An exercise on developing an ontology-epistemology about schizophrenia and neuroanatomy

Rodolpho Freire [1] ; Danilo N. dos Santos [1] ; Marcus V.T. Santos [2] and Paulo E. Santos [1]
[1] FEI - São Paulo, Brazil ; [2] Ryerson University, Ca.

Abstract

This paper describes preliminary ideas on formalizing some concepts of neuroanatomy into ontological and epistemological terms. We envisage the application of this ontology on the assimilation of facts about medical knowledge about neuroimages from schizophrenic patients.

Introduction

This paper is part of a major effort into the formalization of the knowledge contained in neuroimages of patients with schizophrenia. Our long term goal is to build an ontology that is a formal basis for the expectations generated from statistical data analysis.

There are a number of biomedical ontologies, perhaps central to this area are the Foundational Model of Anatomy (FMA)[6] and the Open Biomedical Ontologies (OBO)[9], amongst others as summarized in by Friedman, Chen and Fuller, *et al*[3]. FMA is a knowledge source of classes and relations about observable characteristics of the human body structure; thus, FMA is mainly concerned with representing anatomical information. In contrast, the OBO Foundry project is a collaborative development which includes a large amount of biological information. Some attempts have also been made to build ontologies of neuroanatomical structures.[4,5]

The goal of the present paper is to relate a space ontology about the ventricular brain system (VBS) with findings about changes in this structure that are picked out in neuroimages from schizophrenic patients.

The structure of the VBS can evidently be represented within an ontology, however changes in neuroimages refer to knowledge about a domain, and not to the domain itself; findings about schizophrenia falls within the epistemology umbrella. A complete solution of combining ontologies with epistemology is still an open issue. However, we make explicit which are the classes related to the domain of neuroanatomy and which are related to the knowledge about the domain (the epistemological classes). In the present paper we propose a region-based ontology using the Basic Inclusion Theory (BIT)[1], due to its clear definitions of spatial regions through part-whole, taxonomic and topological relations, with the explicit use of logical relations. Another characteristic of BIT is that its underlying language is the first-order logic, which allows the inclusion of axioms about complementary theories into a single formalism. Figure 1 presents BIT base relations.

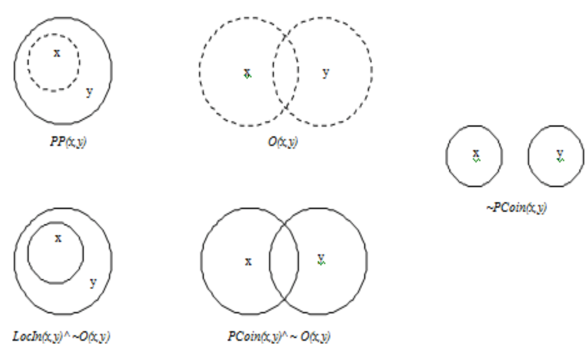

Figure 1. Basic Inclusion Theory relations.

Ventricular Brain System (VBS)

The ventricular brain system is a cavity disposed within the brain, which is composed of the third, fourth and lateral ventricles. The lateral ventricles are subdivided as body, frontal horn, occipital horn and temporal horn. The communication between the lateral ventricles and the third ventricle is done by the Monro foramina. The third ventricle is sub-divided into anterior commissure, optical recess, supraparienal recess and infundibulum and communicates with lateral ventricles by Monro foramina. The third ventricle also communicates with the fourth ventricle by the cerebral aqueduct and in the centre of the third ventricle is located the interthalamic connection. The fourth ventricle is composed by the lateral recess and the Luschka foramina linking up with the third ventricle through the brain aqueduct.

A spatial bio-ontology for VBS

To represent the ventricular brain system and the medical knowledge about schizophrenia, we define Fiat Boundaries[11,10] and a notion of continuity[8,11] using BIT relations. Next section presents some ideas about how it is accomplished.

