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Creating a Magnetic resonance imaging ontology

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Abstract. The goal of this work is to build an ontology of Magnetic Resonance Imaging. The MRI domain has been analysed regarding MRI simulators and the DICOM standard. Tow MRI simulators have been analysed: JEMRIS, which is developed in XML and C++, has a hierarchical organisation and SIMRI, which is developed in C, has a good representation of MRI physical processes. To build the ontology we have used Protégé 4, owl2 that allows quantitative representations. The ontology has been validated by a reasoner (Fact++) and by a good representation of DICOM headers and of MRI processes. The MRI ontology would improved MRI simulators and eased semantic interoperability.

Keywords. MRI, MRI Simulator, OWL, ontology.

Introduction

Magnetic Resonance Imaging is the most versatile diagnostic imaging technique. It can study T1, T2, diffusion, PH, temperature, spectroscopy… of tissues and of course make images. The vocabulary used by medical imaging constructors is very heterogeneous [1] and physical phenomena involved during MRI are very complex. So the MRI domain needs ontology to make the MRI community sharing the same concepts. To build our ontology we will take into account two MRI representations: MRI simulators and DICOM. The DICOM is an applicative representation with daily-use concepts. MRI simulators give a representation of complex physical phenomena that are involved in MRI and that are not describe in DICOM. The fusion of MRI simulators and DICOM concepts is needed to represent MRI examinations not only in an administrative way but in a useful way for radiologist interpretations.

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1. Material and methods

1.1. Analyzing DICOM [2]

The DICOM standard is divided in different parts. The relevant part for MRI is C.8.13 « Enhanced MR Image ». It is a section of the standard part 3: « Information Object Definition ». All concepts of this part, and their DICOM tags, will be included in our ontology, thus will give a semantic interoperability to the ontology. In DICOM, there is a lack of definition for an ontology. We will fill this gap by domain expert definitions, thanks to MRI simulators analysis.

1.2. Analyzing MRI simulators

We decided to analyze two MRI simulators JEMRIS and SIMRI.
SIMRI [3], is implemented in C language and is based on the Bloch equations. It enables simulations of 1D, 2D, and 3D images. Although simple, the user interface requires the use of C.
The simulator is divided in different parts:
- **Model** (Virtual object): Each voxel of the virtual object contains a set of physical values that are necessary to compute the local spin magnetization vector with the Bloch equations. These values are the proton density and the two relaxation constants T1 and T2.
- **MRI sequence**: During an MRI experiment, the object is placed in a static magnetic field B0 and is excited by electromagnetic events of two types: RF pulses (B1 field) and magnetic field gradients.
- The acquisition of the object magnetization state is stored as a complex signal in the **k- space** to obtain the image. This part is divided in 4 parts: The **free precession**, **precession with application of gradients** (specified by its duration and the gradient magnitudes in the three spatial directions), **signal acquisition** (number of points to capture, bandwidth, readout gradient magnitude and position of this signal in the k-space), the **application of RF pulses** (specified by its duration, a flip angle and the rotation axis). RF inhomogeneity and gradient non-linearity are not simulated.

The user can define the echo train and sequence parameters (repetition time, echo time, flip angle…). Chemical shift and susceptibility artefacts are modeled.

JEMRIS [4-5], is a C++ software with XML tags. It uses an optimized library for numerical solutions equations needed to simulate complex RF-pulses. It can deal with multichannel Tx-Rx coil geometries and configurations, nonlinear gradients, chemical shift, reversible spin dephasing (T2*), susceptibility-induced off-resonance, temporal varying processes of the object (e.g., movement or flow), and concomitant gradient fields.
The **graphical user interface** (GUI) is divided in three: one for interactively designing the MRI sequence, another for defining the coil configuration, and one for the setup and execution of the main simulator.
The software is divided in **5 classes: sample** (describes the physical properties of the object) **signal** (holds information about the MR signal) **model** (describes the functionality for solving the physical problem) **coil** (contains the code for spatially varying RF transmission and signal reception), **sequences**. The sequence loop is represented as a left-right ordered tree with loops (Fig1). The xml language has been

used to serialized C++ objects, describing the different steps of each sequence. The management of time interval has also been taken into account and formalised. The different modules interact with each other.

