Fédération et analyse de données distribuées en imagerie biomédicale

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on behalf of the NeuroLOG and
the CrEDIBLE consortiums

Nouvelles méthodologies en imagerie du vivant

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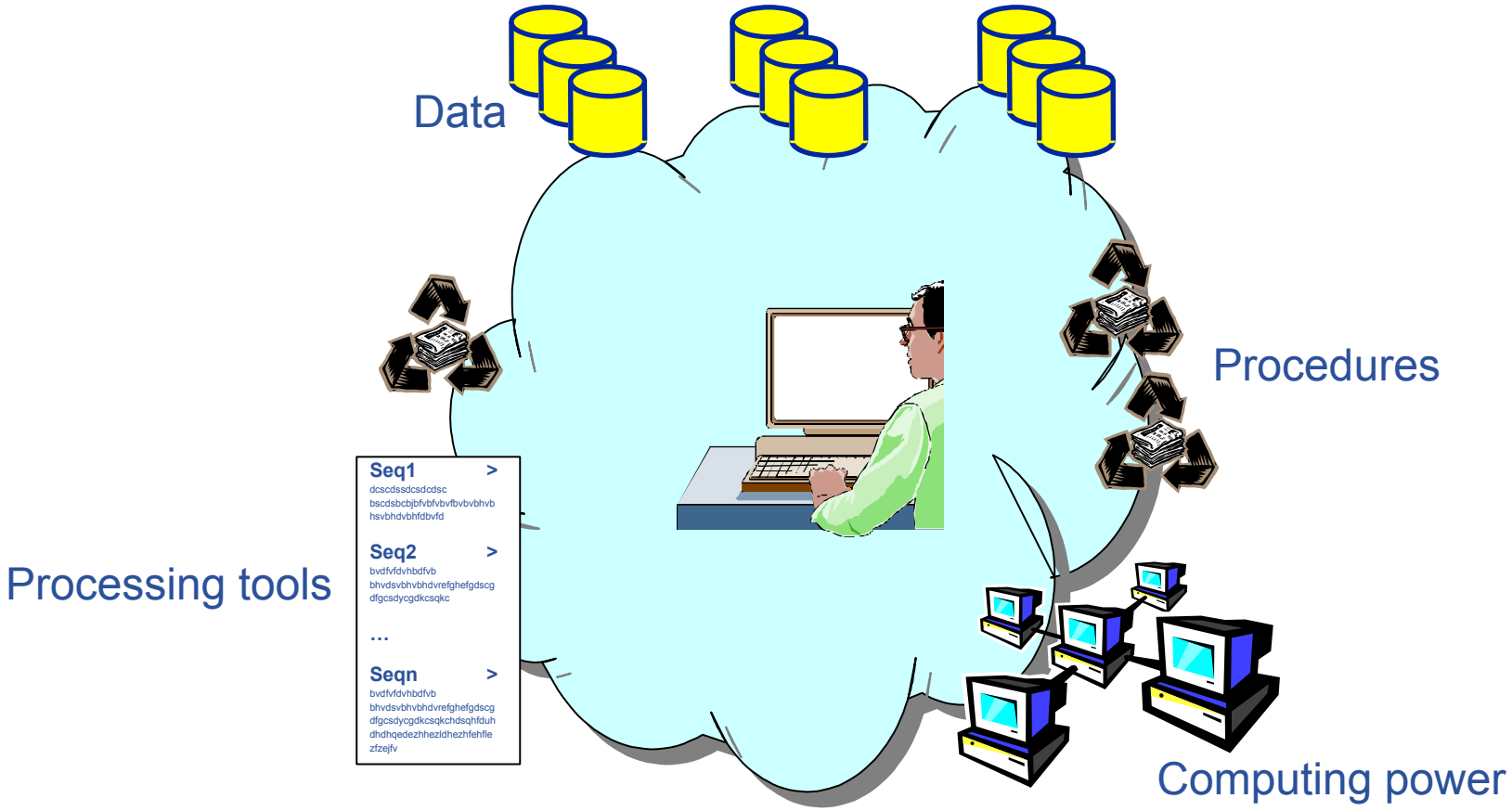
Multi-centric studies in neurosciences

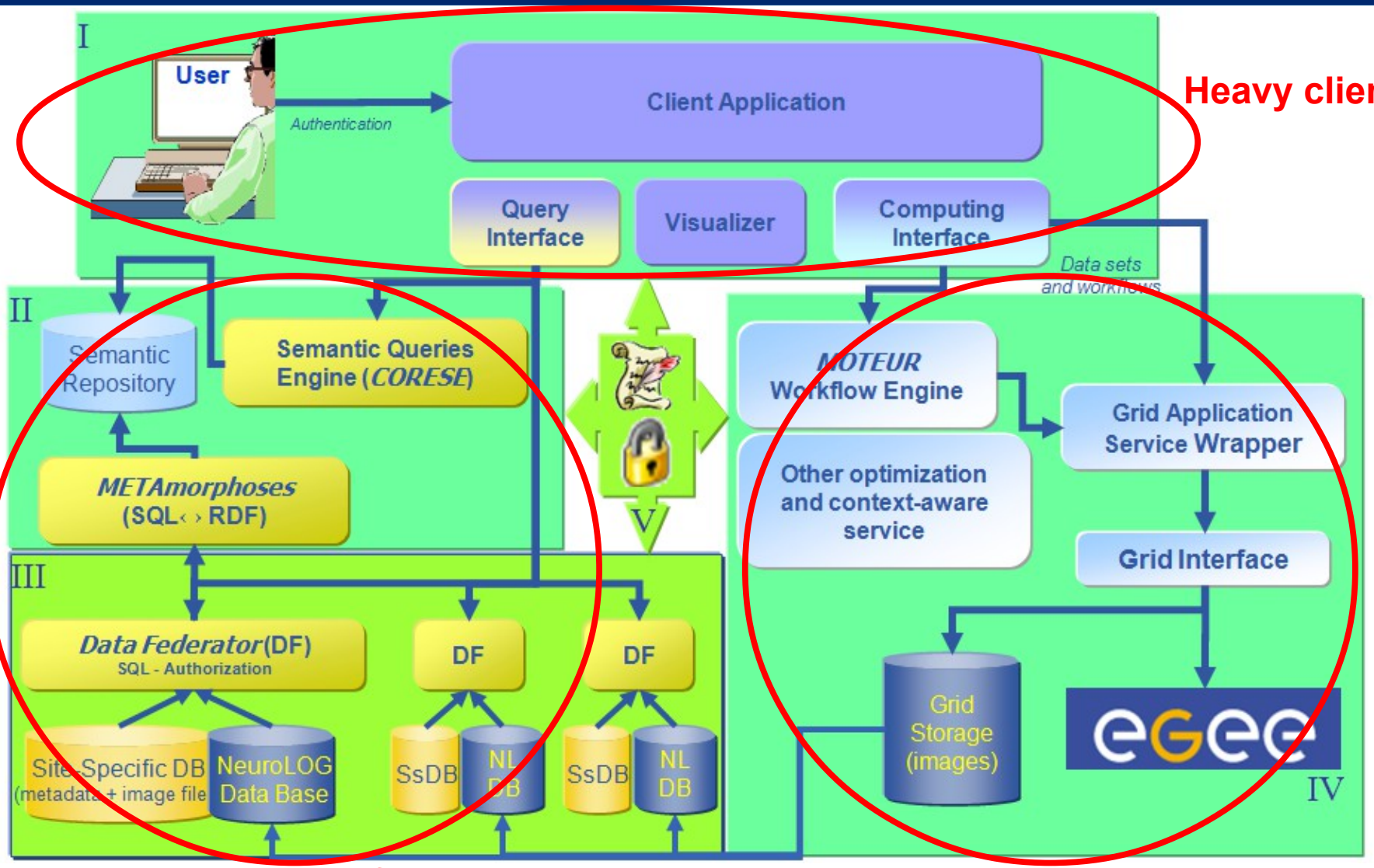
- **Sharing computing resources and algorithms**
  - Research (large data sets, statistical studies, models design...)
  - Complex analysis (compute-intensive studies, validation procedures...)