Fiat Boundaries and continuity

Fiat boundaries are used for representing abstract limits, i.e., those limits that are commonly accepted, but which do not have a concrete existence[11,10]. In the biomedical area fiat boundaries can be used to delimit anatomical regions[2], such as the limits between ventricular regions. We define the relation LFiat, read as "x is a fiat boundary in y", and is axiomatised as follows:

$$LFiat(x, y) \quad (1)$$

$$LFiat(z, x) \rightarrow PCoin(z, x) \quad (2)$$

$$LFiat(x, y) \rightarrow \neg \exists z\, LFiat(z, x) \quad (3)$$

$$LFiat(x, y) \wedge LFiat(x, z) \rightarrow \neg Desc(y, z) \quad (4)$$

$$LFiat(x, y) \wedge LFiat(y, z) \rightarrow PCoin(x, y) \quad (5)$$

A discontinuity can be defined as a disjunction among two distinct spatial regions which became disconnected. Santos e Cabalar[8] proposed a theory based to represent discontinuity based in Varzi[11]. We use this notion to represent (for instance) the third ventricle, which has a material discontinuity called the interthalamic connection. We represent a discontinuity using the relation Disc(x,y) ("x is a discontinuity in y") and define the following axioms to constrain its meaning:

$$Disc(x, y) \quad (6)$$

$$Disc(x, y) \rightarrow LocIn(x, y) \quad (7)$$

$$Disc(x, y) \rightarrow \neg Disc(y, z) \quad (8)$$

Using Desc/2 we can define the notion of "continuous part": PCont(x, y) meaning that x is a continuous part of y, as shown in formula 9.

$$PCont(x, y) \equiv [PP(x, y) \vee P(x, y)] \wedge \forall z\, \neg Disc(z, x) \quad (9)$$

Then, we define a segment x of an object y (*Segm(x,y)*) as the "maximal continuous part" of y according to formula 10.

$$Segm(x, y) \equiv PCont(x, y) \wedge \neg \exists z [PP(y, z) \wedge PCont(z, y)] \quad (10)$$

Representing the VBS

There are 21 Fiat boundaries limiting all ventricular anatomical elements. The formulas 11 to 14 represents the fiat boundaries (represented by Z) that delimit the right and left lateral ventricles, third ventricle and fourth ventricle.

$$LFiat(Z_1; Left\_Lateral\_Ventricle) \quad (11)$$

$$LFiat(Z_2; Right\_Lateral\_Ventricle) \quad (12)$$

$$LFiat(Z_3; Third\_Ventricle) \quad (13)$$

$$LFiat(Z_4; Fourth\_Ventricle) \quad (14)$$

Given the definitions of Fiat boundaries and continuity, we have conditions to represent each ventricle individually without ambiguities. The foramina area is defined in similar terms. The formulas 15 define the right lateral ventricle, the volume of ventricle is given by variable φ. In the similar way the formulas 16 to 18 define the third left lateral ventricle, third ventricle and fourth ventricle, respectively:

$$Inst(x, Right\_Lateral\_Vent) \leftarrow (Vol(x) = \varphi) \wedge [\varphi > Vol\_TV] \wedge [\varphi > Vol\_FV] \wedge LFiat(Z_2, x) \wedge Segm(x, Ventricular\_Brain\_System) \quad (15)$$

$$Inst(x, Left\_Lateral\_Ventricle) \leftarrow (Vol(x) = \varphi) \wedge [\varphi > Vol\_TV] \wedge [\varphi > Vol\_FV] \wedge LFiat(Z_1, x) \wedge Segm(x, Ventricular\_Brain\_System) \quad (16)$$

$$Inst(x, Third\_Ventricle) \leftarrow (Vol(x) = \varphi) \wedge [(\varphi < Vol\_LLV) \wedge (\varphi < Vol\_RLV)] \wedge (\varphi > Vol\_FV) \wedge LFiat(Z_3, x) \wedge Segm(x, Ventricular\_Brain\_System) \quad (17)$$

$$Inst(x, Fourth\_Ventricle) \leftarrow (Vol(x) = \varphi) \wedge [(\varphi < Vol\_LLV) \wedge (\varphi < Vol\_RLV)] \wedge (\varphi < Vol\_TV) \wedge LFiat(Z_4, x) \wedge Segm(x, Ventricular\_Brain\_System) \quad (18)$$