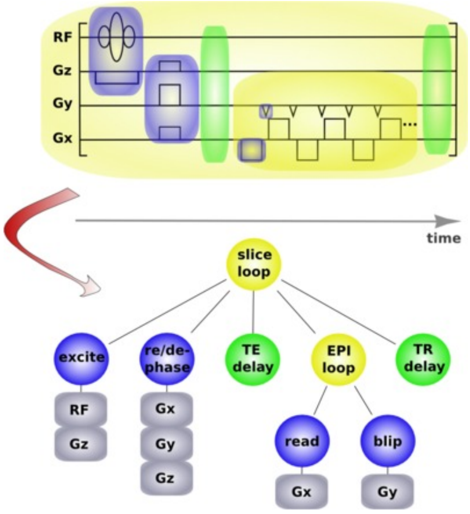


Fig.1: Echo Planar Imaging sequence schema in JEMRIS [4] yellow =loops , blue = pulses, green = intervals.

1.3. Using Protégé 4, owl2, Ontology validation

To build our ontology, we will use Protégé [6], which is a free, open source ontology editor and knowledgebase framework and the owl language. In our case, the domain has a lot of quantitative informations so we choose owl2, which allows us to define quantitative data properties. First of all, we have taken into account concepts from DICOM and secondly we have added concepts from MRI simulators.
We will use an ontology classifier FACT++ to check the ontology consistency. The ontology will be validated by the analysis of 10 MRI examination DICOM headers, extracted with OSIRIX [7] and the possibility to write sequences with the ontology.

2. Results

2.1. Ontology taxonomy

The main classes of ontology **taxonomy** are:
Object of the study: Defined by its size, voxels size, properties (T1, T2, Proton Density, Diffusion, Contrast enhancement cinetic), T2*, movements (general and flux)
Device: Magnet (intensity, shape, kind) coil (receiver coil, transmitter coil, multi-element coil, region) Gradient (magnetic field, slice selection, diffusion…)
Sequence, from this point our vision is different from JEMRIS. Actually, the representation of loop in a vertical way (fig.1) of physical events that are horizontal (dependant to time) and independent cannot be included in an ontology. Therefore we

have divided sequences in elementary events: radiofrequency pulse, slice selection gradient, readout gradient… according to SIMRI description of events.

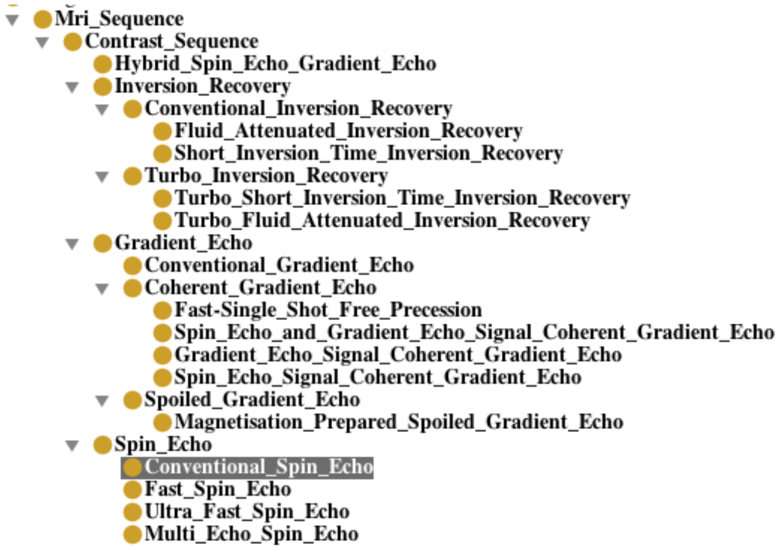
The signal acquisition modeled, has to be formalised by a mathematical way thanks to Bloch equations resolution as in the two softwares. The formula will be integrated in the ontology.

Acquisition results will be divided in: image, quantitative result…

Organisation of **sequences** in taxonomy is a difficult management. An article [8], written in a didactical goal, has organized sequences with their technical characteristics and with loops. Taxonomy doesn't have loop and the problem is that sequences can be a mix of different techniques that can't be organised in taxonomy. The solution we have chosen is to classify sequence according to their goals.

This solution is intuitive for clear goal: diffusion, angiography image… but less obvious for contrast sequences. So we have chosen to start with a general taxonomy of sequences (Fig.2), adding to each of them the Weighting of final images: T1Weighted, T2Weighted, DPWeighted and T2*Weighted.

Constructor acronyms of sequences have been added as synonyms of sequence name.



