Sharing models for multi-modality image simulation in VIP

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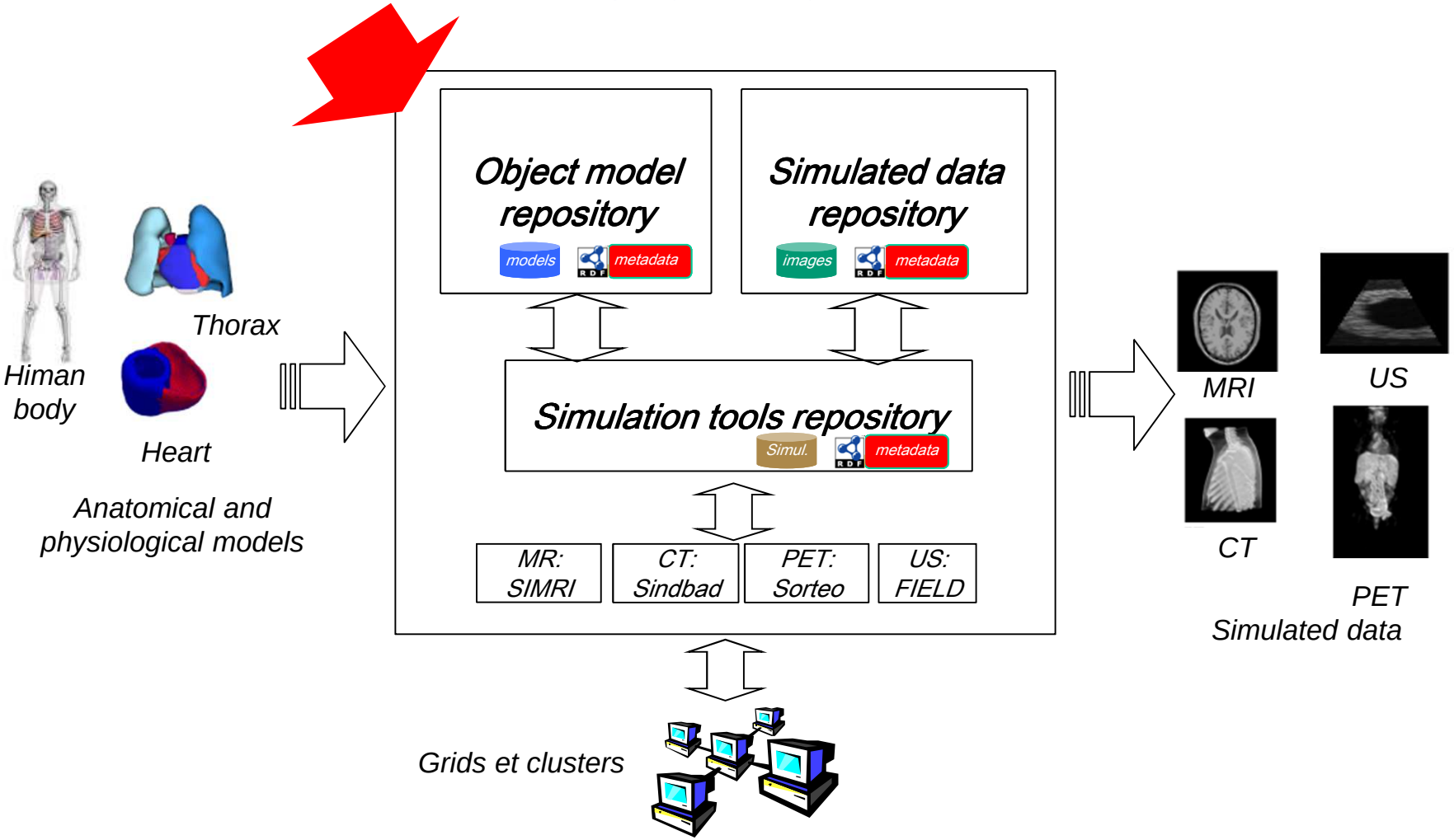
Overview

- Introduction – Goal and scope
- Part 1. Methodology
- Part 2. Result: OntoVip ontology
- Part 3. Result: Utilization in VIP platform
- Discussion and conclusion

Introduction

Goal and scope

Context

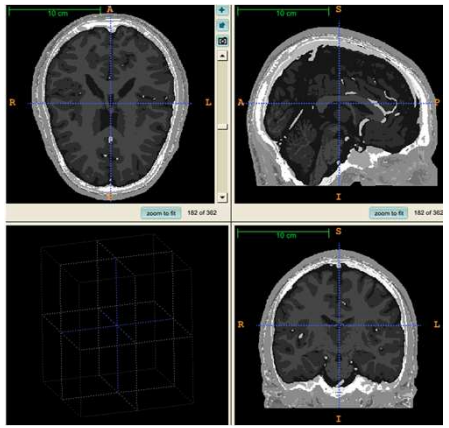

Himan body
Thorax
Heart
Anatomical and physiological models
Object model repository
models
metadata
Simulated data repository
images
metadata
Simulation tools repository
Simul.
metadata
MR: SIMRI
CT: Sindbad
PET: Sorteo
US: FIELD
Grids et clusters
MRI
US
CT
PET
Simulated data

Goal

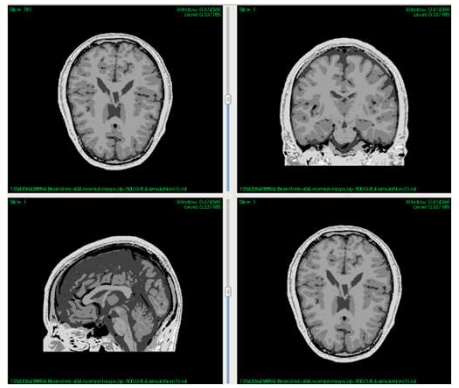
- Define a common vocabulary to describe shared information within the VIP platform
  - Content of the models used in simulation
  - Nature and provenance of simulated data
- Use of ontologies
  - Common vocabulary
  - Formal definitions of entities and relationships, enabling reasoning

Scope

- Models:
  - Data files, modeling a 3D scene
    - either objects (voxel maps, meshes)
    - and / or maps of values taken by physical parameters
- Simulated data
  - Non-reconstructed and Reconstructed data
- Simulation actions



BrainWeb model



Simulated T1weighted images

Specific constraints

- A common framework for all imaging modalities
  - X-Ray imaging, e.g., radiographs and computed tomography (CT)
  - Magnetic resonance imaging (MRI)
  - Ultrasound (US)
  - Positron Emission Tomography (PET)