We include in Protégé all axioms that represent the Fiat boundaries and which anatomical structures they are related to. This definition is expressive enough to answer questions such as: "given one region x, that belongs to y, which is this region?", or "which ventricular region is the foramina x connected with the ventricles"?.

Epistemological Classes

In order to define common characteristics among distinct groups, the medical specialist relies on the relative literature (using information from meta-analysis), image or statistical analysis. The information available in these sources is not part of the domain (so it cannot be captured by an ontology) but it is knowledge about it.

The knowledge about things are not the things itself, therefore, including it in the ontology would lead to Kantian confusion. In this work we avoid this confusion by assuming "epistemological classes", which are related to the ontological classes by a modified Is_a relation (Is_a2). Given an epistemological class E, an ontological class O and a binary primitive relation κ(x, y) (representing that x is the knowledge about a domain y), we define Is_a2 in BIT in the following way:

$$Is\_a2(E,O) \equiv \forall x(Inst(x,E) \rightarrow \neg Inst(x,O) \wedge \kappa(x,O) \quad (19)$$

Informally, E is an epistemological class within the ontology O iff every instance of E is not an instance of O but is knowledge about O. In Figure 2 we can see a graphical schema that shows epistemological classes about the right lateral ventricle. The epistemological classes are described by the formulas 20 to 27.

$$Is\_a2(CONTROL\_RIGHT\_LV,RIGHT\_LV) \quad (20)$$
$$Is\_a2(PATIENT\_RIGHT\_LV,RIGHT\_LV) \quad (21)$$
$$Is\_a2(CONTROL\_LEFT\_LV,LEFT\_LV) \quad (22)$$
$$Is\_a2(PATIENT\_LEFT\_LV,LEFT\_LV) \quad (23)$$
$$Is\_a2(CONTROL\_TV,THIRD\_VENTRICLE) \quad (24)$$
$$Is\_a2(PATIENT\_TV,THIRD\_VENTRICLE) \quad (25)$$
$$Is\_a2(CONTROL\_FV,FOURTH\_VENTRICLE) \quad (26)$$
$$Is\_a2(PATIENT\_FV,FOURTH\_VENTRICLE) \quad (27)$$

Therefore, we can include both ontological and epistemological individuals in the same formalism. In this work, an epistemological individual is a piece of knowledge about anatomical changes in the VBM (related to schizophrenia) that comes from the medical literature (meta analysis for instance) or from image data analysis procedures. It is now possible to execute queries about, for instance, the composition of the ventricular brain system, or about specialist knowledge about the domain.

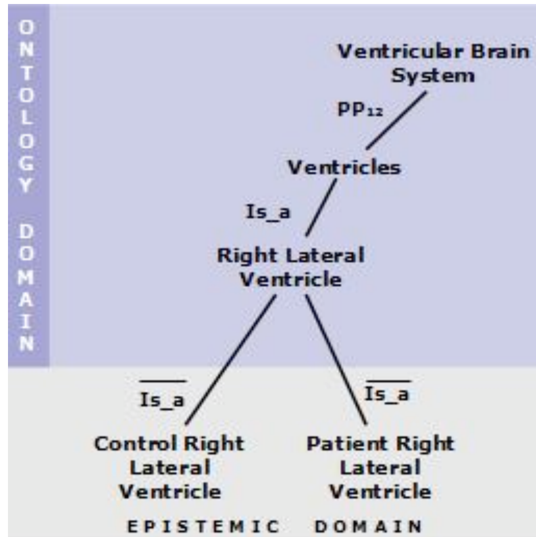

Figure 2: Differences About Ontological and Epistemological domains.