Motivations

- **Neuroscience data**
  - Increasing use of imaging biomarkers for research and diagnosis
  - Increasing number of (multi-centric) large-scale studies
  - Distribution of resources over acquisition sites
    - Need to consider existing site-wide legacy environments
- **Computing resources**
  - Heavy computing power required
  - Data analysis pipelines
    - Integrating neurodata analysis codes from different toolkits
- **Centralized approaches encounter limitations**
  - Large data volumes to transfer / archive / search
  - Sensitive patient data / complex access control policies
  - Need to adopt uniform data model & format
- **Approach: federate existing resources in a distributed, collaborative platform**

NeuroLOG middleware



NeuroLOG platform

ANR TLOG (2006-2010)

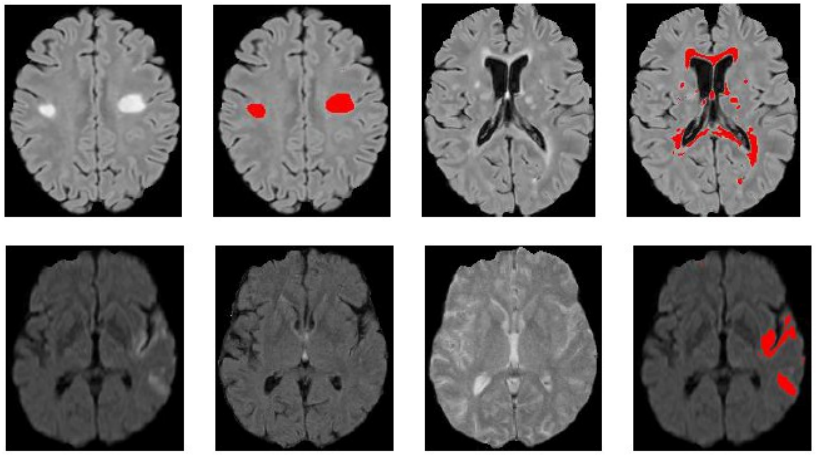
Multi-centric environment for neurosciences

5 neuroscience centers federated

- I3S (Sophia Antipolis) core technical site
- IRISA (INRIA Rennes), collaborating with the University Hospital of Rennes
- IFR49 (INSERM affiliated neuroscience group in Paris La Pitié Salpétrière Hospital)
- GIN (INSERM affiliated neurosciences institute of Grenoble, Michalon Hospital)
- INRIA Sophia Antipolis collaborating with Centre Antoine Lacassagne (Nice)