Part I - Methodology

Methodology
Special concerns

- Reuse existing ontologies as far as possible
  - not re-invent the wheel
  - facilitate future interoperation with biological modelling software
- Create ontologies when necessary
  - ensure adequate documentation
- Integrate all components in a consistent whole
  - use of consistent integration framework

Reuse of existing ontologies

• Anatomy	✓ *FMA (865)*
• Pathology	✓ *Mouse pathology (494)*
• Physical qualities	✓ *PATO* (84)*
• Contrast agents	✓ *RadLex (81)*
• Radiopharmaceuticals	✓ *RadLex (49)*
• Foreign bodies	✓ *RadLex (189)*
• Atoms	✓ *ChEBI (255)*

** PATO: Phenotypic Attribute and Trait Ontology*

Creation of ontologies

- Domains
  - Models *(medical image simulation object models* or *models)*
  - Simulated data *(simulated data)*
  - Simulation actions *(medical image simulation)*

  (Extensive reuse of OntoNeuroLOG)
- Two representations
  - OntoSpec documents
  - OWL implementation

Extract of an OntoSpec document

Subsumption relation (« is a »)

Essential property / existential restriction

Medical image simulation, simulation

Meta Properties

MR SIMULATION, CT SIMULATION, PET SIMULATION and US SIMULATION and *is a disjunctive sub-division of* MEDICAL IMAGE SIMULATION.

Properties

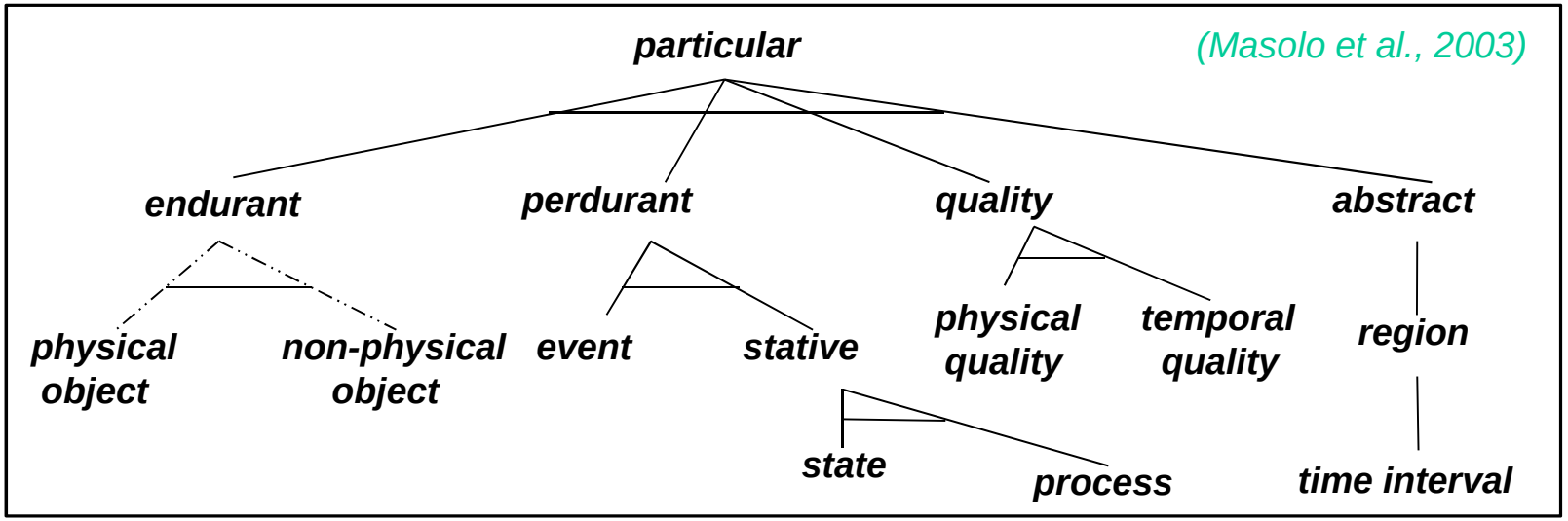
[EP/SL] A MEDICAL IMAGE SIMULATION is a DATASET PROCESSING [EP/ER] A MEDICAL IMAGE SIMULATION *has for data* exactly one MEDICAL IMAGE SIMULATION OBJECT MODEL *at* a TIME INTERVAL. [EP/ER] A MEDICAL IMAGE SIMULATION *has for result* some SIMULATED DATA *at* a TIME INTERVAL. A MEDICAL IMAGE SIMULATION *has for instrument* some MEDICAL IMAGE SIMULATOR *at* a TIME INTERVAL.

Comment

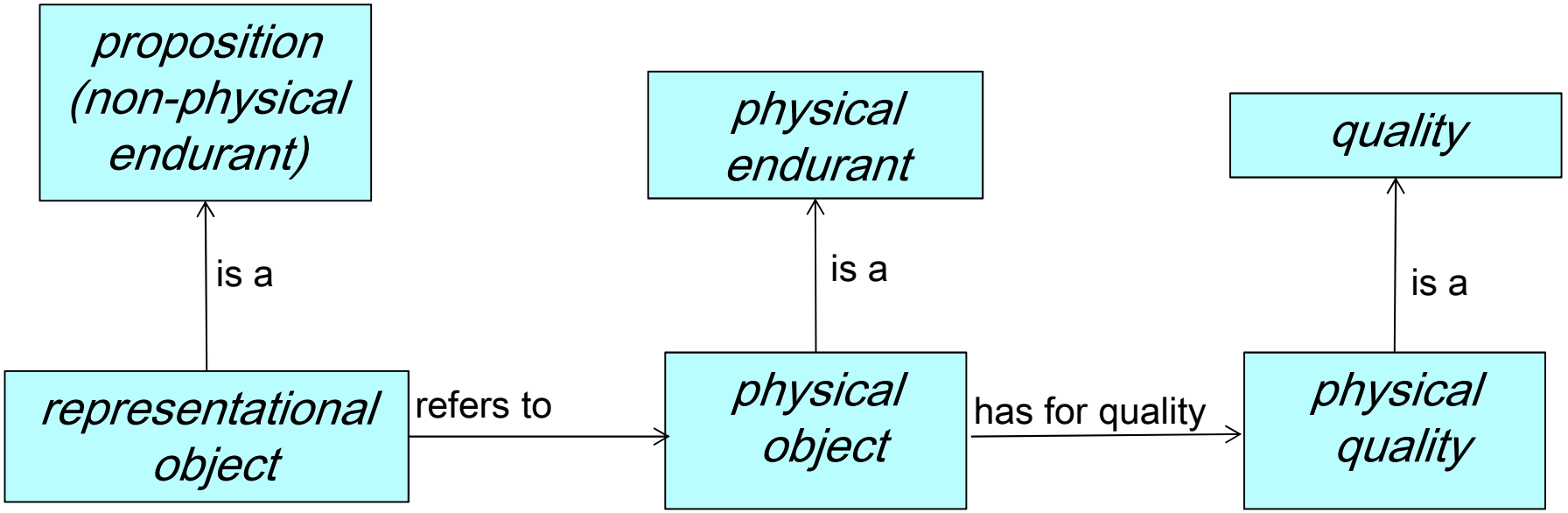
[DEF] A medical image simulation is a dataset processing consisting in calculating medical images representing an object (usually a biological object, but it can also be a geometric phantom) from a model of this object. The calculations involved in this process include the simulation of the physical phenomena that occur during a real image image acquisition using an imaging equipment (e.g. emission of photons and interactions with the imaged object and the detector).