An example of an ontological query is: "Which structures compose the ventricular brain system ?" This query in Protégé (using Manchester syntax) becomes "PP only Ventricular_Brain_System" and results in all classes that compose the ventricular brain system. Figure 3 shows us a part of some of these results.

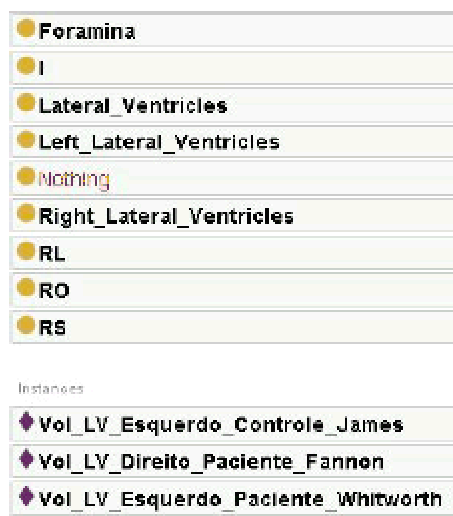

Figure 3. Ontological Query Result

Epistemological reasoning is possible in a similar way: the query "the volume 6.52 of the right or left lateral ventricles is classified as patient or control groups ?". In Protégé this query becomes "Lateral_Ventricles and Vol value 6.52", and produces the result: "Vol_Right_LV_Control_Barr", which means that the classification of an individual whose lateral ventricle (LV) has a volume of 6.52 is “control" according to Barr [7].

Conclusion and future works.

This paper briey described a formalization for ontological and epistemological classes about the ventricular brain system defined using BIT, and realized computationally in Protégé. This allows us to include and consult the domain entities as well as the knowledge about the domain. Future work will consider the formalization of new evidences about schizophrenia to be included in this framework.

References

1. Thomas Bittner and Maureen Donnely. A formal theory of qualitative size and distance relations between regions. In Proceedings of the 21 International Workshop on Qualitative Reasoning, 2007.

2. James M. Fielding and Dirk Marwed. The image as spatial region: Location and adjacency within the radiological image. In Formal Ontology in Information Systems, pages 444–448, 2006.

3. Carol Friedman Hsinchun Chen, Sherrilynne S. Fuller and William Hersh, editors. Medical Informatics, volume 8 of Integrated Series in Information Systems, chapter Biomedical Ontologies, pages 211–236. Springer US, 2006.

4. Bota M and Swanson LW. Bams neuroanatomical ontology: design and implementation. Front. Neuroinform., 2(2), 2008.

5. R. F. Martin, J. L. V. Mejino, D. M. Bowden, J.F. Brinkley, and C. Rosse. Foundational model of neuroanatomy: Implications for the human brain project. In Proc. of the American Medical Informatics Association Fall Symposium, pages 438–442, 2001

6. C. Rosse and J. Mejino. A reference ontology for biomedical informatics: the foundational model of anatomy. Journal of Biomedical Informatics, 36(6):478–500, 2003.

7. Shenton M.E.; Dickey C.C.; Frumin M.; McCarley R.W. A review of mri findings in schizophrenia. Elsevier, 49(1-52):141–144, 2001.

8. P. Santos and P. Cabalar. The space within fisherman’s folly: Playing with a puzzle in mereotopology. Spatial Cognition and Computation, 2008.

9. B. Smith, W. Ceusters, B. Klagges, J. Köhler, A. Kumar, J. Lomax, C. Mungall, F. Neuhaus, A. L. Rector, and C. Rosse. Relations in biomedical ontologies. Genome Biol, 6(5), 2005.

10. B. Smith and A.C. Varzi. Fiat and bona fide boundaries. Philosophy and Phenomenological Research, 2000.

11. A.C. Varzi. Boundaries, continuity and contact. Time, Space and Movement: Meaning and Knowledge in the Sensible World (Proceedings of the 5th International Workshop), 1995.