Neuro-imaging data

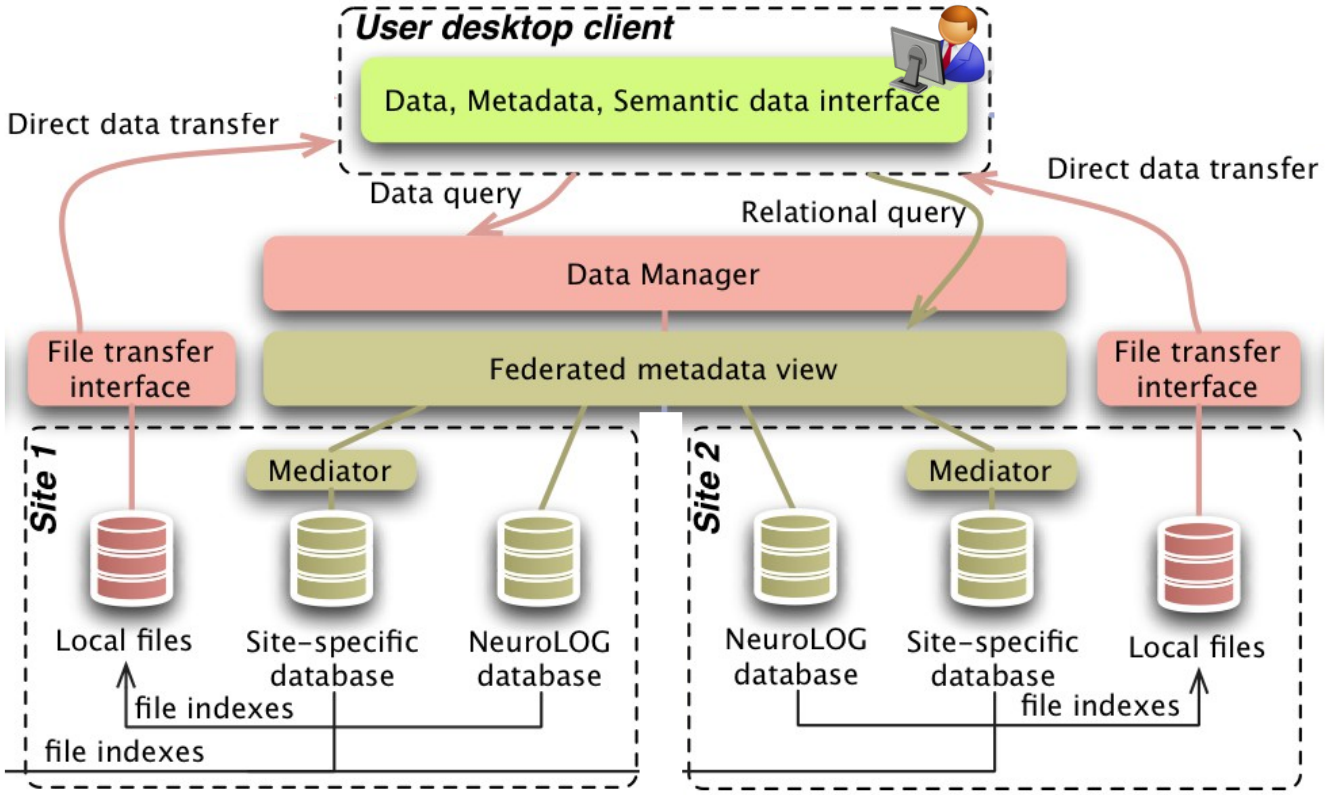
- **Pathologies**
  - Multiple Sclerosis
  - Brain strokes
  - Brain tumors
  - Alzheimer's



- **Data considered**
  - Imaging data
    - Various MR modalities (T1, T1 Gado, T2, Flair, Diffusion, PD)
    - Processed images (Registered, Segmented, …)
  - Associated metadata
    - Studies
    - Subjects
    - Data acquisition context and provenance
    - Neurophysiological and Neuroclinical tests
    - Measurements derived from image data

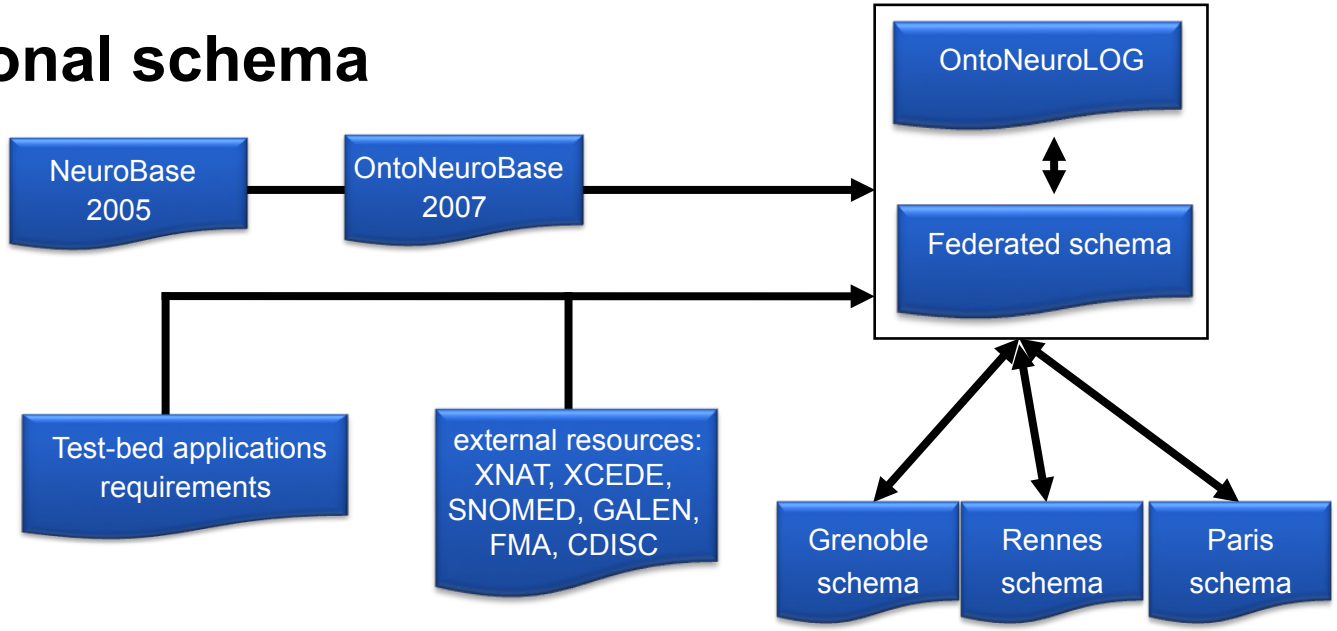
NeuroLOG data mediation & federation

- Preserve legacy environment (e.g. relational databases)
- Cope with heterogenous schemas
  - Use a relational database mediation & federation engine (BusinessObject/SAP DataFederator product)

