A` are automatically inferred to be disjoint, and much less axioms used.

Algo 1. The algorithm handling symmetrical siblings parses all names of classes to get the terms matching the specific prefixes of modality (e.g. *Left*_A/*Right*_A). For each class (e.g. Left_A), if (a) A exists and (b) A (or Anatomical_A) is a direct superclass of Left_A, then several processes are performed on Left/Right A, on its symmetrical sibling and father. (P1.1) each time A has a child *Left_A/Right_A*, unless exceptions, A should have the pair as children, thus any missing child is complemented; (P1.2) each time A has two children *Left_A* and *Right_A* and `A` has an existential restriction `part some B` on *part* or a subproperty, e.g.; *constitutional_part; regional_part*, the two symmetrical siblings should have similar restrictions (modulo symmetry), thus any restriction missing in Left/Right_A, is created; (P1.3) if a (symmetric) restriction is present in two symmetrical siblings but not in their direct superclass, the similar abstracted restriction is added to the superclass. For example,

(a) *Left_Hand* < *constitutional_part* some *Investing+fascia+of+left+hand*

(b) *Right_Hand* < *constitutional_part* some *Investing+fascia+of+right+hand*

the subclass axiom *Hand* < *constitutional_part* some *Investing+fascia+of+hand*, which is missing for *Hand* is created; (P1.4) the equivalent class is created: *P_A* ≡ *Prim* and *A*, where *P* is a subclass of *Primary_Anatomical_coordinate;* A subclass axiom is created that states that A should have exactly one of two opposite coordinates. For example, the equivalent class and subclass axioms *Left_A* ≡ *Left* and A and A < *anatomical_coordinate* exactly 1 {*individual_Left, individual_Right*} are created.

Algo 2 handles patterns A_of_B. First, all names are parsed to get the terms that match the pattern A_of_B. **(P2.1)** If two conditions are met

(a) `A_of_B < A` or `A_of_B < Anatomical_A`

(b) `A < p_of some B', B< B'`, that is (a) the direct superclass of A_of_B is A or Anatomical_A (b) `A` has an existential restriction (some) on a *part_of* property or subproperty: `A < p_of some B'`, B' direct superclass of B, then the axiom `A_of_B ≡ A and p_of some B` is created (e.g. for *Ganglion_of_cranial_nerve*). (P2.1b) is a slight variant for `B'` not a direct superclass of `B` (it may be a distant ancestor): if entity A exists (or Anatomical_A) and B' has a restriction `p some A_of_B'` for the inverse p of p_of, then the axiom is created as well; (**P2.2**) If two conditions are met (a) `A_of_B < A` or `A_of_B < Anatomical_A` and (b) `A_of_B < p_of some B`, that is `A_of_B` has an existential restriction, then the axiom *`A_of_B`* ≡ *`A`* `and` *`p_of`* `some` *`B`* is created e.g.; *Tendon_of_biceps_femoris*

Example. a) the direct superclass of `Lobe_of_Lung` is `Anatomical_Lobe` b) `Lobe_of_Lung` is a subclass of `regional_part_of some Anatomical_Lobe` then the definition `Lobe_of_Lung ≡ Anatomical_Lobe and regional_part_of some Lung` is created. (P2.3) is a specific process for classes A_of_B where A is *Region_of, Zone_of, Segment_of, Subdivision_of* that creates the axiom A_of_B ≡ *`S`* `and` *`regional_part_of`* `some` *`B`*, `S` being the direct superclass of `A` (1273 classes).

- **Completing or compacting axioms**. Other axioms are created or moved. In particular (P00) 669 missing subclasses are created for expressing 'symmetrical' restrictions on *part* and *part_of* properties e.g., `Hand < regional_part some Thumb` and `Thumb < regional_part_of some Hand` should exist because in canonical anatomy, if an entity A has some part B, then B should also have some part A (which is not logically equivalent). (P0) If all the subclasses of A have the same restriction p some C, then the restriction is moved to A and removed from its subclasses.
- **Properties characteristics axioms.** OWL 2 allows to assign object properties with new characteristics. Following FMA authors advice, *part, regional_part, constitutional_part, systemic_part and member* and their inverse are asserted to be transitive, irreflexive, asymmetric, *continuous_with* and *connected_to* symmetric, *continuous_with* reflexive.

