On the use of Ontologies for Information Systems Interoperability

joint work with

Flavio Corradini, Rosario Culmone e Emanuela Merelli

Dipartimento di Matematica e Informatica
Università di Camerino
Italia

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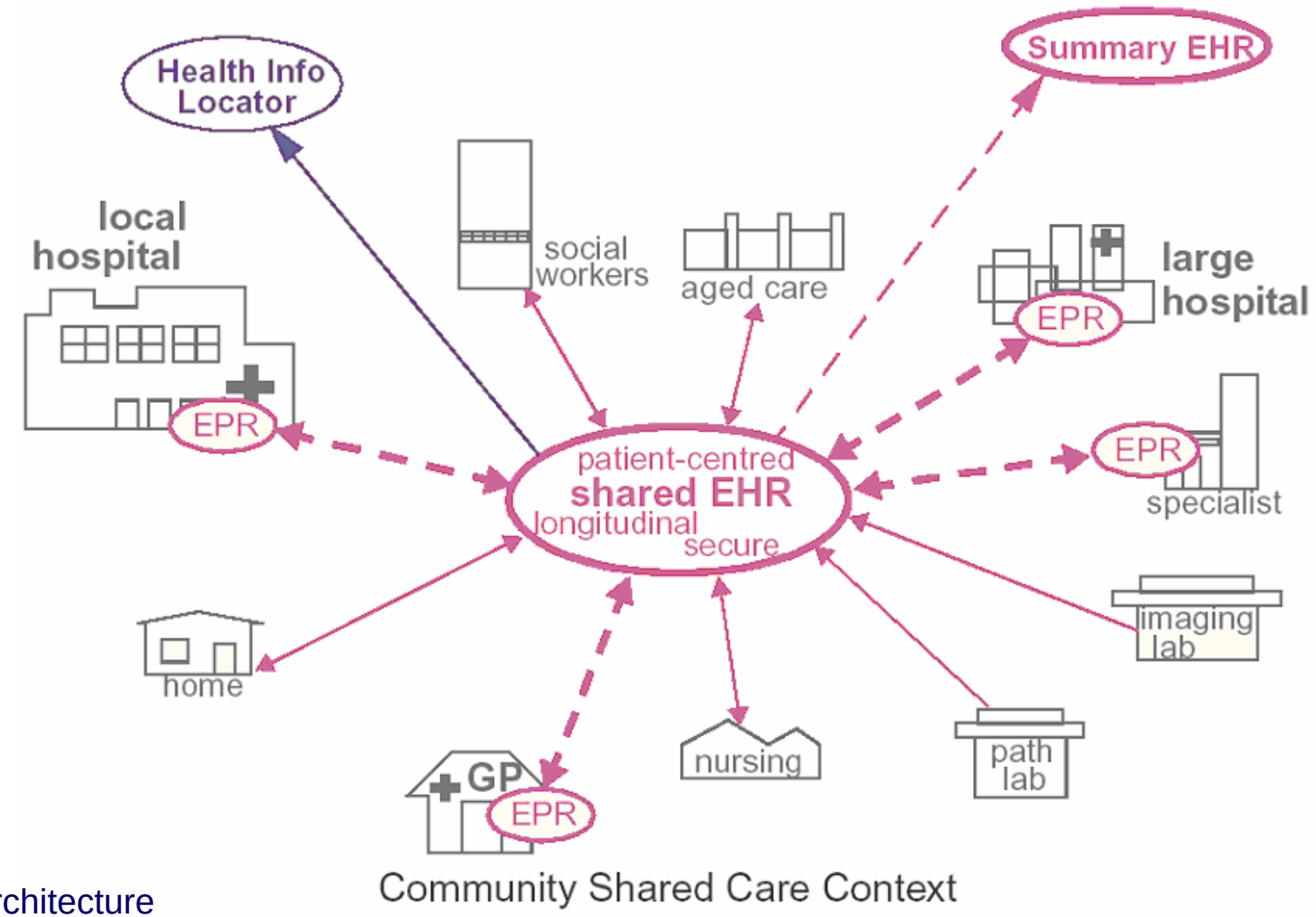
Information Systems

- The information system is the component of an organization that manages (gets, processes, stores, communicates) the information of interest [Atzeni et al. 1999]
  - each organization has its own information system (protocols, terminology, processes, activities, resources, …),
  - usually, the information system operates in support to other components of the organization

- The very notion of information system is partly independent of its computerization
- The Organizational System dealing with rules and roles

e-Health scenario 1/3

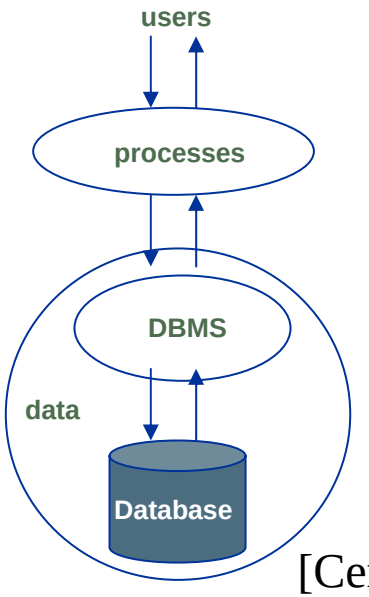


Reference Architecture
of *open*EHR (Electronic Health Record)

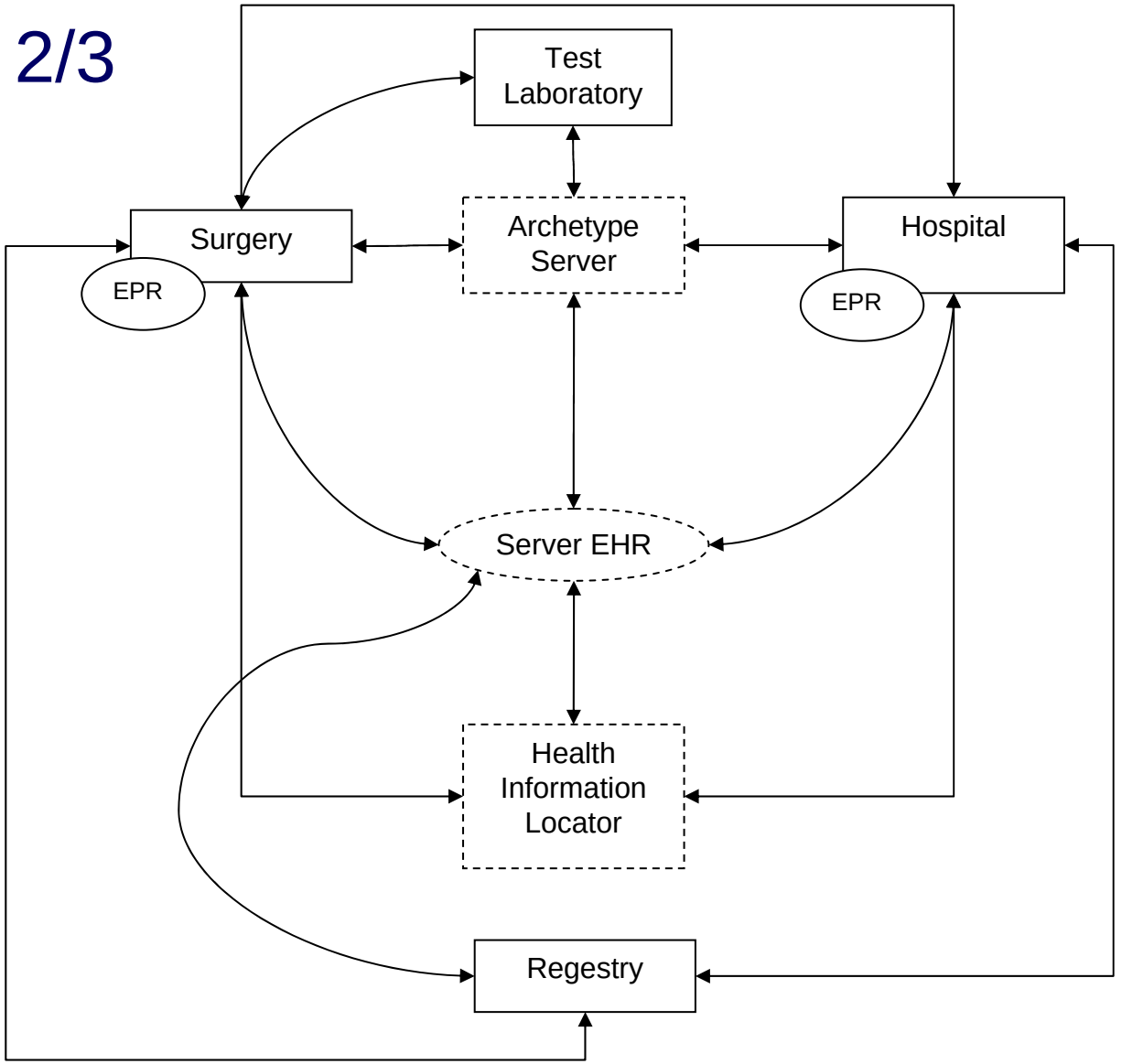
e-Health scenario 2/3

The Information System is responsable of

- information flows (processes)
- information resources (data)



[Ceri, 1999]



e-Health scenario 3/3

The EHR must contain the hystorical updated clinical information of an individual

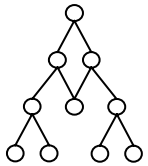
1. The information must be complete as much as possible
   - ➢ Every clinical event, that happens in any place of the world, must be recorded
   - ? *How to precisely describe any event?*

2. The information must be accessible from each health structures placed everywhere
   - ➢ Every structure must be able to exchange clinical data
   - ➢ *How to share information description?*

Information systems interoperability

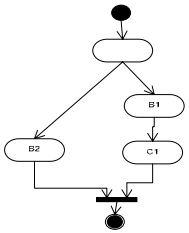
Information Systems Interoperability by integrating …

- Ontology



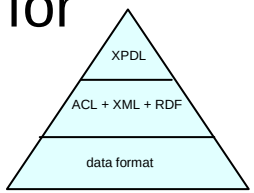
Explicit specification of a conceptualization. An abstract simplified view of the world represented for some purpose [Gruber ‘93]

- Activity-based Application (Workflow)



The computerized facilitation or automation of a business process, in whole or part. (from Workflow Management Coalition-Reference Model)