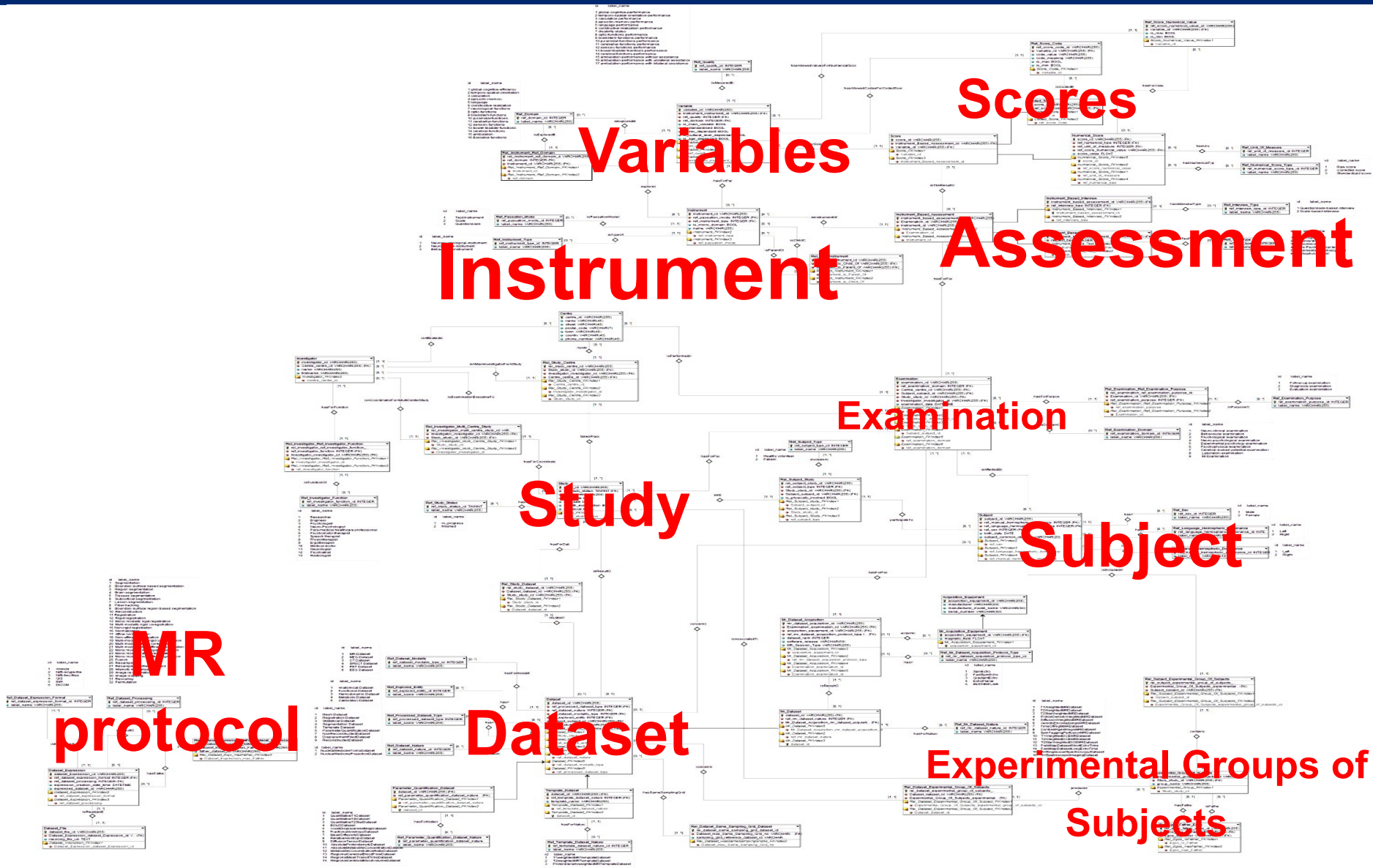


Semantic reference

- **Application ontology OntoNeuroLOG**
  - **Based on a common modeling framework**
  - **3-levels structure**
    - **one Foundational ontology: i.e. DOLCE**
    - **Several Core ontologies**
    - **Several Domain ontologies**
- **Implemented in OWL-Lite**
- **Derived relational schema**