(c) Annotations

- **Standard terms.** A number of property names of FMA frames are replaced by terms of "standardized" vocabularies like Dublin Core, RDF etc., e.g., *Preferred-name* is replaced by `label@en`, *Non-English-equivalent* by `label@lg` (`lg` refers to a language tag), *date entered modified* by `dc:date`, *author* by `dc:creator` etc.
- **Annotation of annotation.** In FMA frames metadata on classes are defined via metaclasses. Most slots; e.g; *preferred name, synonyms, non-English equivalents,* are assigned individuals of the *Concept name* class as values. Instead, metadata are defined here by OWL 2 annotation of annotations. For example, `Heart` is annoted by `"Coeur"@fr`, and the labeling itself is annotated by the annotations `FMAID "217079", creator JOSE MEJINO, MD, date, publisher` etc. This is more correct from a modeling viewpoint, and it also allows to remove a huge number of useless (non anatomical) individuals.

(d) Metaclasses. OWL DL required a strict separation between the names of classes and individuals. OWL 2 DL relaxes this separation allowing different uses of the same term, e.g., *Heart*, used for a class, the class of all hearts, and for an individual, the individual representing the class *Heart* instance of the (meta)class of all *Organ with cavitated organ parts*. Metaclasses might reflect more accurately the intentions of the FMA's authors to model anatomical entities templates.

FMA-OWLizer Tool

FMA-OWLizer is a friendly and easy to use tool that automatically moves the FMA to OWL (1 or 2). It can process *all* existing public FMA versions, FMA 2005 version, FMA3.0 (2008), and even the last 11/20/2009 beta. It is highly versatile and flexible, a) allowing to provide users, whatever OWL developers FMA authors or application designers, with a customized FMA-OWL, and b) supporting future FMA versions. To avoid confusing the users with many different options, and to keep the tool as simple and easy to use as possible, the main parameters have to be selected via a friendly graphical user interface (GUI**)**, while other ones must be configured via configuration files. For example, users can specify the classes (and subclasses) they want to be removed in the OWL ontology via the configuration file "classes_to_delete.txt". The file "forbidden_for_symmetry_classes.txt" stores all symmetrical classes that must not be automatically generated by the program, because they do not denote real anatomical entities, according to FMA authors. The FMA-OWLizer includes the options below:

- **Source file** option allows selecting the input file: either Protégé frames or an OWL file.
- **Classes** option allows *FMA-OWL* 2 to include all FMA classes or only specific classes by excluding a) the classes specified in a configuration file b) or all the classes containing the term *left/right*, e;g.; `Skin_of_right_eyelid` c) or all *left/right* leaves, e.g. `Left/Right_hand`. It also possible to choose to keep the FMA original metaclasses or not.

- **Properties** option allows having all FMA properties or only specific ones specified in a configuration file.
- **Axioms** option allows customizing the class and property axioms *FMA-OWL* 2 in various ways. It is possible to supply particular classes definitions by creating equivalent classes axioms based on specific properties entered by the user, e.g.; *constitutional_part, bounded_by* etc. It is also possible to include/remove all the subclass axioms (e.g. for performance tests). It is possible to configure properties characteristics, e.g. to ignore functional, transitive, or irreflexive and asymmetric etc. For example, to get an OWL 2 DL ontology that reasoners can process, it is recommended to select the option 'ignore irreflexive and asymetric'. Otherwise, as *part* and their inverse are transitive (hence, not simple), asymmetric and irreflexive properties, *FMA-OWL* 2 would violate the restriction that only simple roles can be used in asymetric and irreflexive object property axioms [9] .
- **Syntax** option allows selecting the concrete syntax used to store *FMA-OWL* 2: RDF/XML, OWL/XML, or Functional Syntax.
- **OWL specy** option allows selecting the OWL specy: OWL1 DL or OWL 2 DL.
- **Version** option allows to select a partial *FMA-OWL v1* or a complete *FMA-OWL* 2 conversion.
- **Language** option allows selecting French or English for the GUI.