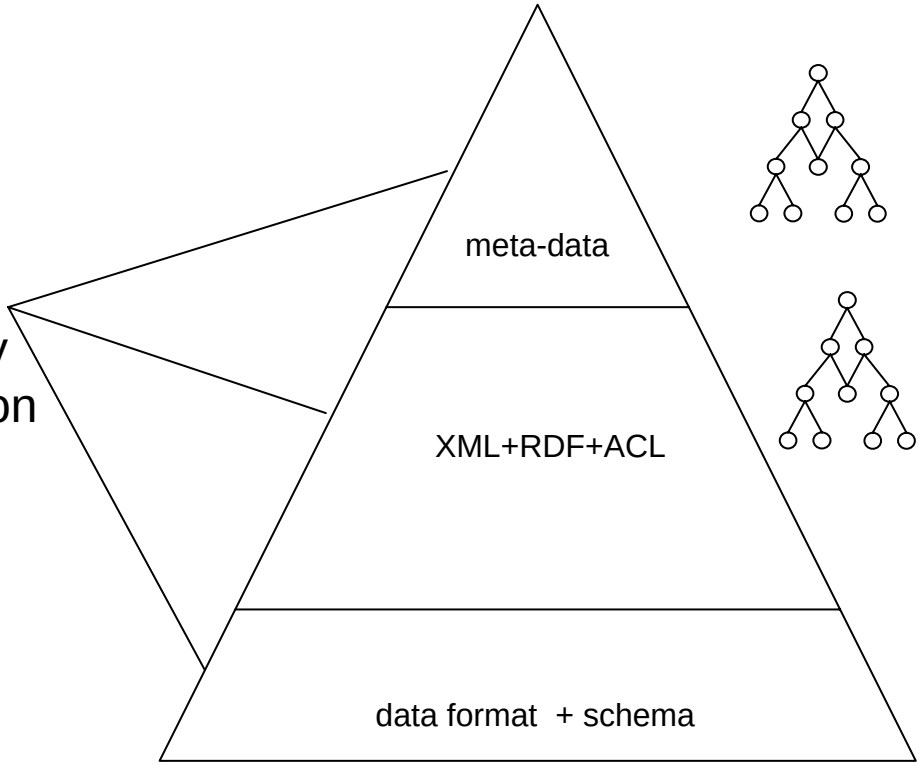
- Agent-based Middleware for mobile computing



Agents are software components that:
- embed a “complete” behaviour in their control,
- are autonomous and react to external stimuli and nvironment
- can be mobile (in the sense that they can move from a site another)

From Data to Knowledge and vice versa

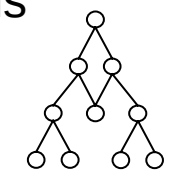
IS Interoperability
through Integration



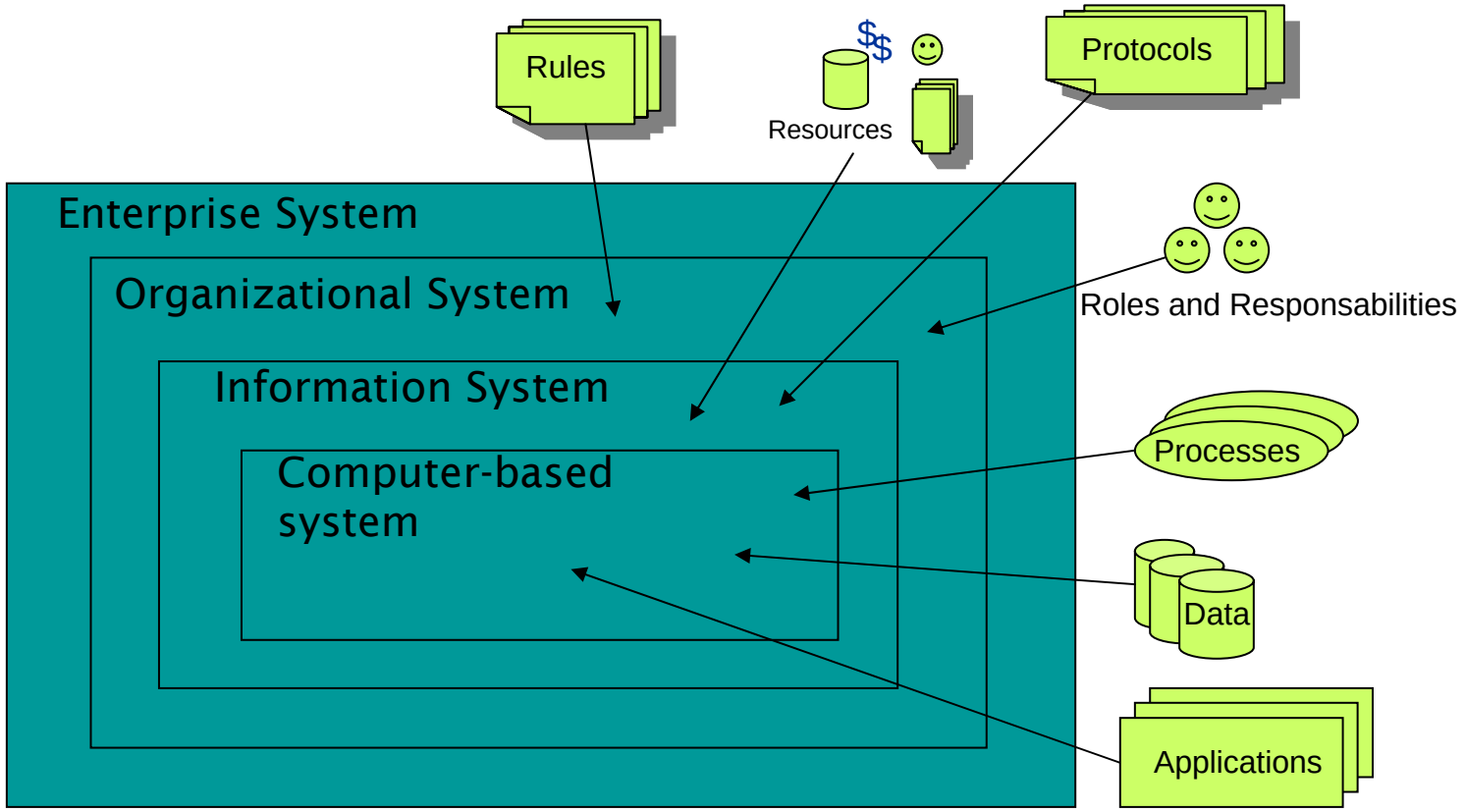
Domain ontologies (human concepts) + workflow

Information +
agent-based coordination+
communication ontology

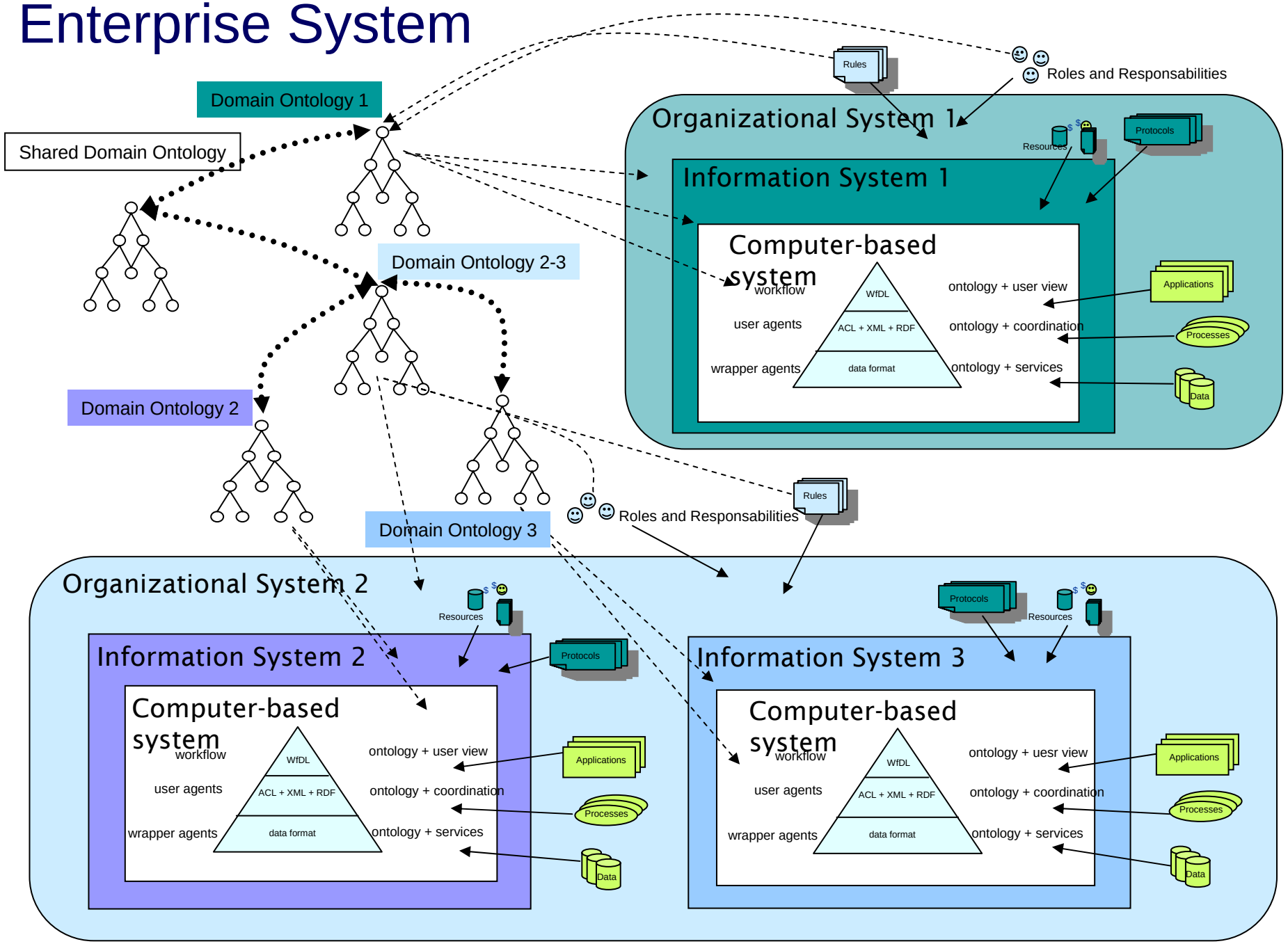
Data + wrapper agents +
common ontology +
mapping tools



Hierarchy Enterprise Systems



Enterprise System



Middleware for mobile computation: motivations

- Middleware sits between the operating system and the application
  - Facilitates the development of distributed applications
  - Provides developers with **abstractions**, hiding details of distribution, enabling rapid, dependable development
  - Includes typical features as communication primitives, replication, concurrency management, etc.

What is HERMES?