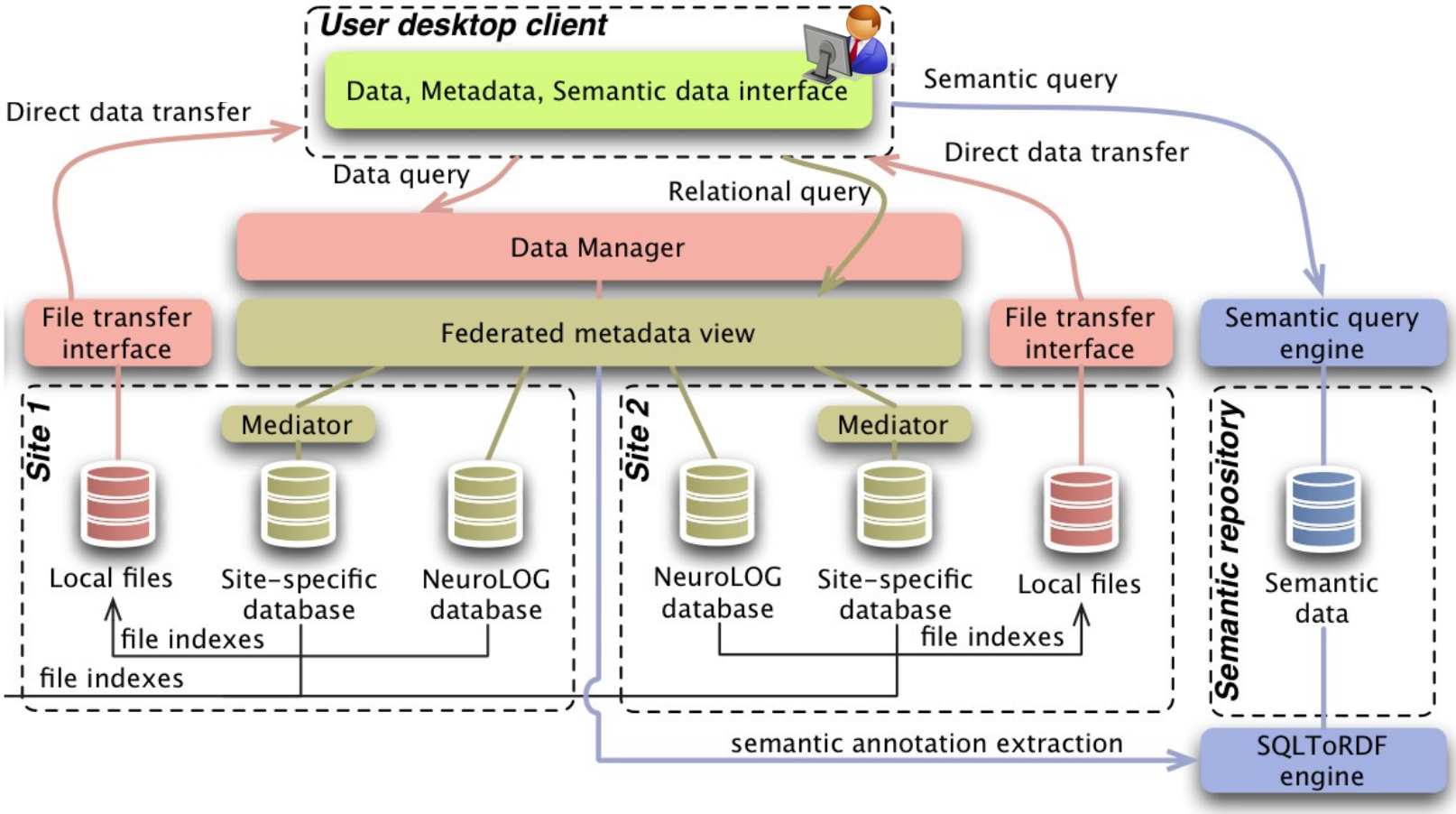


OntoNeuroLOG



NeuroLOG data mediation & federation

- Experimenting both relational and semantics technologies
  - METAMorphoses conversion of (federated) relational databases into a semantic annotations store

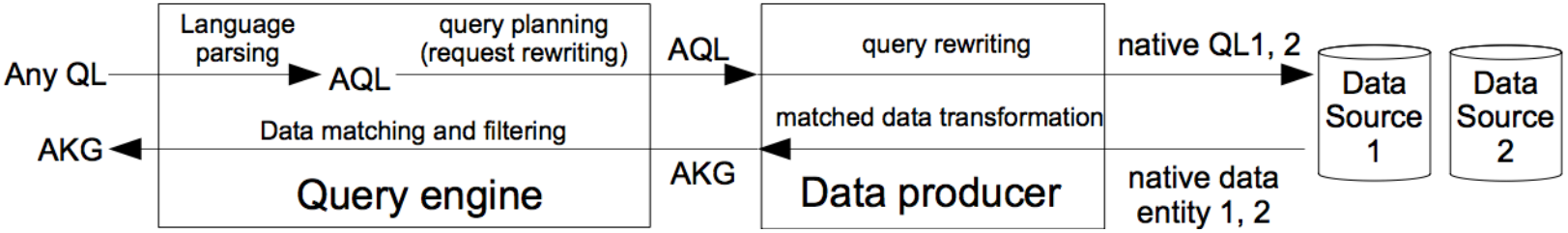


From relational to semantic datastores

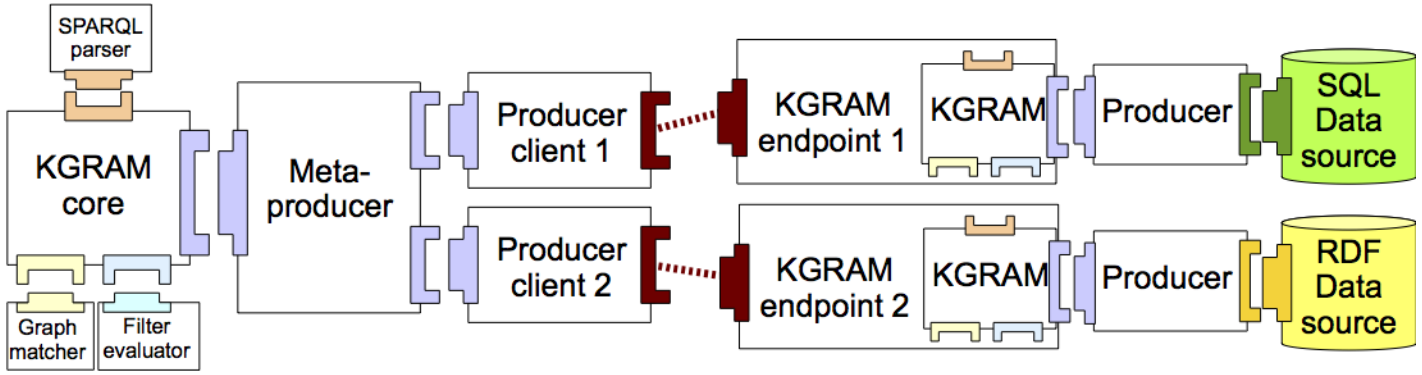
- **CrEDIBLE multi-disciplinary workshop in Sophia Antipolis (Oct. 15-17, 2012)**
  - Semantic models are widely accepted
  - Existing systems in the biomedical community are mostly centralized
  - The need for multi-centric studies support is unambiguous
  - Exploiting / reusing data in a multi-disciplinary context is still preliminary, and ontological resources are not sufficient
- **Approach**
  - Semantic reference design
  - RDF triples-based knowledge bases
    - Semantic alignment for heterogeneous data sources
    - Data sources mapping
  - Distributed semantic query engine
    - SPARQL v1.1 compliant

Distributed query engine

- **Based on KGRAM (Knowledge Graph Abstract Machine)**
  - Full support of SPARQL v1.1
  - Flexible software architecture adaptable to many use cases