FMA-OWLizer is a local Java program designed and developed specifically for the FMA. All the processes are performed via the OWL API 3.0, thus benefiting of its functionalities, for example to generate the various syntaxes of the FMA-OWL. The GUI is achieved with the Swing/AWT Java graphics libraries. It is multilingual support (bundle files), thanks to the CISMeF Utils platform.

Results

File	Size	Classes	Axioms	Expressivity
FMA-OWL 1 from FMA 2005				
#1 without N&S	41,6	41648	236208	$\mathcal{ALCOIF}(\mathcal{D})$
#2. with N&S	40,8	41648	230690	$\mathcal{ALCOIF}(\mathcal{D})$
FMA- OWL 2 from FMA 3.0 2008				
#3. with Equ. Cl.	245	85005	273011	$\mathcal{SROIQ}(\mathcal{D})$

Table 1: Metrics of *FMA-OWL* ontologies

1. FMA-OWL ontology. Complete representations of the entire FMA in OWL 1 or OWL 2 DL are now available. Several FMA-OWL versions of various size and complexity have been created and many others can be generated. For example, *FMA-OWL* v1 variants of Table 1 (files about 41 Mb) are OWL 1 versions of FMA 2005 of which left/right leaves are cut, without (#1) or with (#2) equivalent classes (N&S) built from the property *constitutional_part. FMA-OWL* 2 is an OWL 2 version of FMA3.0 with all classes and properties (except *homonym_of* and *homonym_for,* discarded in agreement with FMA's authors), the new classes definitions and axioms created, no customized N&S, retaining transitivity but ignoring irreflexivity and asymetry.

2. Impacted classes and axioms. The new OWL-izing processes bring to the *FMA-OWL* 2 ontology: 15560 new definitions of FMA classes formalized in OWL, 16113 disjointness out of 248889 OWL axioms, 85467 axioms are removed, replaced by one single axiom (next inherited), 15 subproperties axioms and 228263 annotations are created.

Prefix	Impacted classes	New classes
Left/Right_A	7333	9
Male/Female_A	60	2
Inferior/Superior_A	163	23
Anterior/Posterior_A	280	26
Total P_A	7836	63
Total A_of_B	7664	
Total class definitions	15 560	

Table 2: Number of FMA impacted entities and axioms

3. Classification The FMA-OWL ontologies are perhaps the largest and most complex OWL ontologies available, and reasoning with FMA-OWL proved to be a real challenge. No reasoner could classify them so far. Recently HermiT [8] - since yesterday! it has an algorithm with a special blocking strategy for FMA like ontologies with lots of unsatisfiable classes – could process them in a reasonable time. *FMA-OWL* 2 (Table 1 #3 - 2010-03-11) has 65,753 unsatisfiable classes out of 85,005. The time for classification, including loading and preprocessing, is 58m 12s 929ms (by Birte Glimm). *FMA-OWL* v1 with constitutional-part for N&S (#1) has 33,433 unsatisfiable classes out of 41,648, and time for classification is 33m 46s 55ms.