- Mri_Sequence
  - Contrast_Sequence
    - Hybrid_Spin_Echo_Gradient_Echo
    - Inversion_Recovery
      - Conventional_Inversion_Recovery
        - Fluid_Attenuated_Inversion_Recovery
        - Short_Inversion_Time_Inversion_Recovery
      - Turbo_Inversion_Recovery
        - Turbo_Short_Inversion_Time_Inversion_Recovery
        - Turbo_Fluid_Attenuated_Inversion_Recovery
    - Gradient_Echo
      - Conventional_Gradient_Echo
      - Coherent_Gradient_Echo
        - Fast-Single_Shot_Free_Precession
        - Spin_Echo_and_Gradient_Echo_Signal_Coherent_Gradient_Echo
        - Gradient_Echo_Signal_Coherent_Gradient_Echo
        - Spin_Echo_Signal_Coherent_Gradient_Echo
      - Spoiled_Gradient_Echo
        - Magnetisation_Prepared_Spoiled_Gradient_Echo
    - Spin_Echo
      - Conventional_Spin_Echo
      - Fast_Spin_Echo
      - Ultra_Fast_Spin_Echo
      - Multi_Echo_Spin_Echo

Fig.2: Contrast sequence Taxonomy

Acquisition parameters are divided in two essential parts: parameters modifying image geometry and parameters modifying image contrast.

The ontology relations are:

Different kinds of relations between concepts will be defined: **General:** Has_a , Has_Parameters… ; **Quantitative :** Has_Value, Has_Unit…

Owl2 permits quantitative representation of classes. The relations between classes are then: A Has_Modifyer B, A Increase_When_Decrease B, A Decrease_When_ Increase B will permit to describe variations of parameters.

2.2. Ontology validation

With the concepts present in the ontology we can define events that happen during MRI experiences, for examples:
Spin echo T2 weigthed sequence : Spin_Echo_T2W has_modifier some ((TR and (Has_Unit some milisecond) and (Has_Value some float [>=2000])) and (TE and (Has_Unit some milisecond) and (Has_Value some float [>80])))
radiofrequency pulses of Spin Echo sequence: Spin_Echo Has_Parameter some Radiofrequency_Pulse and (RadioFrequency_Pulse Has_a Flip_Angle ((Flip_Angle Has_Value value =90) or (Flip_Angle Has_Value value =180)).
We extract DICOM headers of 10 MRI examinations with OSIRIX Métadonnées. The analysis shows that concepts of DICOM headers are well represented in the ontology. The problem is that MRI constructors don't share the same DICOM tags for the same concept.

3. Discussion

There is only one work about MRI and ontology. It concerns brain functional MRI [9] and are interested in all the process and not only MRI. However it has already shown the need of ontology in the domain. JEMRIS have also, by using XML, shown the interest of web semantic in physical process description. DICOM also need to be improved with definitions and rules that ontology could define. Our ontology can increase the semantic interoperability in MRI. An ontology has already be implemented on a PACS in that goal [10] but not for MRI examinations.

References

[1] B. Gibaud, The quest for standards in medical imaging. *Eur J Radiol.* May 31, 2010.
[2] Digital Imaging and Communication in Medicine: DICOM web site, available from: http://medical.nema.org/. Access January 2011.
[3] H. Benoit-Cattin, G. Gollewet, B. Belaroussi, H. Saint-Jalmes, C. Odet, The SIMRI project : a versatile and interactive MRI simulator, *Journal of Magnetic Resonance*, Vol. 173, pp. 97-115, 2005.
[4] http://www.jemris.org, Access January 2011.
[5] T. Stöcker, K. Vahedipour, D. Pflugfelder, N. Jon Shah. High-performance computing MRI simulations. *Magnetic Resonance in Medicine*, 64 (1), 186 – 193, 2010.
[6] http://protege.stanford.edu, Access January 2011.
[7] http://www.osirix-viewer.com/ , Access January 2011.
[8] GE. Boyle, M. Ahern, J. Cooke, NP. Sheehy, JF. Meany, An Interactive Taxonomy of MR Imaging Sequences, *RadioGraphics* November-December vol. 26 no. 6 e24, 2006.
[9] T. Nakai, E. Bagarinao, Y. Tanaka, K. Matsuo, D. Racoceanu, Ontology for FMRI as a biomedical informatics method. *Magn Reson Med Sci.* 2008;7(3):141-55. Review.
[10] DL. Rubin, P. Mongkolwat, V. Kleper, K. Supekar and DS. Channin, Medical Imaging on the Semantic Web: Annotation and Image Markup. In: *2008 AAAI Spring Symposium Series, Semantic Scientific Knowledge Integration*, Stanford University, 2008.