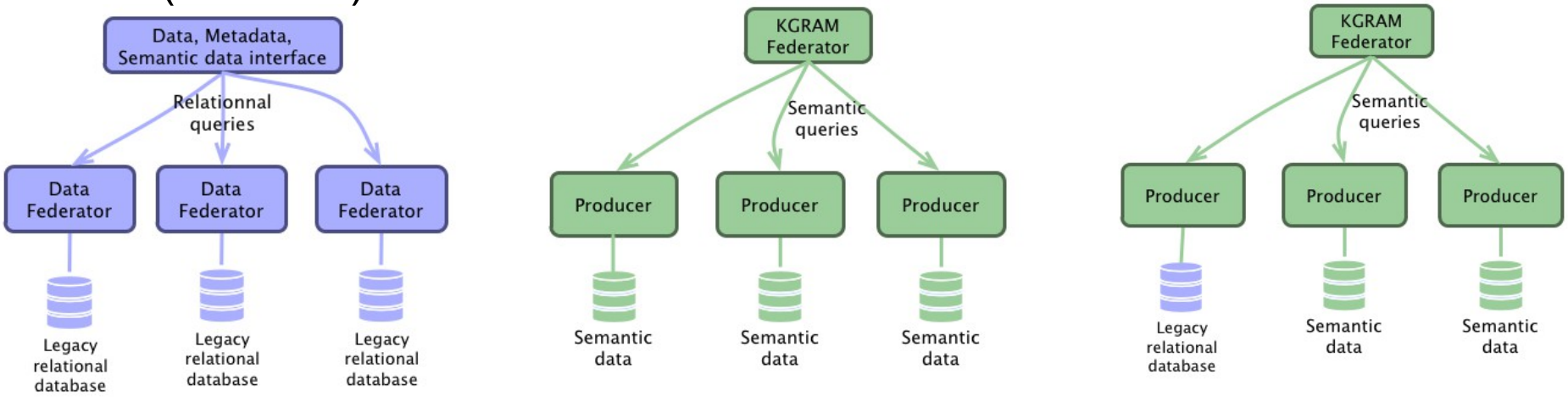


- **Deployment example**
  - Meta-producer distributes queries over multiple query endpoints
  - KGRAM endpoint interfaces with heterogeneous data stores



Results: distributed query processing

- **Multiple neuroscience data stores querying**
  - Relational stores (DF), semantic bases (KGRAM) or both (KGRAM)



- **Performance analysis**
  - Q1 : costly evaluation (336 remote invocations)
  - Q2 : selective query (only 5 resulting datasets)

Query	Relational (SAP DF)	Semantic	Semantic+Relational
Q1	**3.03 s ± 0.25**	6.13 s ± 0.05	11.76 s ± 0.05
Q2	1.52 s ± 0.62	**0.60 s ± 0.03**	1.53 s ± 0.14

Workflow enactor

- **Workflow language + enactor**
  - Abstract description of data analysis pipelines
  - Interface to computing infrastructure
    - Data processing code wrapper component (jigsaw)
    - Interface to grid(s) workload management API
- **MOTEUR workflow manager**
  - http://modalis.polytech.unice.fr/moteur2
  - GWENDIA language
    - Data-driven, implicit-parallelism oriented language
    - Graphic interface to design workflows
  - MOTEUR enactor
    - Transparent exploitation of parallelism
    - Interfaced to multiple submission interface
      - *Local resources, EGI, Grid5000...*