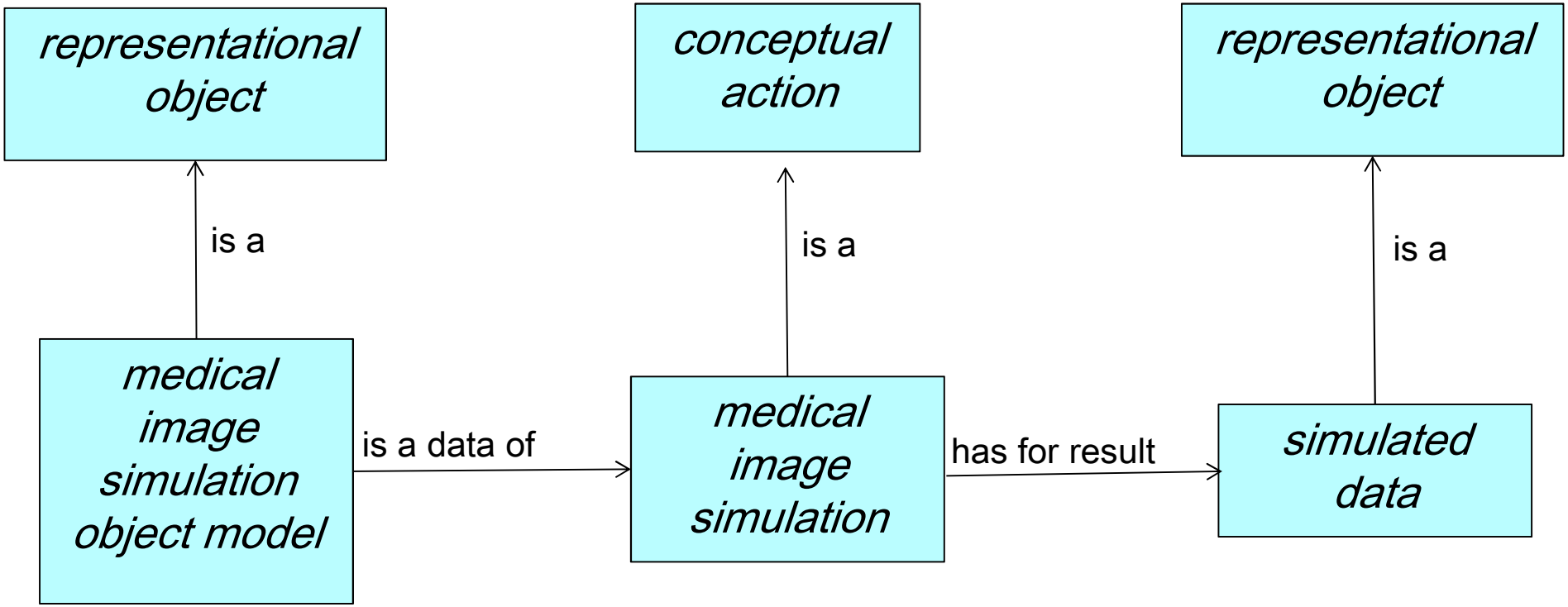
Common integration framework

- One single application ontology (called OntoVIP)
  - ✧ one **Foundational ontology**, i.e. DOLCE



  - ✧ Several **Core ontologies**
    - ✧ e.g. Actions, Artefacts, Participation roles, Agentives, Discourse message acts, I.E.C. (inscriptions-expressions-conceptualizations)
  - ✧ Several **Domain ontologies**


proposition (non-physical endurant)
physical endurant
quality
is a
is a
is a
representational object
refers to
physical object
has for quality
physical quality


representational object
conceptual action
representational object
is a
is a
is a
medical image simulation object model
is a data of
medical image simulation
has for result
simulated data

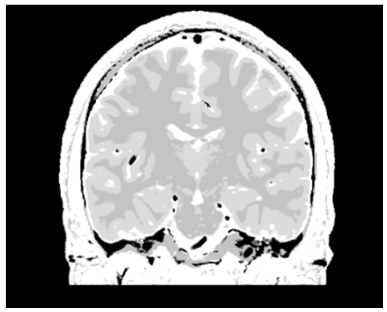
Part 2. Result: OntoVIP ontology

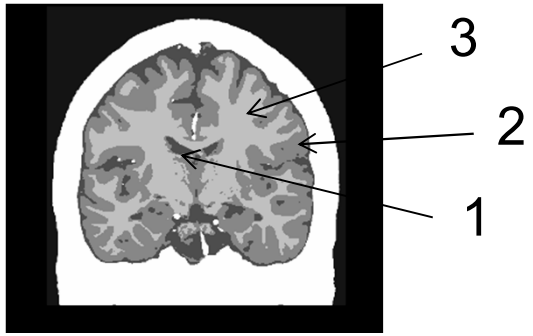
OntoVIP : major features

- Organization in *model layers*
- Relation to physical properties (*physical parameter*)
- Relation to time (*time point*, *instant*)
- Taxonomy of *models*
- Taxonomy of *medical image simulation*
- Taxonomy of *simulated data*
- Provenance

Organization in layers (1/3)

