RC 305 Computer Applications, ECR'2012, Vienna

Semantic web technologies for sharing and reuse of imaging-related information

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Overview

- Introduction : a viewpoint on CAD
- CAD results as DICOM Structured reports
- Semantic web technologies and ontologies
- CAD results using ontologies
- Added value
- Barriers
- Conclusion

Introduction

- CAD: extraction of features from images
 - objective (rather than subjective)
 - accurate and repeatable
 - quantitative (rather than qualitative)
- Used in focused clinical research to assess:
 - e.g., the efficacy of a new drug
 - the performance of a new procedure (e.g. a new image processing)
- as well as translational research

As a prerequisite of deployment in clinical routine, associated to decision support systems

Introduction some examples

- Extraction of RECIST criteria, for the follow-up of solid tumors
- Diagnosis of malignancy of chest nodules in CT and PET
- Detection of MS lesions for diagnosis and follow-up of MS
- Measurement of atrophy of hippocampal structures for diagnosis and follow-up of AD

Introduction Requirements

- Well-systematized modelling of extracted features
 - Explicit meaning
 - Complete (i.e. related to imaging evidence)
 - With appropriate measurement units
- Current state of the art: DICOM SR (structured reporting)



Structure of a SR document

• Tree structure (different types of nodes)



Nodes of a SR document

- CONTAINER
- TEXT
- PNAME (person name)
- DATETIME
- DATE
- TIME
- NUM (numerical value)

- IMAGE
- WAVEFORM
- COMPOSITE
- UIDREF
- SCOORD (spatial)
- SCOORD3D (3D)
- TCOORD (temporal)
- CODE

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CODF

Red: context of observation ; *Blue:* image evidence ; *Black:* other

Relations within a SR document

- Contains
- Has Observation Context
- Has Acquisition Context
- Has Properties
- Inferred From
- Selected From
- Has Concept Modifier

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Contrainsts on relationships ex: Chest CAD SR

Table A.35.6-2

RELATIONSHIP CONTENT CONSTRAINTS FOR CHEST CAD SR IOD

Source Value Type	Relationship Type (Enumerated Values)	Target Value Type
CONTAINER	CONTAINS	CODE, NUM, IMAGE ¹ , CONTAINER.
TEXT, CODE, NUM, CONTAINER	HAS OBS CONTEXT	TEXT, CODE, NUM, DATE, TIME, PNAME, UIDREF, COMPOSITE ¹ .
IMAGE, WAVEFORM	HAS ACQ CONTEXT	TEXT, CODE, DATE, TIME, NUM.
CONTAINER, CODE, COMPOSITE, NUM	HAS CONCEPT MOD	TEXT, CODE ² .
TEXT, CODE, NUM	HAS PROPERTIES	CONTAINER, TEXT, CODE, NUM, DATE, IMAGE ¹ , WAVEFORM ¹ , SCOORD, TCOORD, UIDREF.
CODE, NUM	INFERRED FROM	CODE, NUM, IMAGE ¹ , WAVEFORM ¹ , SCOORD, TCOORD, CONTAINER, TEXT.
SCOORD	SELECTED FROM	IMAGE ¹ .
TCOORD	SELECTED FROM	SCOORD, IMAGE ¹ , WAVEFORM ¹ .



"PET-CT CAD Report"

CONTAINER

Possibilities / limitations of DICOM SR

- Rich possibilities
 - Control of content
 - Rich content (images, ROI, measurements, codes)
- ... but, limitations
 - in DICOM syntax (binary, with DICOM tags)
 - in general, no formal semantics (codes, constraints on relationships)
 - Specific software for querying / reasoning on SR data

Semantic web technologies

Ontologies and ontology languages

• Ontology editors, e.g. Protégé (Stanford Univ.)