- Hermes is a software tool (80 kb of Java code)

- Hermes supports the execution of software applications. The applications it supports can be:
  - Activity-based
  - Distributed

- Hermes provides service agents to
  - Ontology management
  - Web-services orchestration
  - Data repository wrapping
  - …

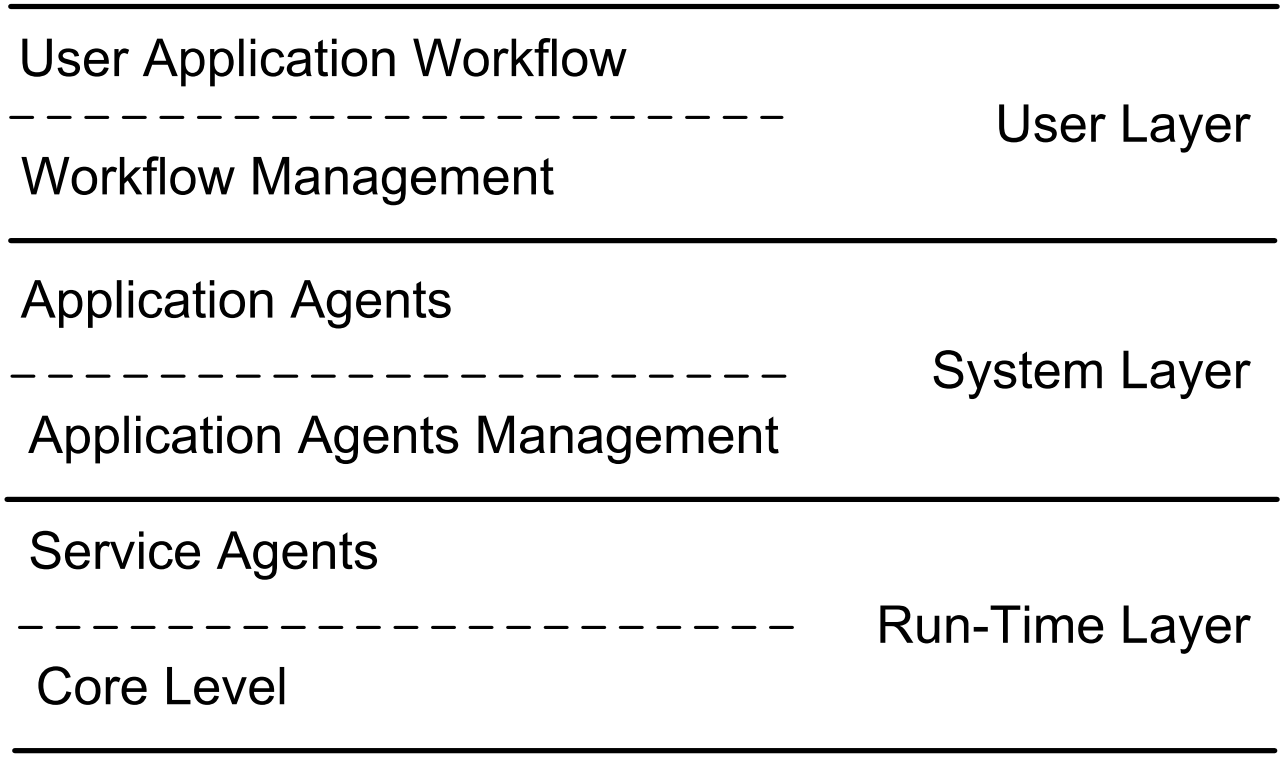
Main Aim for Developing Hermes

For the application domains we are interested in applications must be as much as easy and intuitive possible to specify

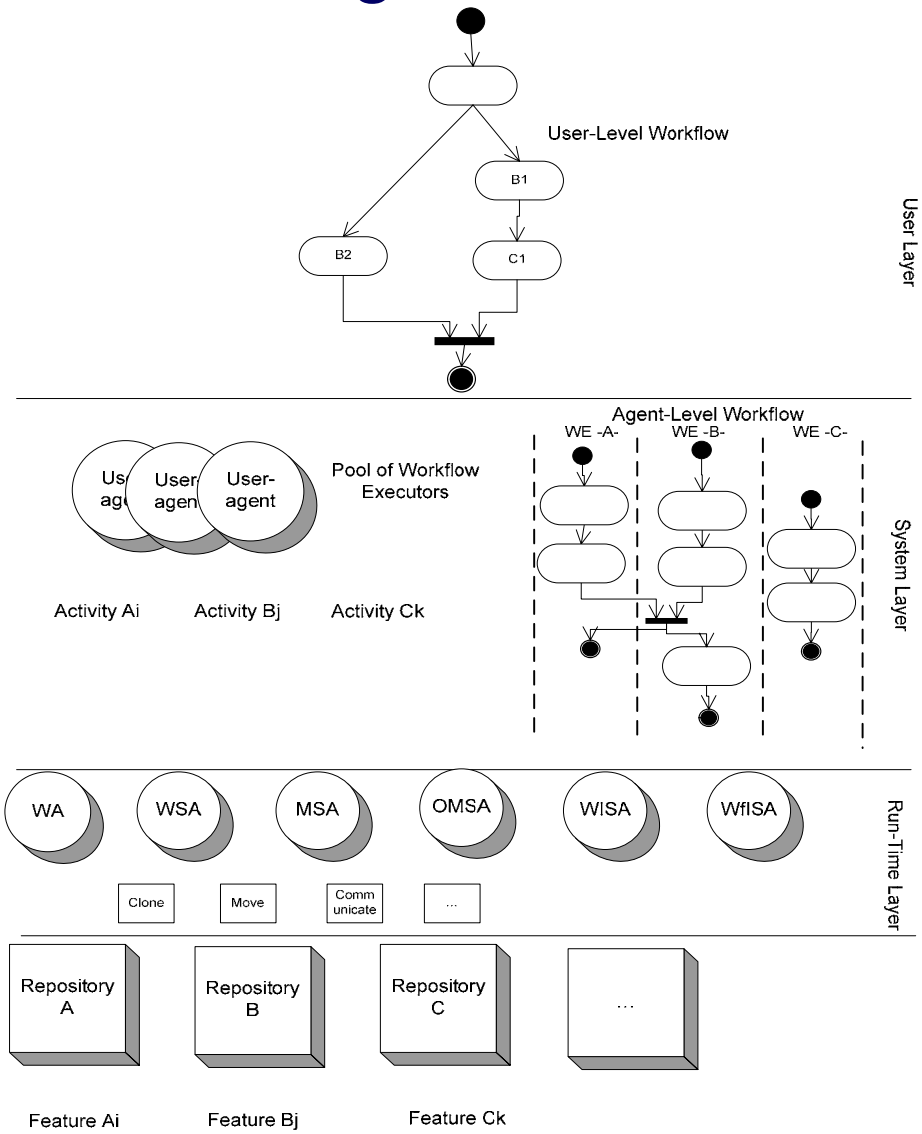
The programmer of applications has to concentrate on the involved activities and can ignore implementation strategies or metodological development issues

Hence, we also demands to the (automatic) tool the bridging of the gap between an application specification and the application itself

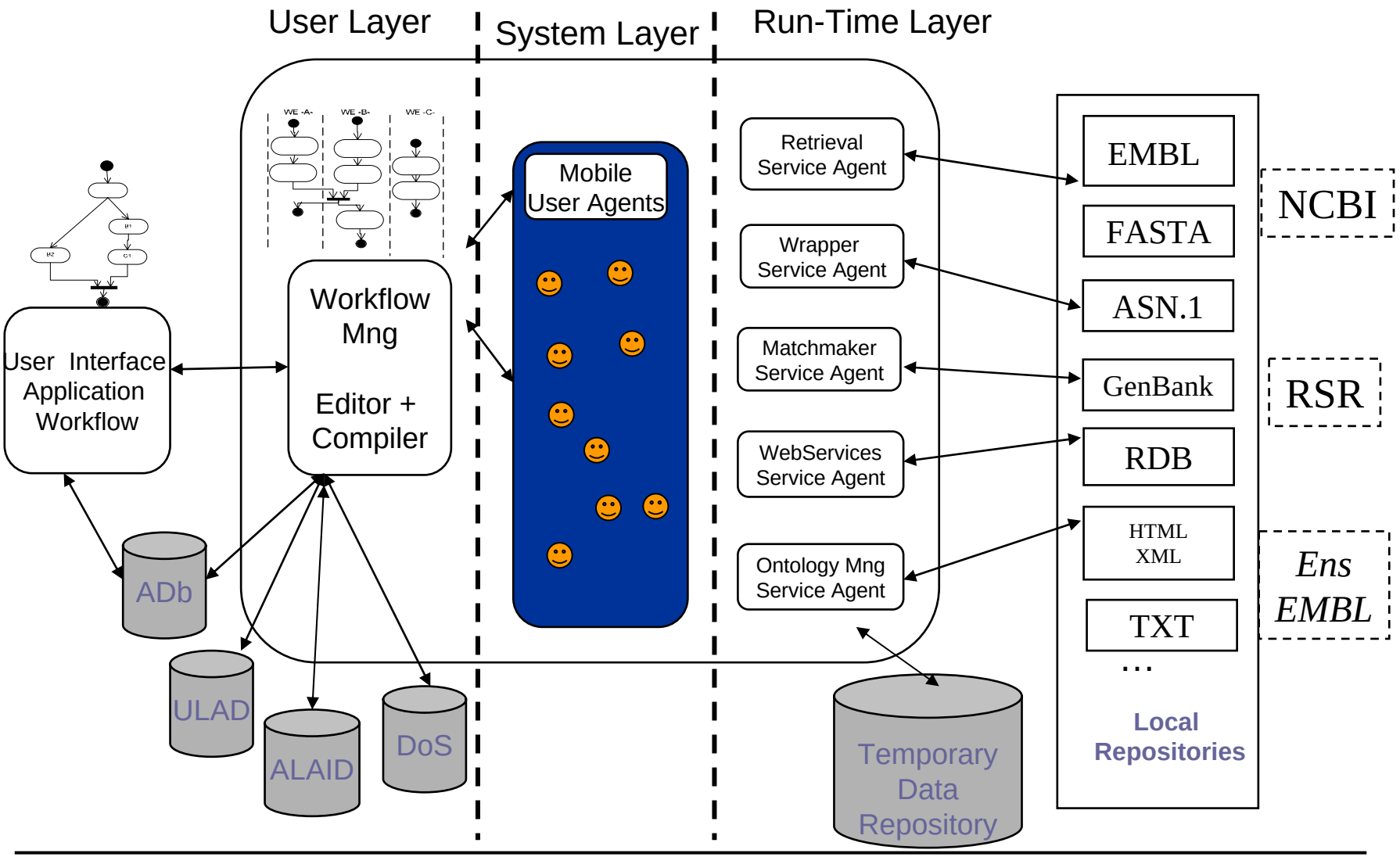
Hermes' software architecture



Hermes: The Agent-based Middleware



Hermes Middleware Architecture for O2I



Activity-based applications for BioMedicine (O2I Project)

Use context: Stanford-Lab -- verification of **proteins mutation** experiment by in-silico reproducing

Goal: Retrieve abstracts from a molecular biology **literature db** for identifying the best **cell line** for reproducing a human **TP53 mutation** experiment linked to a particular tumour-habits-sex combination