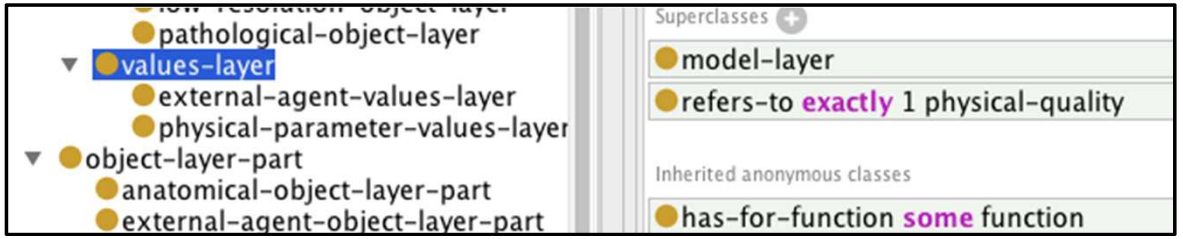
- Layers (*model layers*) are *representational objects* that aim at characterizing the contents of a model
  - Values layers depict the 3D spatial distribution of a parameter
    - e.g. the map of *proton density* values
  - Object layers depict the 3D distribution of objects
    - Composed of *object layer parts*
    - Each associated to a label value



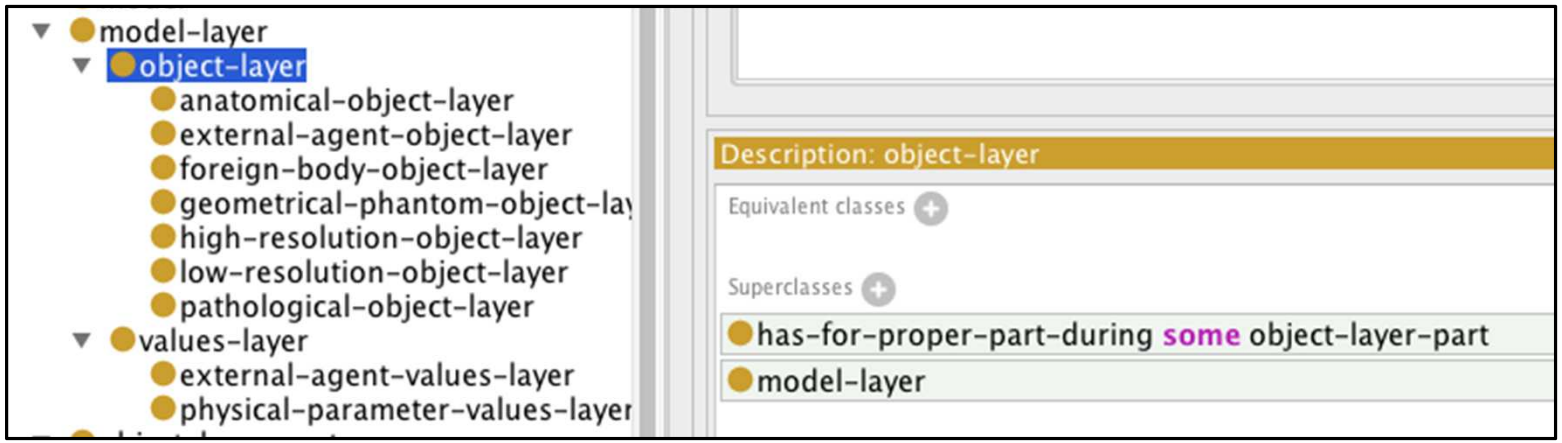


Organization in layers (2/3)

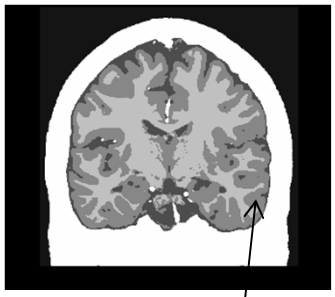
- *Values layer*



- *Object layer*



Organization in layers (3/3)
examples



anat-layer01 *rdf:type* *anatomical-object-layer*

anat-layer01 *is-stored-in-file* ‘anat.nii’

anat-layer01 *has-for-proper-part* anat-layer-part01

anat-layer-part01 *rdf:type* *anatomical-layer-part*

anat-layer-part01 *refers-to* grey-matter01

grey-matter01 *rdf:type* *fma:grey-matter*

anat-layer-part01 *has-for-label-in-model* ‘2’

…

Relation to physical properties
examples

- In the case of values layers…

  values-layer01 *rdf:type* *physical-parameter-values-layer*

  values-layer01 *refers-to* proton-density01

  proton-density01 rdf:type *proton-density*

- In the case of object layers …
  - *mathematical distribution of physical quality*

  anat-layer-part01 *has-for-physical-parameter-distribution* math-distrib01 math-distrib01 *rdf:type* *gaussian-distribution*

  math-distrib01 *has-for-mean* mean01

  math-distrib01 *has-for-standard-deviation* std01

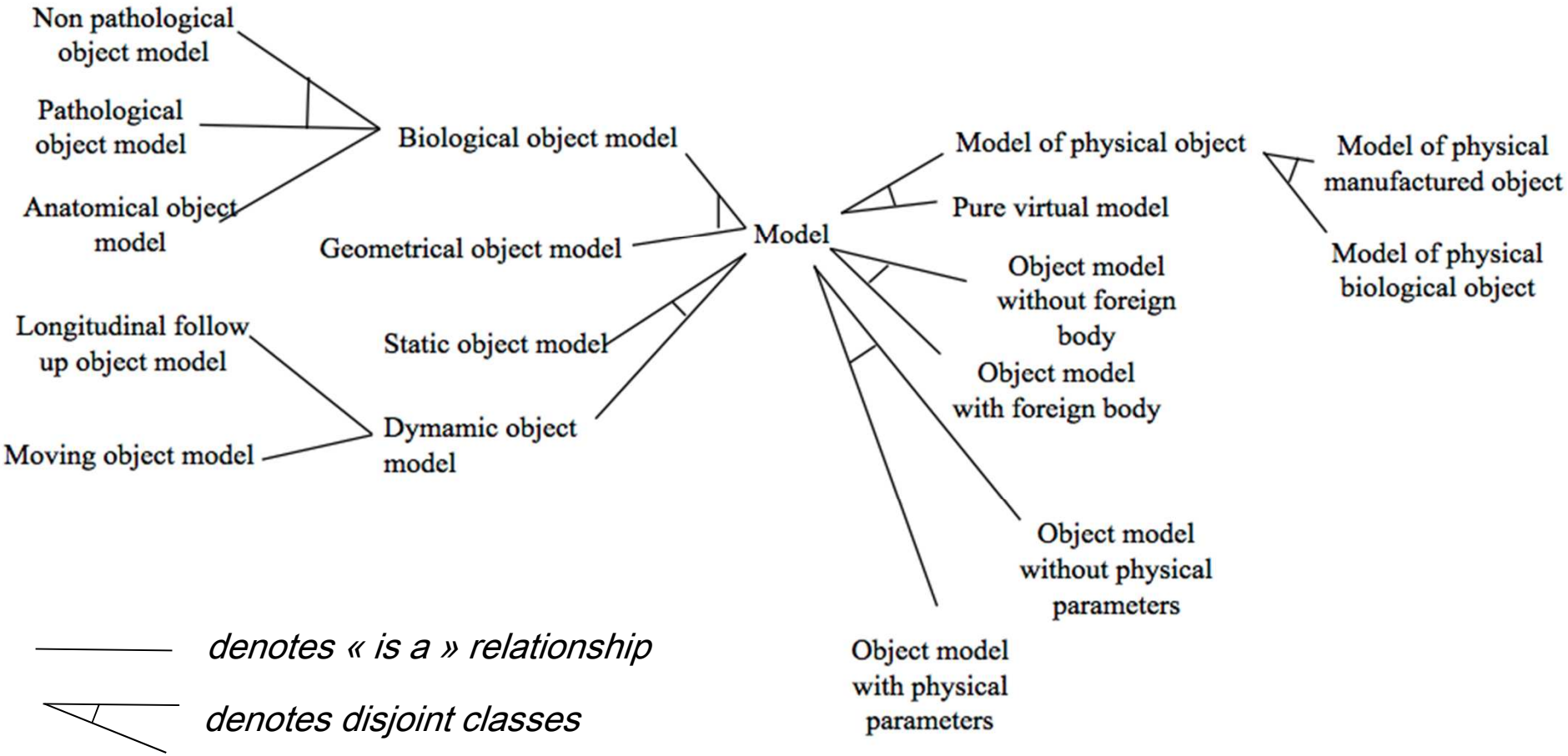
  math-distrib01 *refers-to* proton-density01