• Query languages, e.g. SPARQL (W3C recomm)

• Reasoners, e.g. FaCT++, Pellet, HermiT

Ontologies

- Definition (informatics and AI)
 - « a formal, explicit specification of a shared conceptualization » (Gruber 1993)
- Two basic aspects
 - A shared vocabulary
 - Formal semantics : axioms expressed in a logical language



Formal semantics

- Definitions of classes of objects
 - Taxonomy of classes: subsumption (i.e. « is a » relation)
 - Instanciation (relation between an individual and a class)
- Definitions of properties
 - Taxonomy of properties
 - Domain and range, inverse properties, etc.
- Processing by a reasoning engine
 - Assess satisfiability (consistency)
 - Classification of ontologies
 - Classification of instances

Reasoners are not application-specific

Some ontologies

- NCBO Bioportal:
 - More than 300 ontologies in the field of biology/medicine
- Examples
 - FMA: Foundational Model of Anatomy (Rosse et al.)
 - RadLex (RSNA)

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Welcome to the NCBO BioPortal NCBO BioPortal								
Welcome to the NCBO BioPortal +								
bioportal.bioontology.org		٩) 🖈						
🔯 Les plus visités 🔻 🥹 Débuter avec Fir 🔝	À la une 🔻 📄 anatomie	e 🔻 🛄 dicom 🔹 🧰 inserm 👻 🛄 Master 👻 🧰 irisa 👻 🧰 neurolog	🔻 🧰 VIP 👻 🧰 perso 👻 🧰 snomed 🔻 🧰 url 👻 » 💽 Marque-pages 🔻					
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Welcome to BioPortall For help using BioPortal, click on this icon: ?								
Search all ontologies Enter term, e.g. Melanoma Search Advanced Search		Find an ontology Enter ontology name, e.g. NCI Thesaurus Explore Browse Ontologies >	Search resources Enter a term, e.g. Melanoma Advanced Resource Search					
Most Viewed Ontologies (January, 2012)		Latest Notes	Latest Mappings					
Ontology	Views	Change Property Value Proposal: label (ABA Adult Mouse Brain) 11 days ago by Ifrench	State of consciousness and awareness (SNOMED Clinical Terms) => b1100. State of					
National Drug File	6071		consciousness (International Classification of Functioning, Disability and Health (ICF))					
MedDRA	2872	New Relationship Proposal: is_a (Cell line	BioPortal UI 01/20/12 samsontu					
SNOMED Clinical Terms 2018		ontology) 2 months ago by foxvog	<u>DI100. State of consciousness (international</u> <u>Classification of Functioning, Disability and</u>					
International Classification of Diseases	1349		Health (ICF)) => State of consciousness and awareness (SNOMED Clinical Terms) BioPortal UI 01/20/12 samsontu					
Medical Subject Headings	988	New Relationship Proposal: is_a (Cell line ontology) 2 months ago by foxvog						
Statistics		New Relationship Proposal: is_a (Cell line	b110. Consciousness functions (International Classification of Functioning, Disability and Health (ICF)) BioPortal III 01/11/12 samsontu					
Ontologies	303	Citalogy - months ago by locked						
Terms	5,835,227	New Relationship Proposal: is a (Cell line						
Resources Indexed	23	ontology) 2 months ago by foxvog						
Indexed Records	3,920,987							
Direct Annotations	686,755,419							
Direct Plus Expanded Annotations	5,269,200,920							

The National Center for Biomedical Ontology is one of the <u>National Centers for Biomedical Computing</u> supported by the <u>NHCRI</u>, the <u>NHLBI</u>, and the <u>NHL Common Fund</u> under grant U54-HG004028. Copyright © 2005-2012, The Board of Trustees of Leland Stanford Junior University. All rights reserved.

NCBO Website Release Notes Terms of Use Privacy Policy

Foundational Model of Anatomy

- Origin : C. Rosse et J. Mejino (Univ. Washington, Seattle)
 - « Digital Anatomist »
- Objective
 - « Theory of structural phenotype »,
 - Application-independent (« foundational »)
- Scope
 - Multi-scale: from organism down to cell
 - Multi-species
 - Embraces « development » (ontogenesis)
 - Canonical anatomy
 - Normal anatomy



FMA: snapshot from NCBO bioportal (ontology browser)