Activities: by using Bioinformatics Services avaible in the net

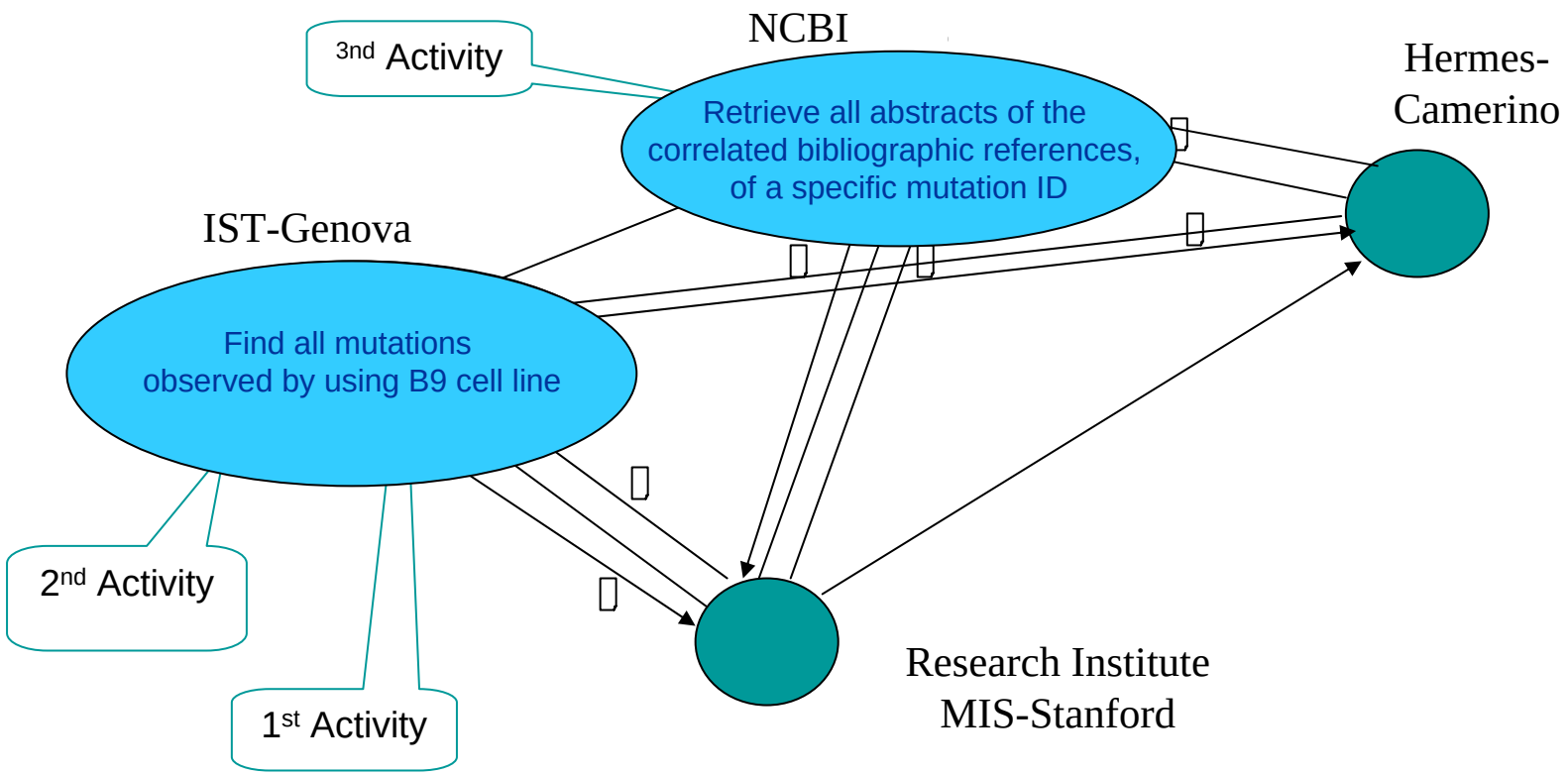
1. Retrieve all ***mutations (IDs)*** observed in the **7th exon** in **men** who are ex-smokers and drinkers
   - by searching p53 mutations database SRS (IST, Genova)

   1st Activity
2. Retrieve all ***mutations (IDs)*** observed by using **B9 cell line** as original resource
   - by searching p53 mutations database SRS (IST , Genova)

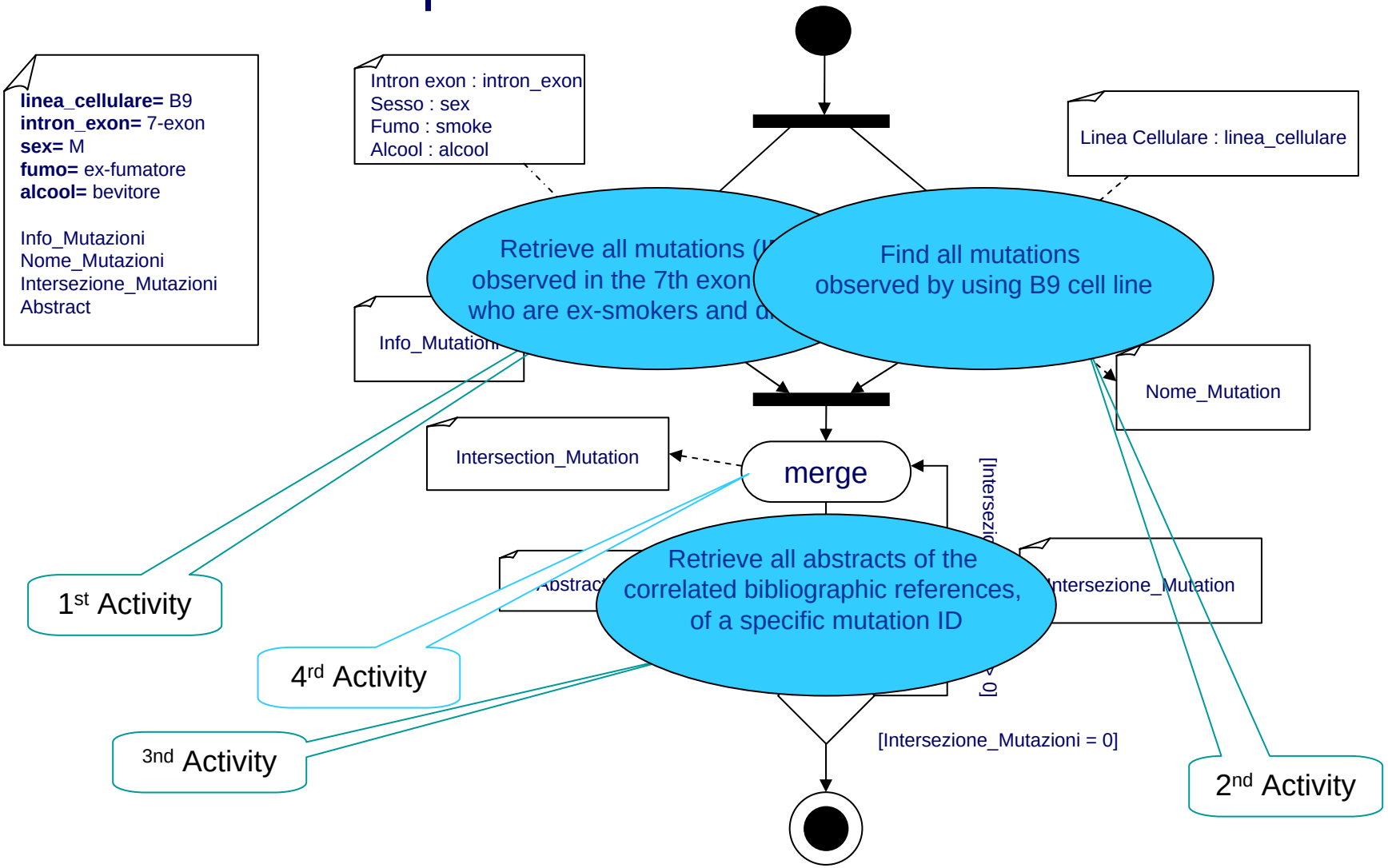
   2nd Activity
3. Retrieve all abstracts of the correlated bibliographic references, of a specific ***mutation ID***
   - by searching Medline (NCBI)

   3rd Activity

The Geographical Distribution



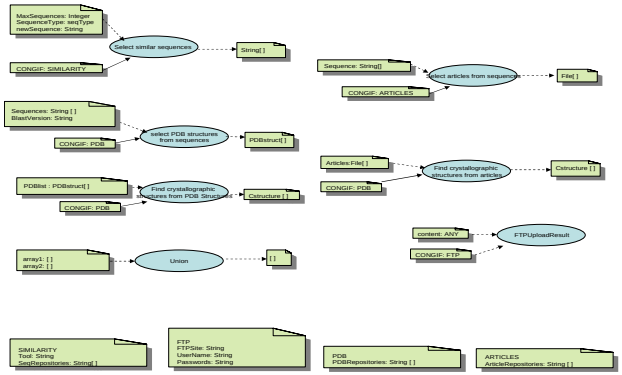
An Example of Workflow at User Level



Activities Database for O2I

Activities in Cell Line domain

A1: Find information about the **cell line** named x
A2: Find all **cell lines** derived from a **specific tumour** or **pathology**
A3: Find all **cell lines** producing a specific **protein**
A4: Given a specific **cell line**, find all related **bibliographic references**
A5: Given a specific **cell line**, find all information about produced **proteins**

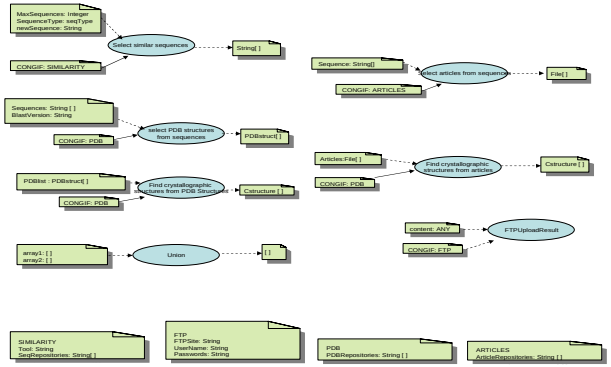


Activities in Mutation domain

B1: Find all mutations observed in a specific intron/exon in subjects with specific sex and life habits (i.e. smokers/ drinkers)
B2: Find all mutations in subjects affected by a given pathology
B3: Find all subjects affected by a tumoural pathology and with a given protein mutation
B4: Find all mutations observed by using a given cell line
B5: Given a specific mutation, find all abstracts of the correlated bibliographic references

Activities in Bibliographic domain

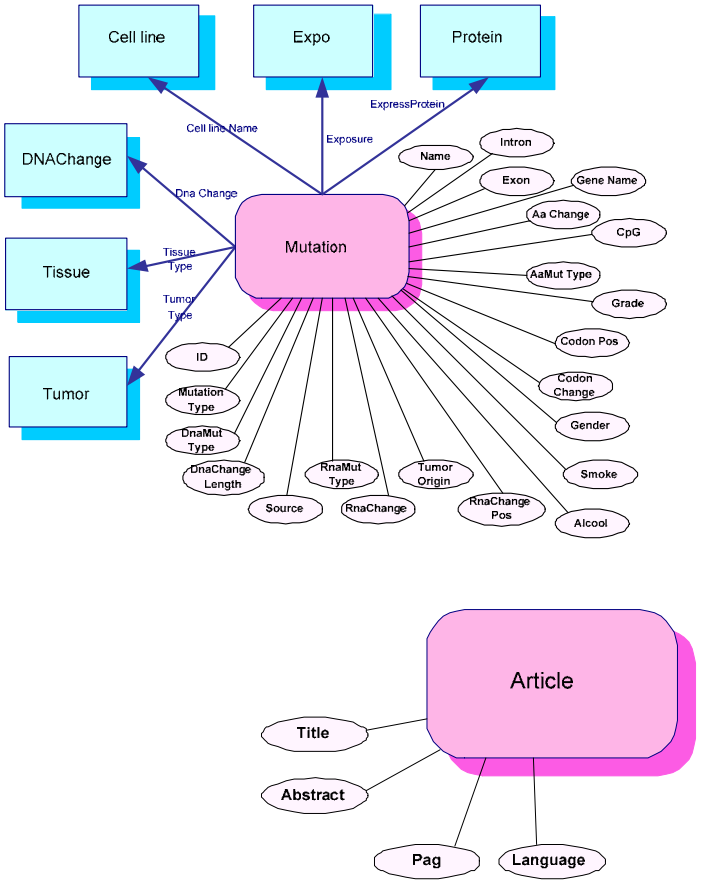
C1: Select all abstracts of bibliographic references, whose text includes a given term
C2: ……..