  proton-density01 rdf:type *proton-density*

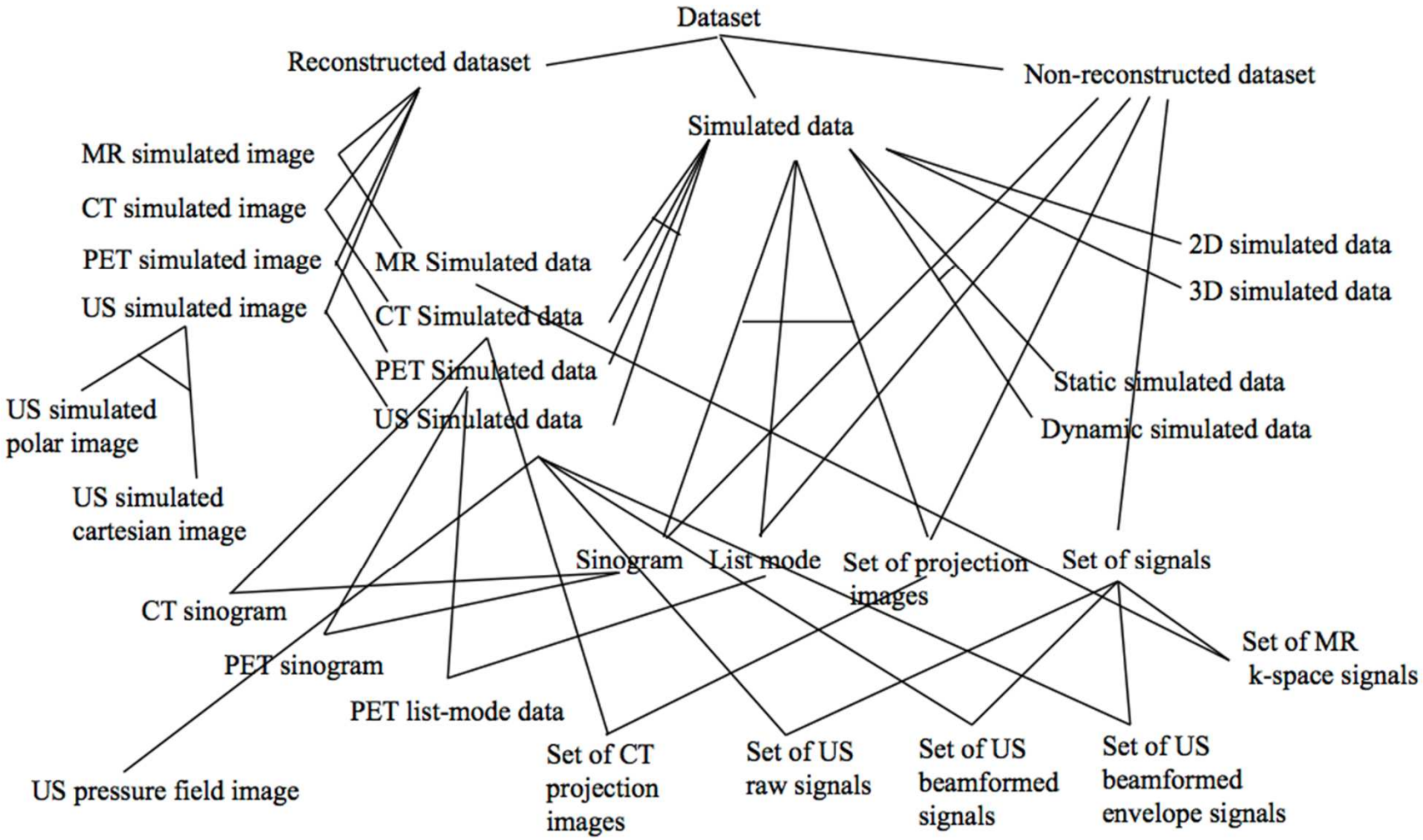
Relation to time

- Models' components (such as *model layers*) refer to discrete *time intervals*
- Two scales are considered
  - *Time points* depict « long intervals », i.e. between several imaging procedures (e.g. days, months, years)
  - whereas *instants* depict « short intervals » within an imaging procedure (e.g. seconds, minutes)

Taxonomy of models

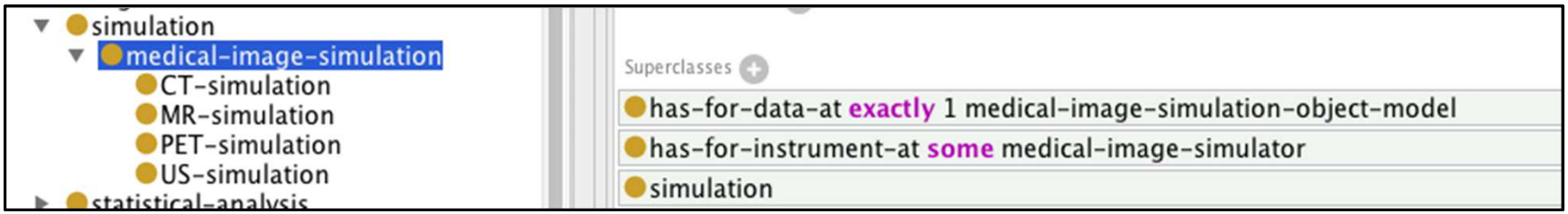


Taxonomy of simulated data



Simulation (actions)