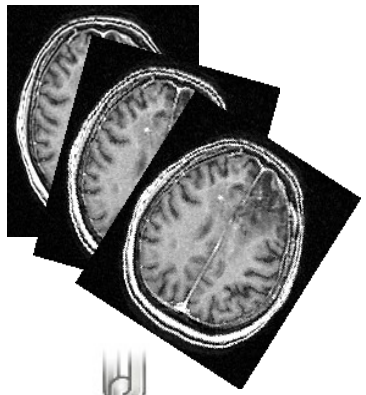
Codes packaging and enactment

Data analysis
code bundling

Bundles
deployment

Enactment

data sets



descriptor

.aar

code
+
dependencies

site server

deploy

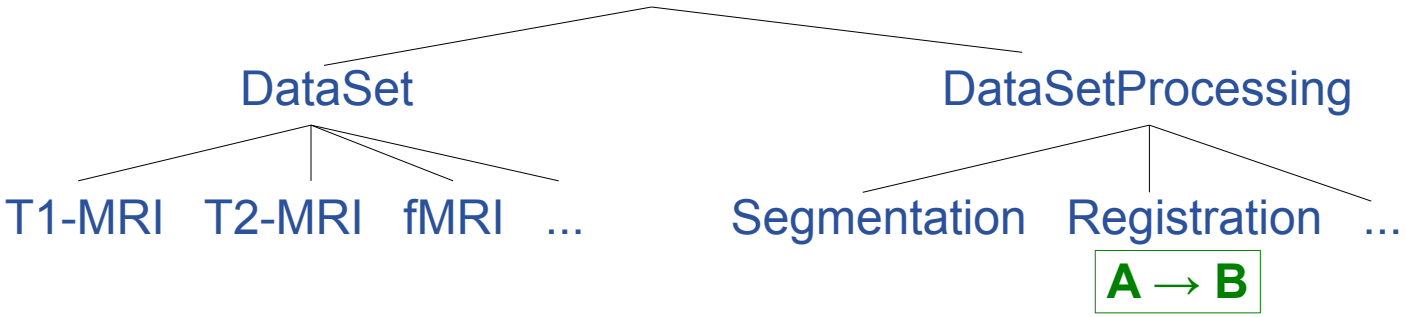
invoke

MOTEUR 2

workflow engine

Semantic extensions

- **Ontology**
  - Concepts & **Rules**

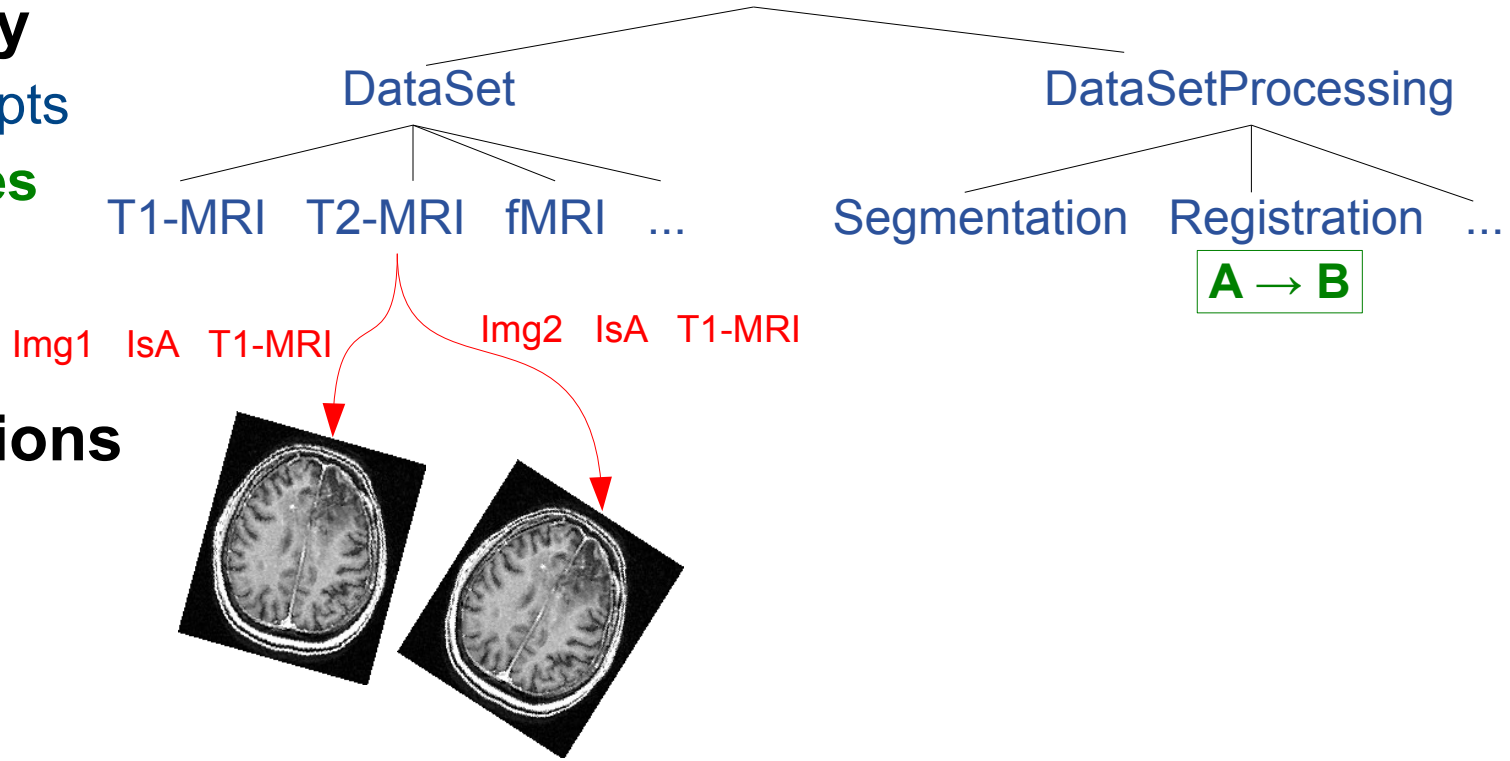


- **Annotations**

- **Processing**

Semantic extensions

- **Ontology**
  - Concepts & **Rules**



- **Annotations**

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Semantic extensions

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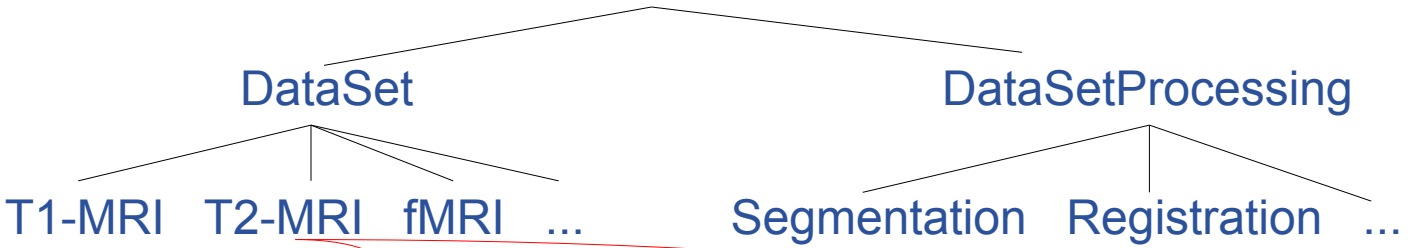
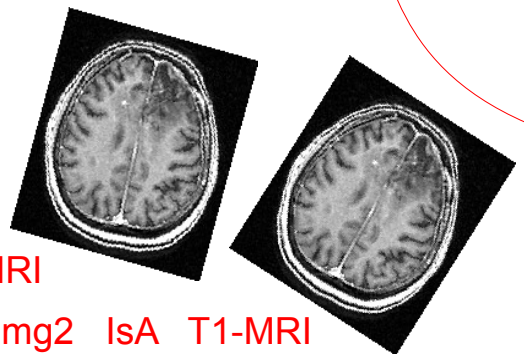