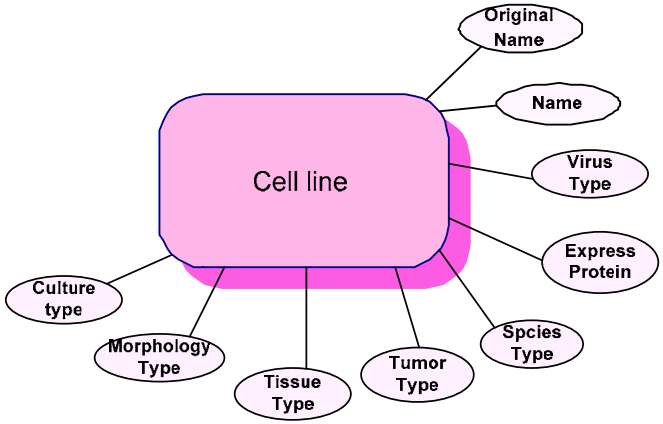


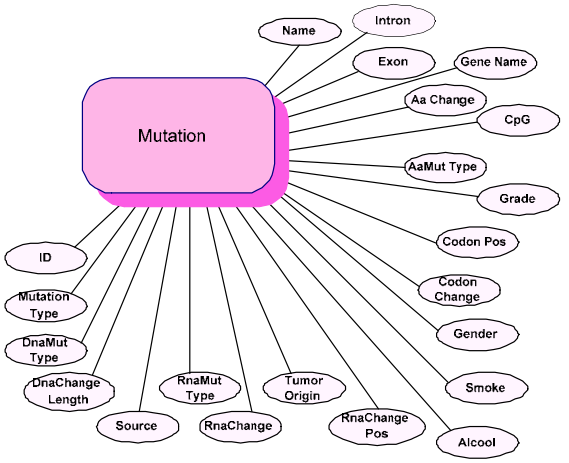
Activities in Hermes

H1: Merge in AIXO-WA
H2: ……..

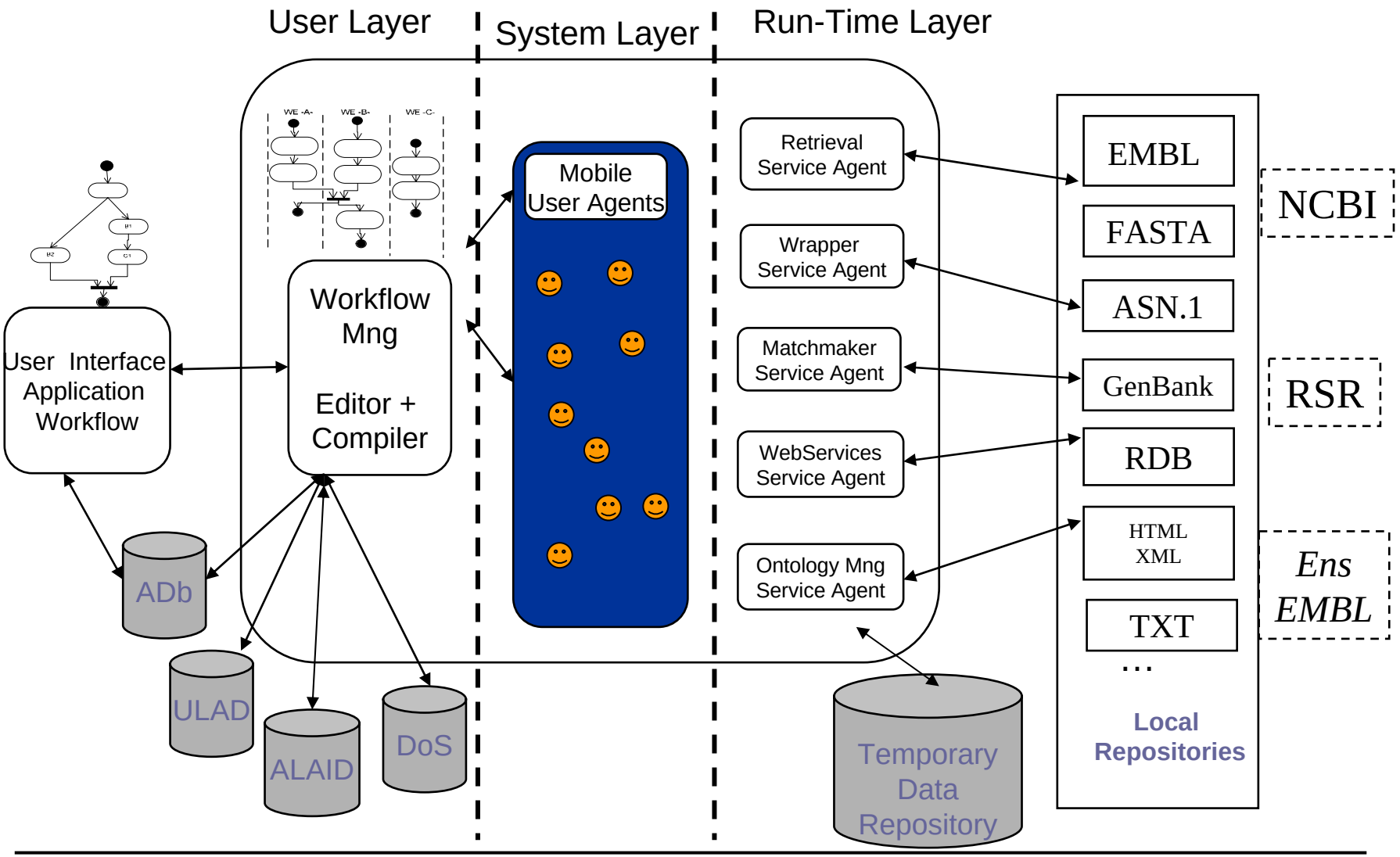
Domain Ontology







Hermes Middleware Architecture for O2I



Workflow (Context-Aware) Compiler

The compiler generates a pool of cooperating agents form the workflow specification

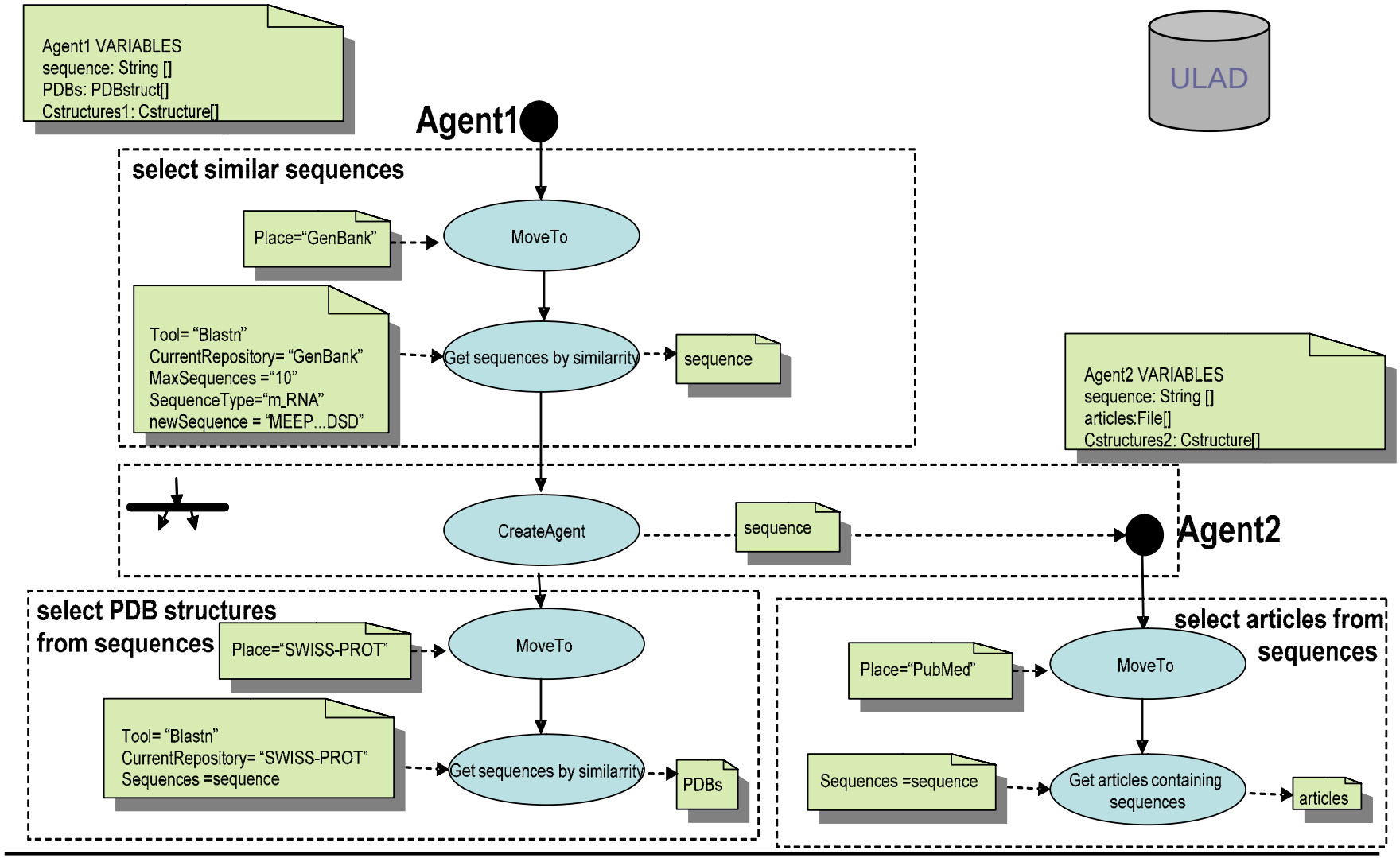
Two steps compilation:

- Step1: from user level Wf to agent level Wf
  - User Level Activity Database (ULAD)
    - contains the mapping from each user activity to an agent level Wf specification
- Step 2: agent synthesis
  - Database of Skeletons (DoS)
    - contains the “empty” implementation of an agent role (skeleton)
  - Agent-Level Activity Implementation Database (ALAID)
    - contains the implementation of each agent level activity

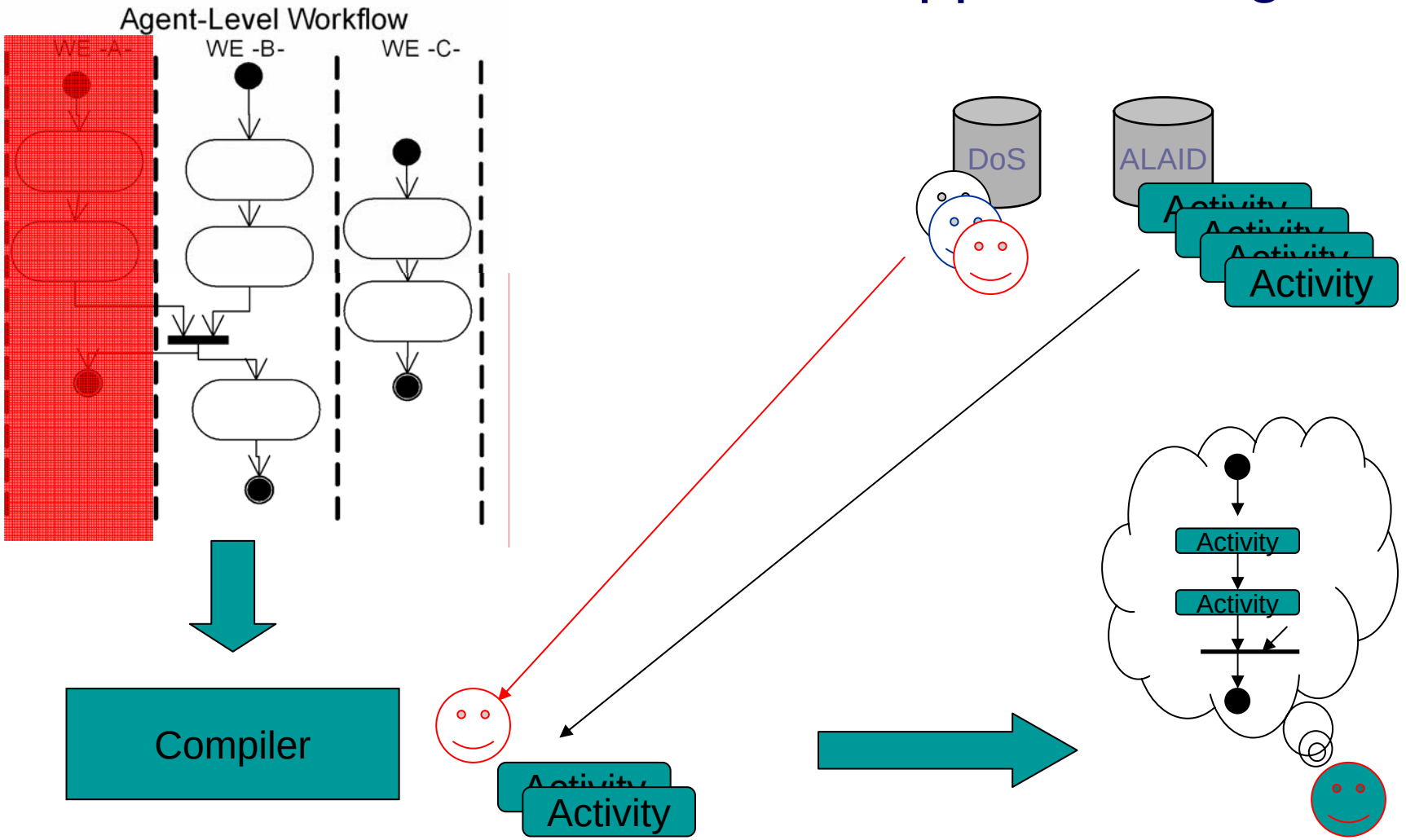
Context-awareness

The compiler takes advantage of information about the state of the global environment during the agent synthesis

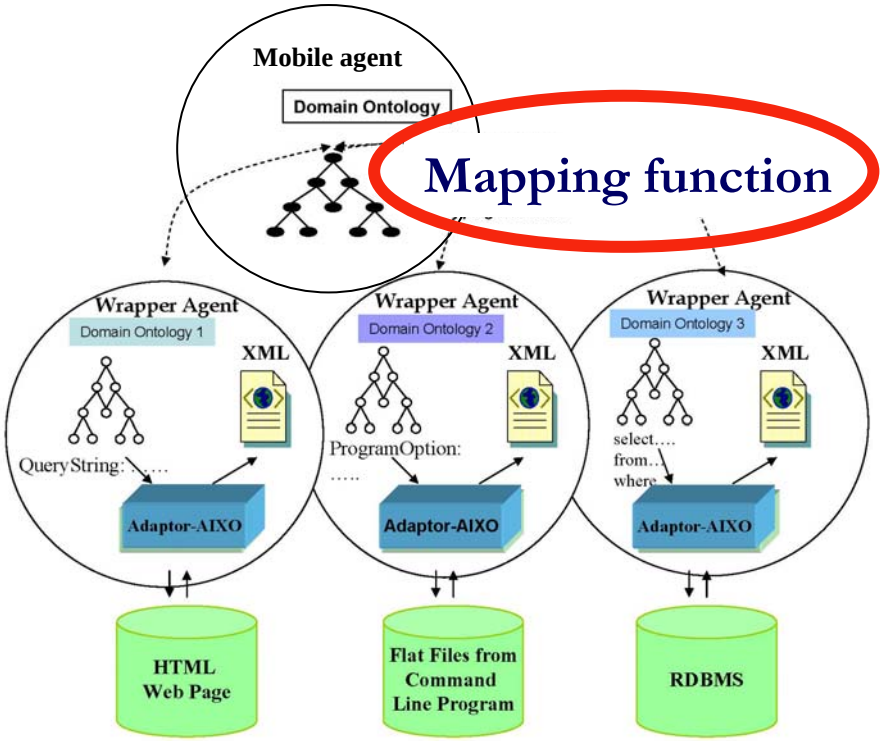
Compiler Step 1: from User to Agent Level Workflow

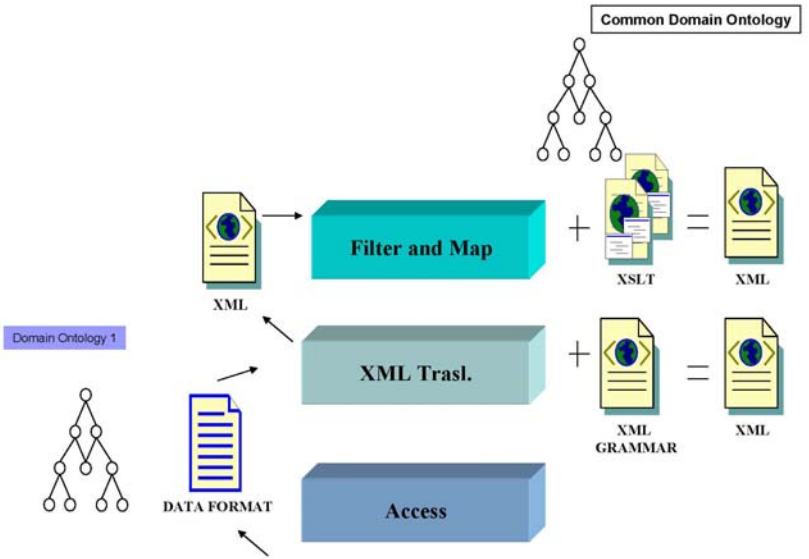


Compiler Step 2: executable application agents



Ontology Based Wrapper Agent





Ontology Graph

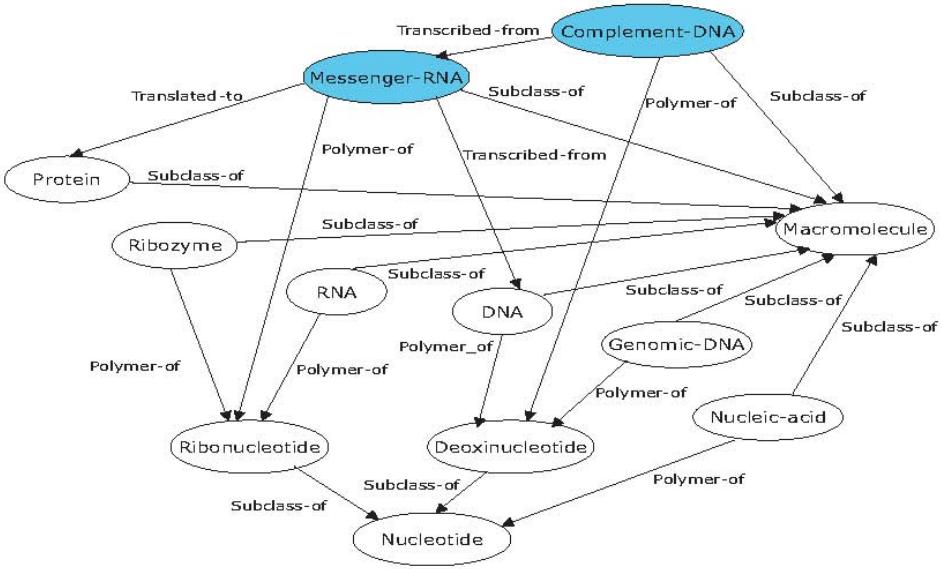


Fig. 1. An Ontological Graph for the lexicon L_1

An ontological graph is formalized by the following definition:

Definition 1 (Ontological Graph). *An* ontological graph O=*(N,A) is a directed, node and arc labelled over the lexicon $\mathcal{L}$, graph. Where N is the finite set of ontology concepts and A is the finite set of relations among concepts. The node labelling function, $\lambda : N \rightarrow C$ uniquely associates a node to a concept in the lexicon. The arc labelling function $\delta : A \rightarrow R$ uniquely associates an arc to a relation in the lexicon.*