- Simulation (actions)



- Relation to *simulated data*
  - Examples

    simulation01 *rdf:type* *PET-simulation*

    simulation01 *has-for-result* simul-data01

    simul-data01 *rdf:type* *PET-sinogram*

Provenance of simulated data
examples

- Relation between *simulated data* and *models*

  simul-data01 *rdf:type* *MR-image*

  simul-data01 *derives-from-model* model01

  model01 *rdf:type* *MR-compatible-model*

- Relation between *simulated data* and *parameters* and *parameter sets*

  simul-data01 *derives-from-parameter-set* par-set01

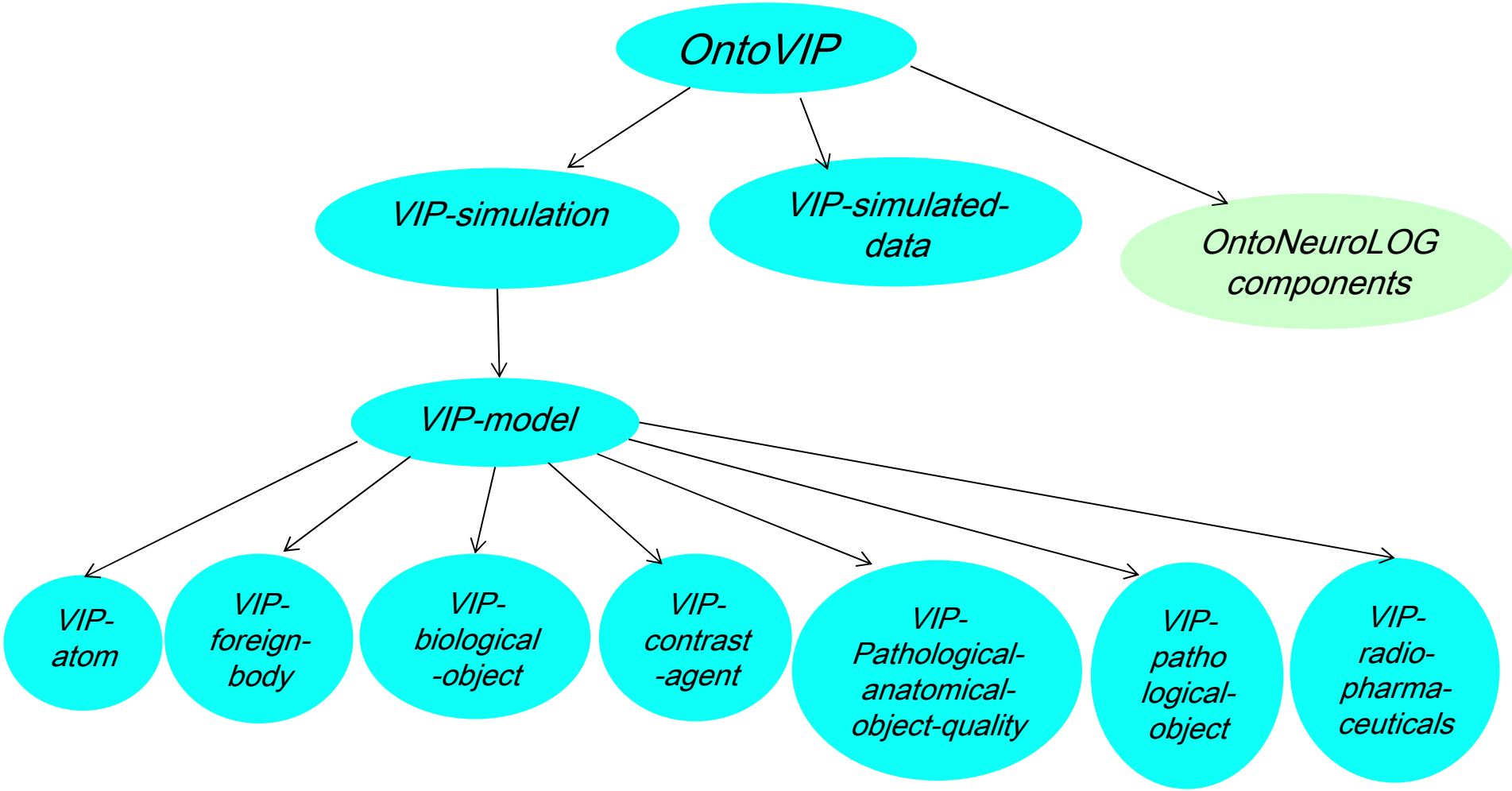
  par-set01 *rdf:type* *parameter-set*

  simul-data01 *derives-from-parameter* param01

  param01 *rdf:type* *simulation-parameter*