Discussion and perspectives

The *FMA-OWL 2* ontologies created differ from previous OWL conversions. [6] translation focuses on sticking to the *explicit* information present in FMA frames and its metaclasses modeling. The result is an OWL 1 Full ontology importing an OWL DL ontology. Similarly [4] translation is an OWL 1 Full ontology, the authors arguing for a two-layers approach. In contrast, our migration represents not only the *explicit* but also the *implicit* information. It creates OWL 2 DL ontologies, leveraging OWL 2 expressiveness to enrich the representation, for example with qualified cardinality restrictions or annotation of annotations. Even metaclasses are now possible, if desired. Regarding the pattern-approach, a few patterns used to DL-ize the FMA are shared with those of [7] used to abstract a portion of and reduce FMA size. But the goal of "Abstracting and Generalizing the FMA", is clearly different. Also our patterns are more general, including for example A_of_B, Region_of_B etc. Besides, our approach goes further. It exploits the patterns not only to bring safe classes definitions to the FMA, but also to detect and fix FMA errors (e.g. missing restrictions), and to add disjointness and subclass axioms. Automatically generating these axioms is partly shared with [5] but the latter focuses only on the automatic generation of disjointness and covering axioms, is restricted to the Physical Anatomical Entity subtree, and subclass and part relations, while our approach is more general and systematic. The program is extensible and will support further extensions that are under way for example, definitions from other modalities, new patterns, e.g. for branches of nerves, etc. Other directions are considered to push the DL-izing process further for example, exploiting synonyms, e.g. *Wall of Organ* and *Organ wall*. Probably one of the most promising perspective is to analyze and exploit the classification and inconsistencies results produced by DL reasoners. However, this is contingent upon OWL 2 editor, reasoners, and explanation tools (recent or future) progress. A plugin for P4 might be also of interest for FMA users. A first possible application of this work might be the future integration of *FMA-OWL 2* as an health terminology into the Health Multi-Terminology Portal in French (http://pts.chu-rouen.fr)

Conclusion

We have presented a method to bring semantics to the FMA and a flexible tool to move it to OWL 2. Complete representations of the entire FMA in OWL 1 or OWL 2 DL are now available and over 15500 FMA classes have a logical definition. The FMA-OWLizer tool allows for producing several FMA-OWL variants. However, representing accurately the semantics of the FMA model is still a long way. The FMA describes anatomical structures composed of complexly interconnected parts. Defining automatic procedures that correctly encode the semantics without risking errors *and* that DL reasoners can process, is a real challenge. This work is a first important step forward. The approach and results obtained so far are very promising. Future work will aim at pushing yet further the formalization in OWL 2 and its exploitation by reasoners to improve the FMA design and its maintenance.

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References

1. C. Rosse, J.L. Mejino Jr, The Foundational Model of Anatomy Ontology Cornelius Rosse and José L. V. Mejino , In Burger A, Davidson D, Baldock R (editors): Anatomy Ontologies for Bioinformatics: Principles and Practice, Springer,.59-118 ISBN 978-1-84628-884-5. 2008, New York.
2. C. Rosse, J.L. Mejino Jr, A reference ontology for biomedical informatics: the Foundational Model of Anatomy, J. Biomed. Inform. 36 (6) (2003) 478–500.
3. C. Golbreich, S. Zhang, O. Bodenreider, The Foundational Model of Anatomy in OWL: experience and perspectives, Journal of Web Semantics, Web Semantics: Science, Services and Agents on the World Wide Web, 4 (3) (2006) 181–195.
4. O. Dameron, D.L. Rubin, M.A. Musen, Challenges in converting frame based ontology into OWL: the Foundational Model of Anatomy case-study, in: AMIA Annual Symposium, Washington DC, 181-185, 2005.
5. O. Dameronn and Julie Chabalier. Automatic generation of consistency constraints for an OWL representation of the FMA 10th International Protégé Conference, 2007.
6. Natalya F. Noy, Daniel L. Rubin, Translating the Foundational Model of Anatomy into OWL, Journal of Web Semantics, Web Semantics: Science, Services and Agents on the World Wide Web, 6 (2008) 133–136.
7. Eleni Mikroyannidi, Alan Rector and Robert Stevens, Abstracting and Generalising the Foundational Model Anatomy (FMA) Ontology, Bio-Ontologies, 2009.
8. Birte Glimm, Ian Horrocks, and Boris Motik, Optimized Description Logic Reasoning via Core Blocking (submitted).
9. W3C OWL Working Group, OWL 2 Web Ontology Language Document Overview W3C Recommendation 27 October 2009, http://www.w3.org/TR/owl2-overview/.
10. Christine Golbreich and Evan K. Wallace , OWL 2 Web Ontology Language New Features and Rationale W3C Recommendation 27 October 2009, http://www.w3.org/TR/owl2-new-features/