3.1 Algebraic operators

projection $\pi : \mathcal{O} \times C \rightarrow \mathcal{O}$

similarity $\sigma : 2^N \times 2^N \rightarrow [0,1]$

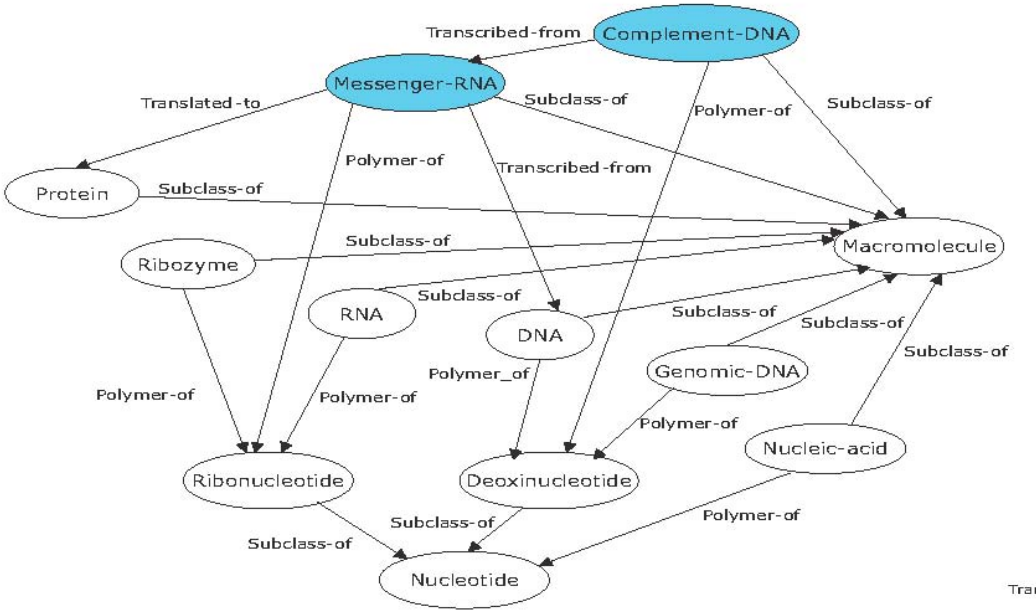
enriching $\cup : N \times N \rightarrow \mathcal{O}$

Semantic Similarity Functions

1. **Similar by relation**: Given a description of two concepts we measure the semantic similarity of two concepts by recursively comparing the existing relations among all the concepts involved in the description

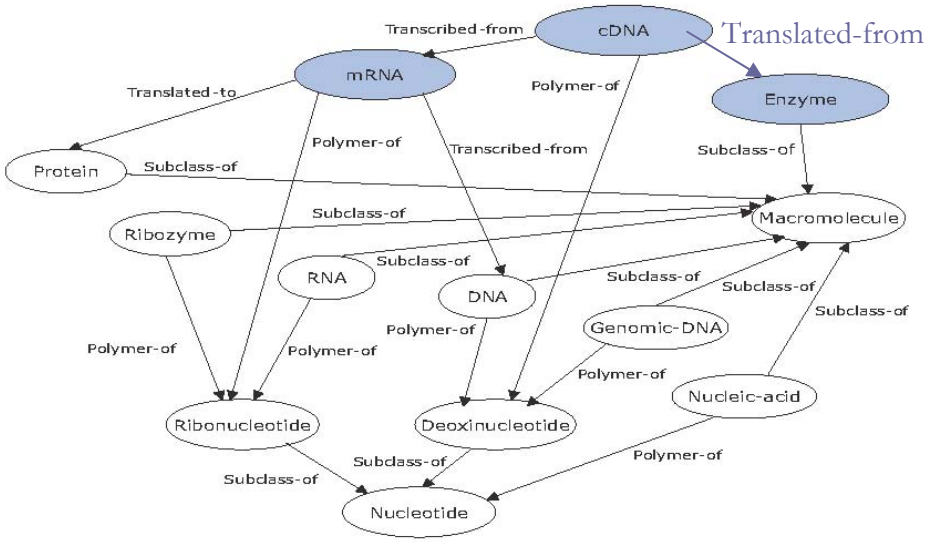
2. **Max-Structural Match**: Given a description of two concepts we measure the semantic similarity of two concepts by recursively comparing the most similar structural matching

Semantic Similarity



Structural similatiry

Similarity by relations



Ontology Functional Similarity

Given two ontological graphs $O' = (N_1, A_1)$, $O'' = (N_2, A_2)$ and two set of nodes $H \subset N_1$ and $K \subset N_2$, the similarity between H and K is measured by the following function

$$f(H,K) = \begin{cases} 1 \quad \text{iff} & \tau(H) = \tau(K) = 0 \\ 0 \quad \text{iff} & (H = \emptyset \text{ xor } K = \emptyset) \text{ or } (\tau(H) = 0 \text{ xor } \tau(K) = 0) \\ \dfrac{\sum_{r \in R_{H,K}} f(\mathsf{prj}_r(H), \mathsf{prj}_r(K))}{\mathsf{card}(R_{H,K})} & \textit{otherwise} \end{cases}$$

Where $\tau(N)$ is the number of outgoing arcs from the set of nodes in N; $R_{H,K}$ is the set of relation associated to the arcs outgoing from nodes in H and K; $\mathsf{prj}_r(H)$ and $\mathsf{prj}_r(K)$ is the set of nodes reachable from any node in H or in K respectively through the relation $r \in R$.

Main Publications

- F. Corradini, E. Merelli. Hermes: An agent-based middleware for Mobile Computing. FMS-Moby, Springer, LNCS 3465, pp. 234-270, 2005

- F. Corradini, L. Mariani, E. Merelli. An agent-based layered middleware as tool integration. Journal of Software Tools Technology Transfer, Vol. 6, pp. 231-244, 2004
- \
- D. Bonura, F. Corradini, E. Merelli, G. Romiti. FARMAS: a MAS for Extended Quality Workflow. Int. Work. on Theory and Practice of Open Computational Systems, TAPOCS'04, IEEE, 2004

- F. Corradini, R. Culmone, M. R. Di Berardini. Code Mobility for Pervasive Computing. Int. Work. on Theory and Practice of Open Computational Systems, TAPOCS'04, IEEE, 2004

- F. Corradini, E. Merelli, M. Vita. A Multi-Agent System for Modelling Carbohydrate Oxidation in Cell. First International Workshop On Modelling Complex Systems, MCS'05, LNCS, 2005
- F. Corradini, R. Culmone, E. Merelli. Integrating mobile agent and ontologies in a distributed environment, working paper.

- F. Corradini, E. Merelli, M. Ruffino Ontology-drive Information System Architecture in the Knowledge Management Perspective, workibg paper