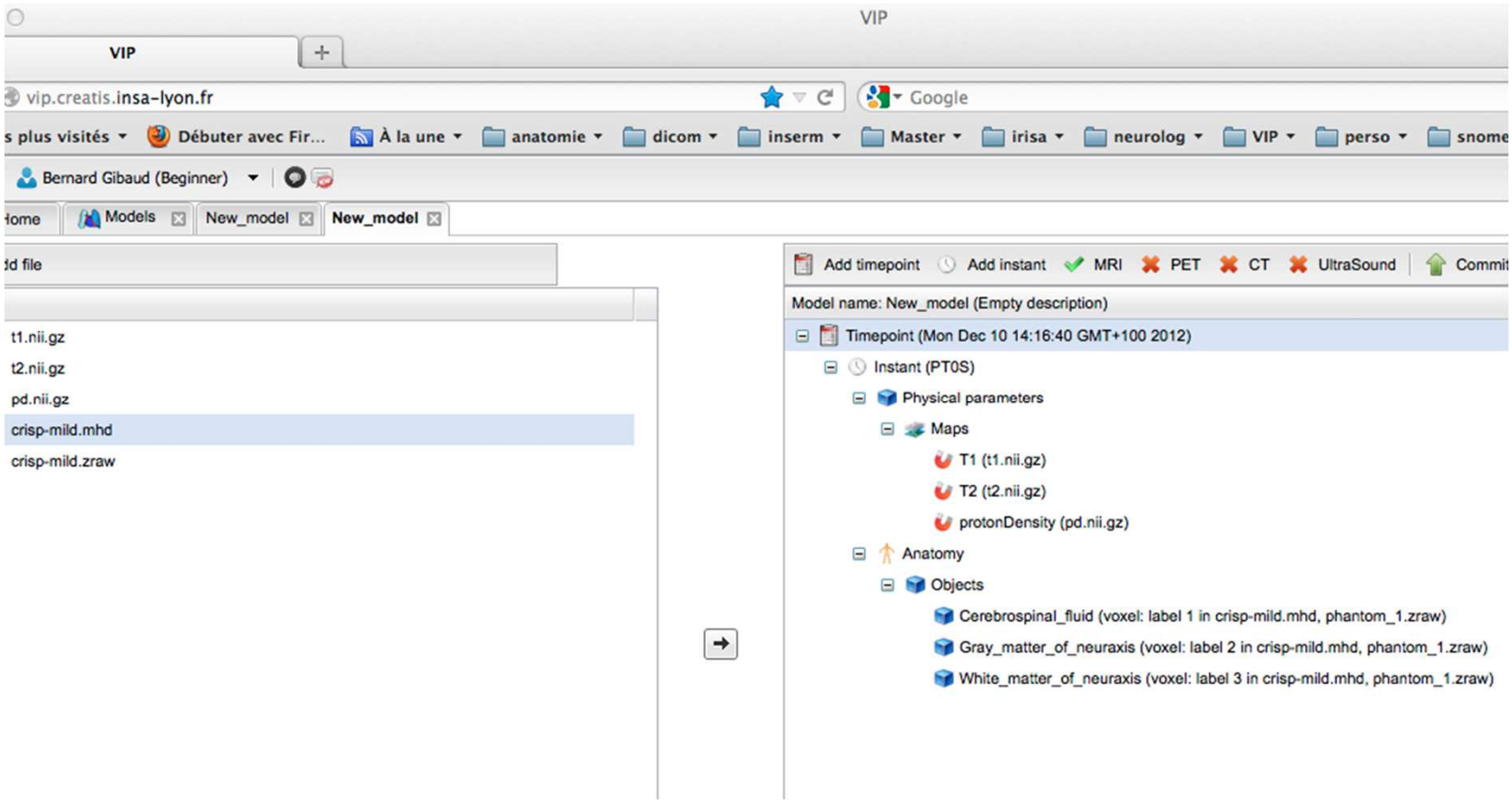
  param01 *rdf:type* *echo-time-value-information*

OntoVIP modular structure



Part 3. Result: Utilization in the VIP platform

Model annotation

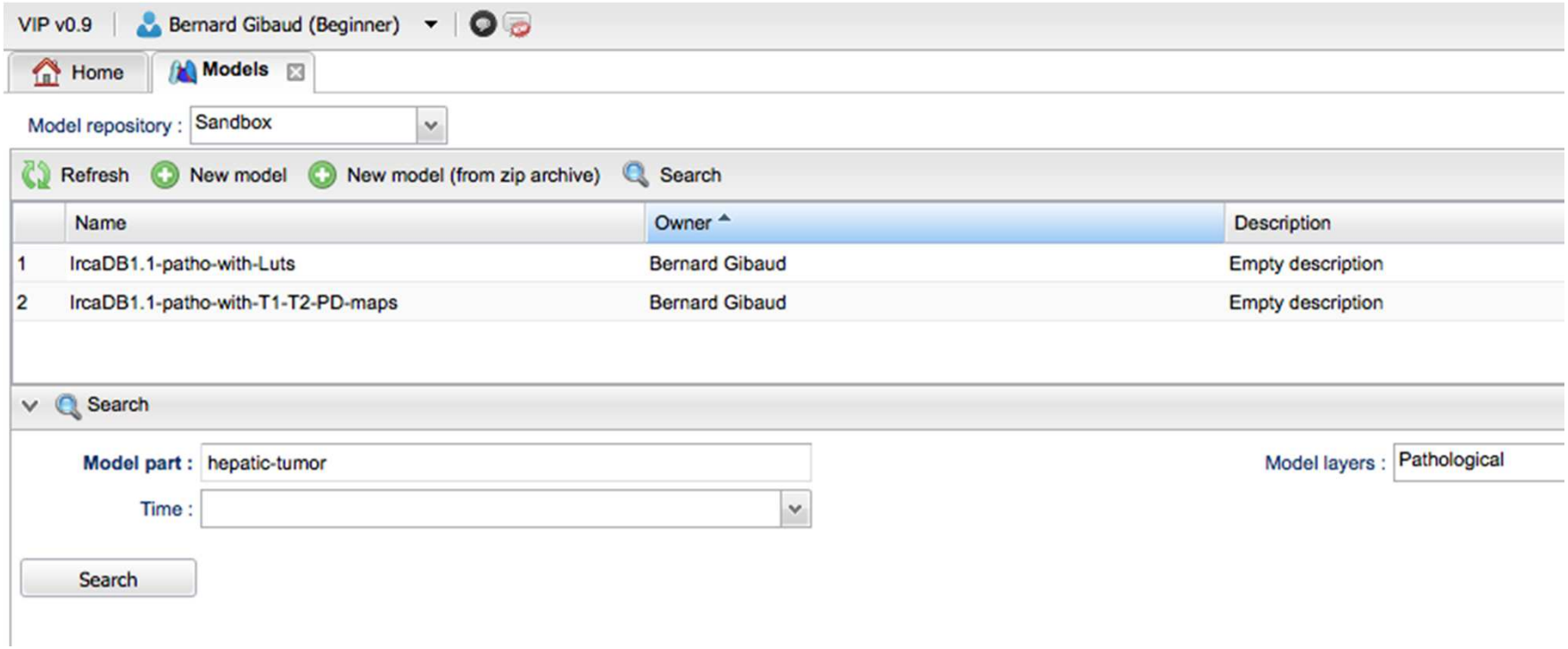


Model annotation

- Ontology-based reasoning at model upload
  - Semi-automatic creation of model layers based on the nature of referred objects
    - e.g. anatomical structure assigned to an *anatomical object layer*
  - Retrieval of ontology terms (rank searching using lucene)
  - Inference of modality compatibility
    - e.g. a model is *MR-simulation-compatible*
  - Control of consistency
  - Automatic creation of `model.rdf` annotation file
    - It becomes a part of the model
- Possibility of upload of an annotated model