 Segment of major alar cartilage Segment of male urethra 		Preferred Name (rdfs:label)	Inferior frontal gyrus
in Segment of neural tree organ		ID	fma:Inferior_frontal_gyrus
- Brain		Full Id	http://sig.uw.edu/fma#Inferior_frontal_gyrus
□ Segment of brain □ Basal forebrain		Arterial Supply	Artery of precentral sulcus
Brainstem Gardinal segment of brain		Attributed Continuous With	fma:Middle_frontal_gyrus, Superior,
Neural lobe of neurohypophysis Image Segment of brainstem			fma:Lateral_orbital_gyrus, Inferior, fma:Precentral_gyrus, Posterior,
Gerebral hemisphere Diencephalon		Bounded By	<u>Semioval center</u> Surface of brain
Segment of diencephalon Segment of telencephalon Segment of subcortical		Constitutional Part	White matter of inferior frontal gyrus Gray matter of inferior frontal gyrus
telencephalon = Segment of cerebral hemisphe	e	Fmaid	61860
Gyrus of brain Anterior paracentral gyru Gyrus of frontal lobe 	yrus rus rus	Location	fma:Inferior_frontal_sulcus, Superior, fma:Precentral_sulcus, Posterior, fma:Superior_temporal_gyrus, Inferior, fma:Lateral_sulcus, Inferior,
Intermediate orbit gyrus	al	Member Of	Set of cerebral gyri
B Medial frontal gyru B Middle frontal gyru	is Is	Neurolex	file:/home/tredmond/Downloads/ONARD_Instance_2410027
Orbital gyrus Precentral gyrus Straight gyrus Superior frontal gy Transverse frontop	rus olar	Non English Equivalent	Gyrus frontal inférieur Regio subfrontalis Gyrus frontalis tertius 20 Gyrus F3
gyrus	-		Gyrus frontalis inferior

CAD results represented using ontologies

- Represented as a set of predicates
 - involving instances of the ontology classes
 - relating these instances using the ontology's properties
- that denote
 - the observation context
 - the imaging features (i.e. images, ROIs, etc)
 - their relationships to real life entities, e.g.
 - Anatomical entities (taken from FMA)
 - Pathological entities (taken from corresponding ontologies, e.g. : SNOMED, NCIT

CAD results using ontologies example (in simplified syntax)

- reportID1 hasTitle 'PET/CT CAD report'
- reportID1 authoredBy CADalgoID1
- reportID1 isAResultOf execofCADAlgoID1
- execofCADAlgoID1 hasData imageSeriesID1
- execofCADAlgoID1 hasData imageSeriesID2
- linear-measurtID1 isADiameterOf patho-objectID1
- linear-measurtID1 hasQuantitativeValue '13'
- Inear-measurtID1 hasMeasurementUnit UCUM:mm
- linear-measurtID1 isResultOf execofCADAlgoID1
- linear-measurtID1 isPartOf reportID1
- linear-measurtID1 isDerivedFrom ROIID1
- ROIID1 refersTo patho-objectID1
- patho-objectID1 locatedIn anat-entityID1

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Added value of semantic web technologies and ontologies (1)

- Standard vocabulary, facilitating data integration
- More explicit and more formal representation of CAD results
 - contrained by the domain and range of the ontology's properties

Added value of semantic web technologies and ontologies (2)

- Standard query language
 - i.e. SPARQL (W3C), a standard language to query semantic repositories
 - Needs to be hidden from the user interface (GUI)

Added value of semantic web technologies and ontologies (3)

- Rich inferencing capabilities
 - Potentially useful for CAD reasoning/classification
 - Ontology classes may include « defined classes » mentioning necessary and sufficient conditions for a particular instance to belong to this class
 - Implemented as standard (DL) reasoners
 - Examples of use
 - Daniel Rubin (Stanford Univ, caBIG) : RECIST criteria
 - Sonja Zillner (Siemens, MEDICO) : Classif. of lymphomas

Barriers

- Availability / adoption of domain ontologies
 - gathering consensus among domain experts (!)
 - with sufficient quality (from an ontology engineering perspective)
 - Overlaping domains
 - Clinical medicine / Physics / Biology / Engineering / Imaging / etc.
- Ontology subset extraction, integration and customization
- \rightarrow Long and iterative process

Conclusion / Summary

- To introduce semantic web technologies and especially ontologies
- To highlight added value in representation, sharing and reuse of CAD results data
- To discuss some of the barriers hampering the application of this technology in the field of imaging and CAD

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Some references

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- NeuroLOG: http://neurolog.i3s.unice.fr/neurolog
- Theseus/Medico: http://theseus-programm.de/en/ index.php
- DICOM Structured Reporting by Dr. David A. Clunie ISBN 0-9701369-0-0. 394 pages
 - http://www.pixelmed.com/srbook.html
 - http://www.dclunie.com/
- DICOM standard: http://medical.nema.org/