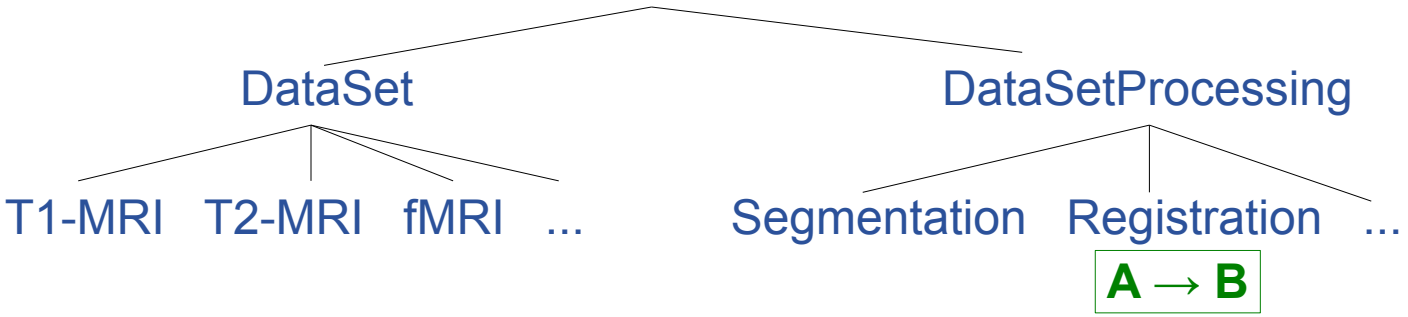
- **Annotations**



- **Processing**

Semantic extensions

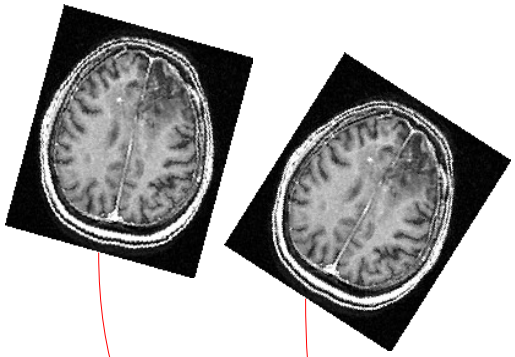
- **Ontology**
  - Concepts & **Rules**



- **Annotations**

Tool1 HasInput T1-MRI
Tool1 HasOutput Transfo
Tool1 IsA Registration

Img1 IsA T1-MRI
Img2 IsA T1-MRI



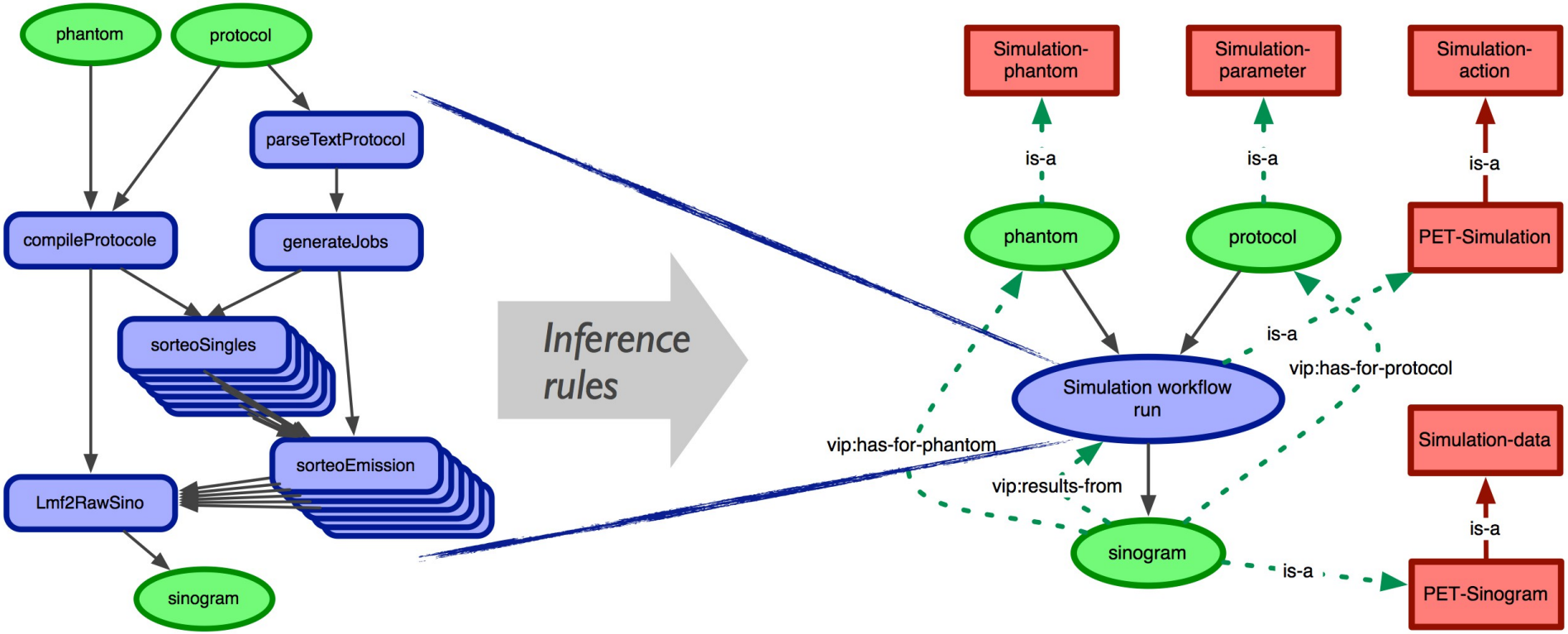
- **Processing**

Img1 IsProcessedBy Tool1
Img2 IsProcessedBy Tool1

Tool1 Produced Transfo1
Transfo1 IsA GlobalTransfo

Semantic knowledge use in workflows

- Fine-grained annotation traces generated at run-time
- Summary generated by inference rules application
  - Produce relevant and human-tractable experiment summaries



- Example in the context of the VIP (Virtual Imaging Platform) project

(Some) lessons learned

Data federation feasibility

- Relational data federation requires semantic reference
- Dual relational / semantic data view is confusing for end users
  - Mapping to a semantic, well-documented data model
- Need to cope with site failures
- Data access control is a tough problem

- **Semantic technologies**
  - Powerful semantic query and inference engine
    - Trade-off between query language expressivity and performance
  - Coupling data and processing semantics
  - Semantic querying and inference capability are foreign to users
  - Non-trivial user interface to be defined to query the federation
- **Application to other domains**
  - VIP Virtual Imaging Platform
  - http://www.creatis.insa-lyon.fr/vip

References

- **Reports & publications available on-line**
  - http://credible.i3s.unice.fr & http://neurolog.i3s.unice.fr
- **Publications**
  - O. Corby, A. Gaignard, C. Faron-Zucker, J. Montagnat.
    KGRAM Versatile Inference and Query Engine for the Web of Linked Data
    IEEE/WIC/ACM International Conference on Web Intelligence, Macao, China, Dec. 2012.
  - A. Gaignard, J. Montagnat, C. Faron-Zucker, O. Corby.
    Semantic Federation of Distributed Neurodata
    MICCAI Workshop on Data- and Compute-Intensive Clinical and Translational Imaging Applications, pages 41-50, Nice, France, October 2012.
  - B. Gibaud, G. Kassel, M. Dojat, B. Batrancourt, F. Michel, A. Gaignard, J. Montagnat
    NeuroLOG: sharing neuroimaging data using an ontology-based federated approach
    AMIA, vol. 2011, pages 472–480, Washington DC, USA, October 2011.
  - F. Michel, A. Gaignard, F. Ahmad, C. Barillot, B. Batrancourt, M. Dojat, B. Gibaud, *et al.*
    Grid-wide neuroimaging data federation in the context of the NeuroLOG project
    HealthGrid'10, pages 112-123, IOS Press, Paris, France, 28-30 June 2010.
- **Research reports**
  - CrEDIBLE-12-1-v1: multi-disciplinary workshop report
  - CrEDIBLE-12-2-v1: distributed semantic query engines
  - CrEDIBLE-12-3-v1: sémantique des données de l'observation