Search and reuse of models

- Models can be searched for based on model contents

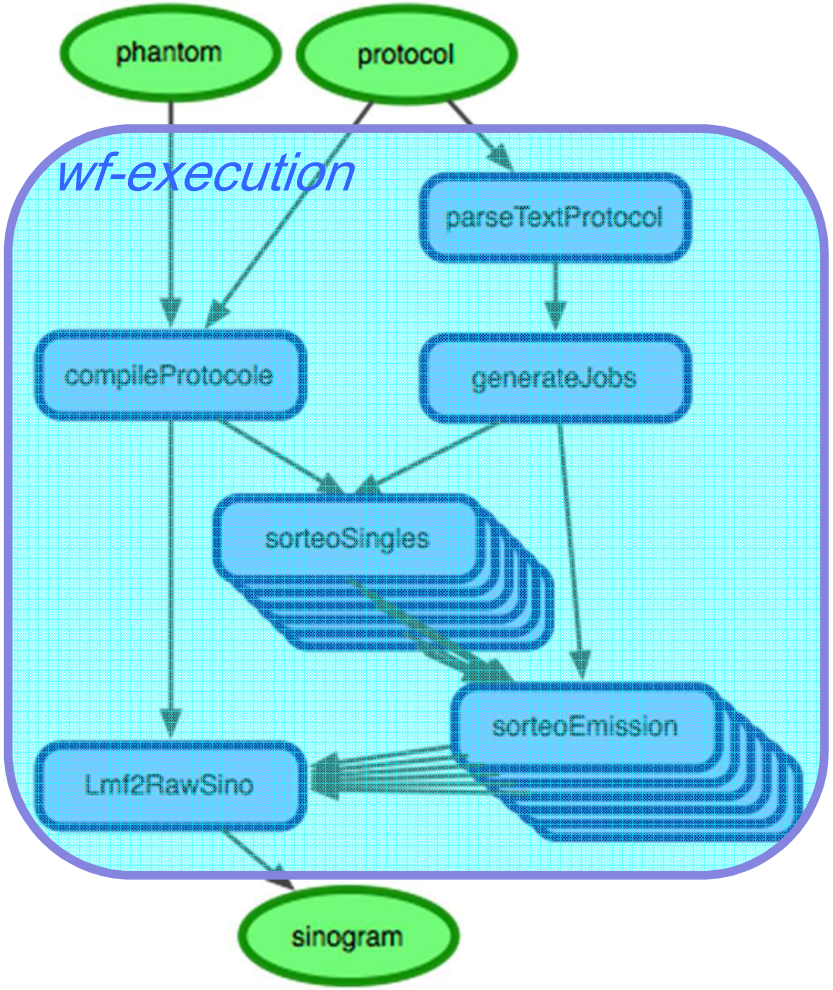


Annotation of simulated data 1/3
(Alan Gaignard PhD work, I3S)

- GOAL: automating the semantic annotation of simulated data, based on:
  - detailed provenance data provided by the execution manager (open provenance model)
  - existing knowledge about models and simulation workflow components (represented as domain-specific inference rules)

Annotation of simulated data 2/3

Example: PET sinogram generated with SORTEO



sinogram rdf:type PET-sinogram
sinogram is-a-result-of wf-execution
wf-execution rdf:type PET-simulation
sinogram derives-from-model phantom
sinogram derives-from-parameter-set protocol
protocol rdf:type parameter-set

Annotation of simulated data 3/3

Example: MR image generated with SimuBloch

- Provenance data is browsable from the portal

			Simulated Data File:	lfn://lfc-biomed.in2p3.fr/grid/biomed/creatis/vip/data/users/tristan_glatard/12-12-2012_10:30:38/1355163884798-1354811111900-Brain_IRISA_2.zip-120.0-8.0-simulation.nii.gz	
MRI					
		Simulated Data File	**Parameters:**	120.0 (repetition-time-value-information) ; 8.0 (echo-time-value-information) ; 0 0 0 0 0 0 (model-to-scanner-geometrical-transformation)	tion Parameters
10		1355163884798-1354811111900-Brain_IRISA_2.			cho-time) ; 1200 (inversion-time) ;
11		1355163884798-1354811111900-Brain_IRISA_2.	**Model:**	Brain_IRISA_2 (medical-image-simulation-object-model-4cc93556d0c748d0918ce7494e3ee97a)	version-time) ; 1900.0 (repetition-t
12		1355163884798-1354811111900-Brain_IRISA_2.zip-120.0-8.0-simulation.nii.gz		MR-simulated-image	120.0 (repetition-time) ; 8.0 (echo-time) ;
13		1355244470407-modelini2.zip-120.0-8.0-simulation.nii.gz		MR-simulated-image	120.0 (repetition-time) ; 8.0 (echo-time) ;

- An alternative to the (relatively ad-hoc) inference rules is provided by conceptual workflows (PhD work of Nadia Cerezo, I3S), which describe actions at a more abstract level (work in progress)

Part 4. Discussion

Reuse of existing ontologies

-  Most terms could be found from existing resources: FMA, RadLex, PATO, MPATH, ChEBI
  - Set of terms selected based on a reasonable guess

-  Hard to see whether it is sufficient
  - Selected corpus can be extended quite easily (vSPARQL query based on a set of terms)
  - Although potentially interesting for reasoning, « Part-whole » relations not retrieved from FMA, yet

→ Need for feedback from actual use

Ontology of models

-  Organisation in *model layers* very satifactory
  - Intuitive, natural relation to physical parameters

-  All objectives not met
  - Hard to integrate all simulators in a single consistent framework
  - Physiological and Physiopathological processes not annoted, yet
    - e.g., no means to express that a model models ‘breathing’ or ‘heart movement’

→ Would still need substantial work

Deployment and adoption

-  Successful use of ontologies in the platform
  - They can be used in similar projects
  - We carefully avoided embedding in the ontologies specific constraints of our platform
-  Still limited exploitation of embedded knowledge
  - Search of models
  - Inference of compatiblity to modalities and/or specific simulators
  - Exploitation of provenance data for assisting users in choosing simulation parameters

→ Possibility to extend the platform's capability based on users' feedback and wishes

Conclusion

- The development of the OntoVIP project required to find a compromise between somewhat contradictory contraints
  - Providing a vocabulary tailored to the deployment of the VIP platform
  - Providing a general enough ontology that could support similar needs in the field of medical image simulation
- Only feedback from actual use (in VIP and elsewhere) will allow us to improve it.

Representation of pathological entities
pathological-anatomical-object

hippo01 *rdf:type* *pathological-anatomical-object*

hippo01 *rdf:type* *fma:hippocampus*

hippo01 *has-for-quality* qual01

qual01 *rdf:type* *decreased-volume*