Hermes Software

- Downloadable from

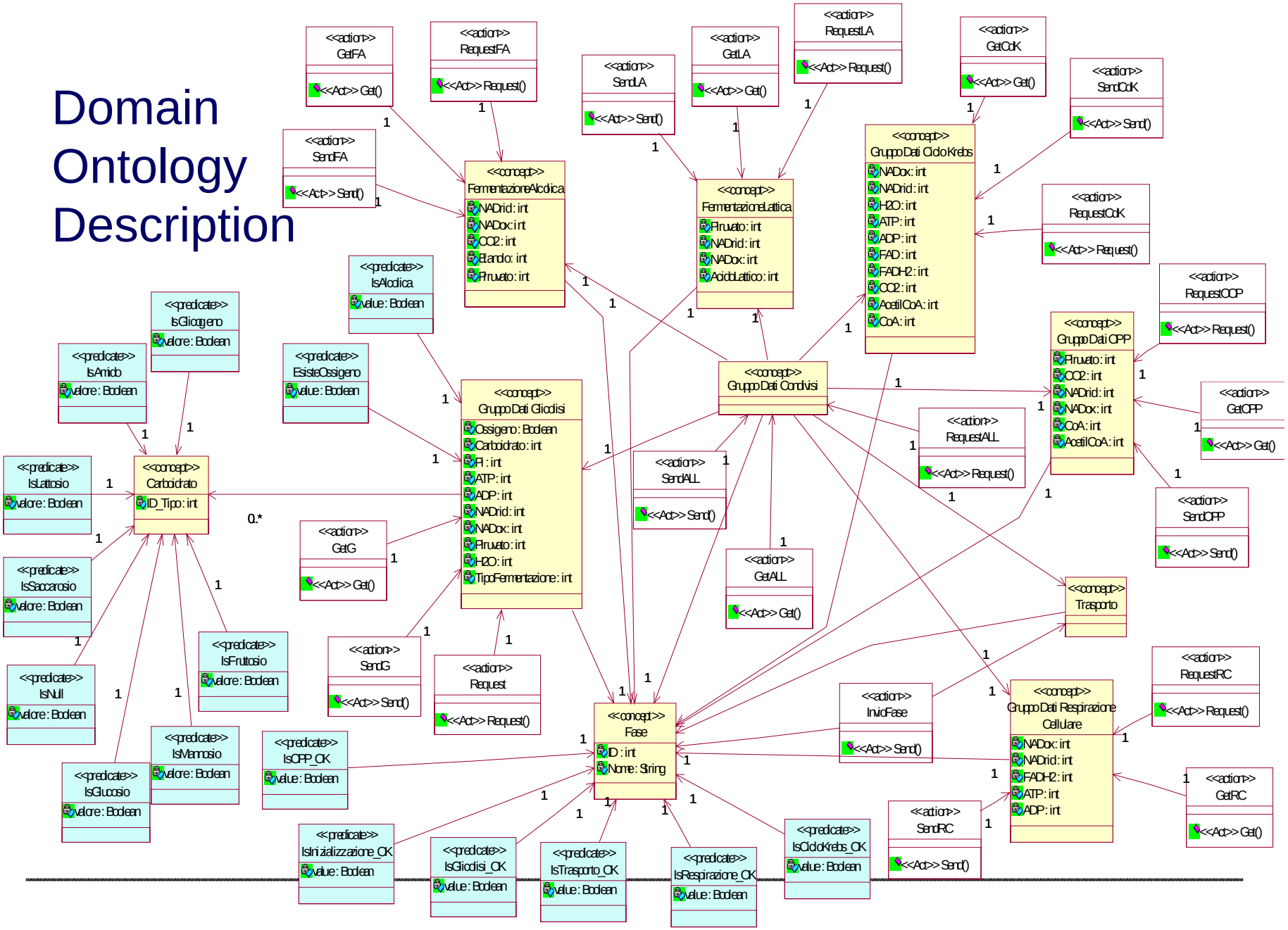
http://hermes.cs.unicam.it

or

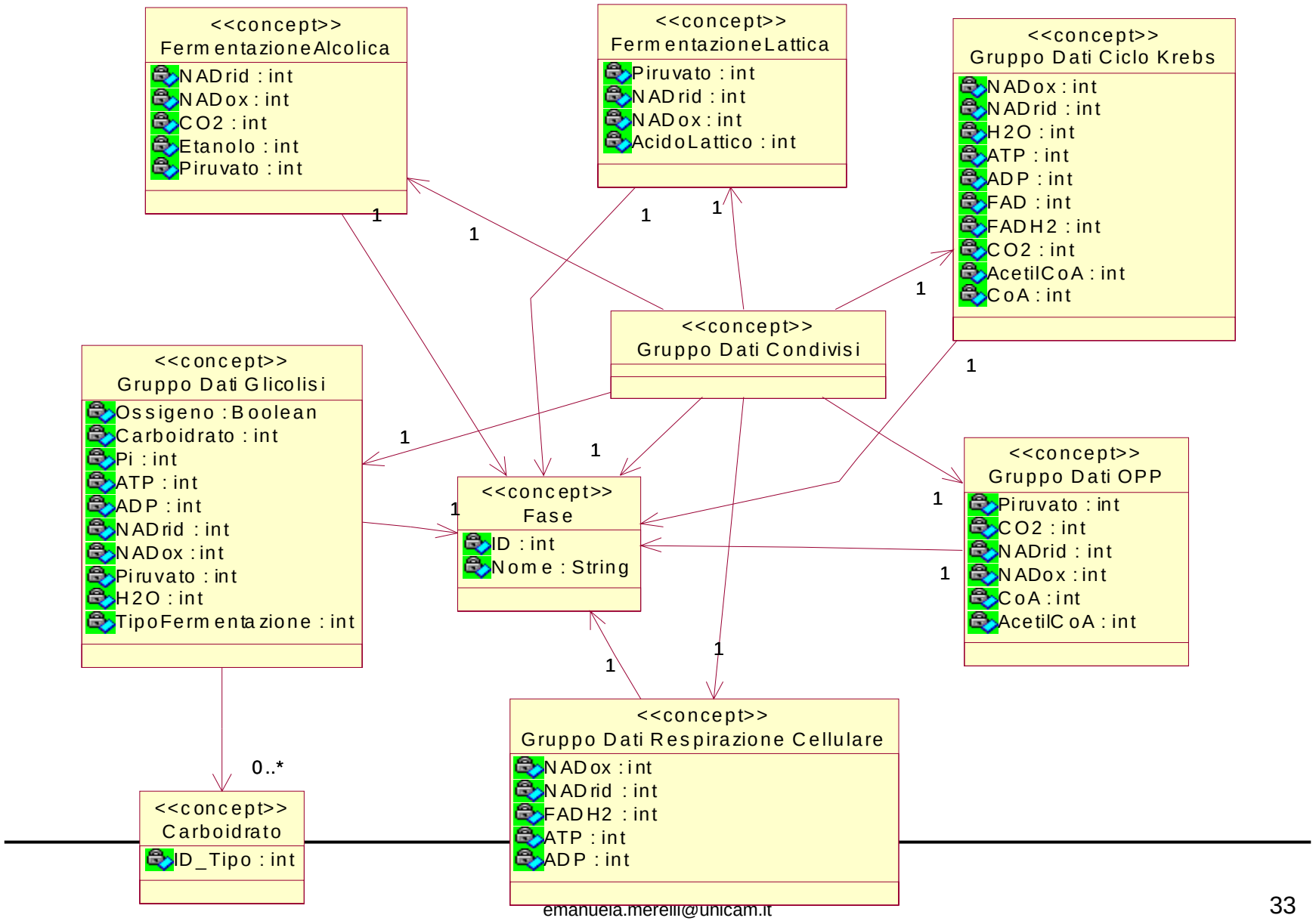
http://www.bioagent.net

Thanks to the audience!

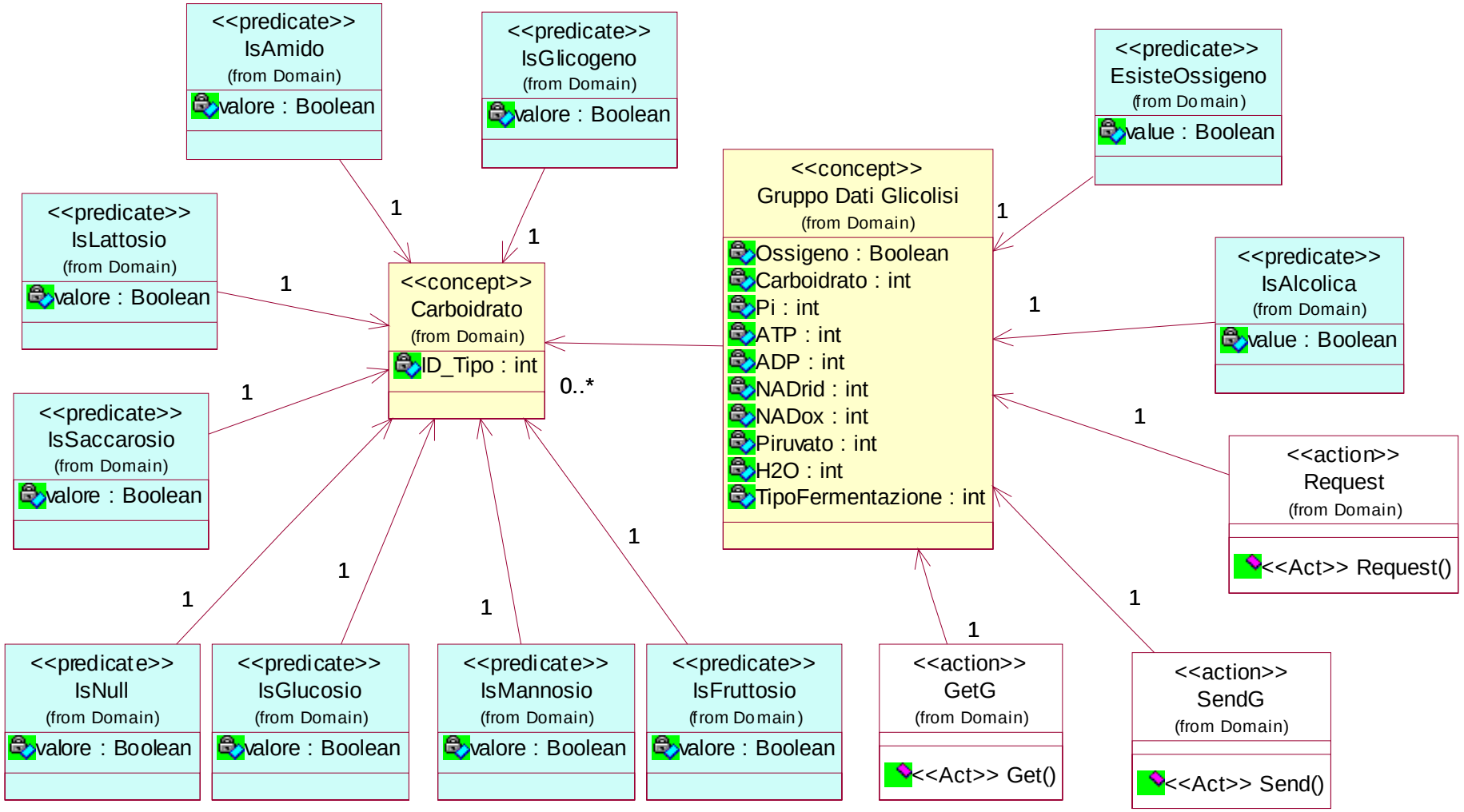
Domain Ontology Description



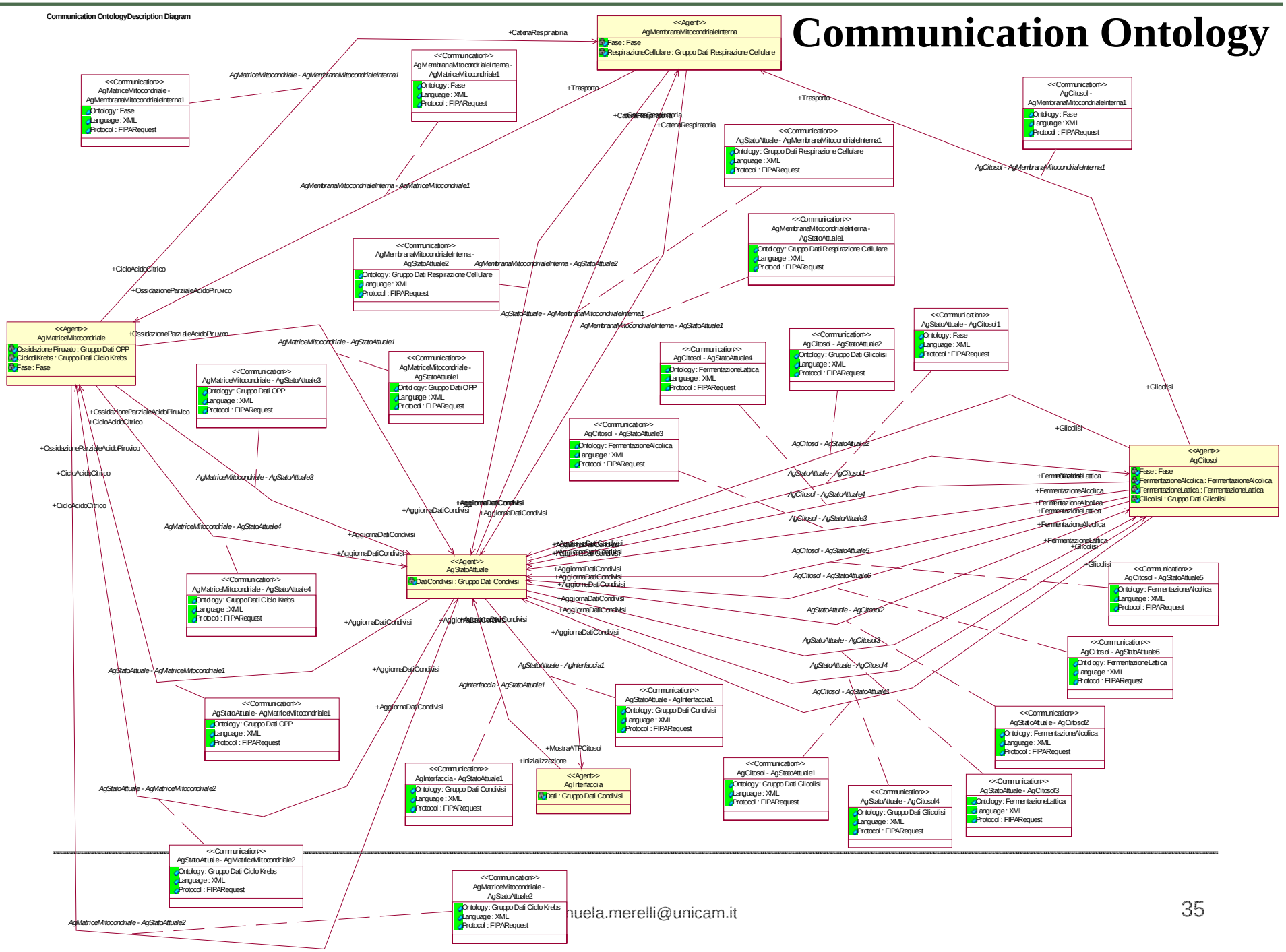
Domain Ontology Description: environment



Domain Ontology Description: functional role



Communication Ontology



Communication Ontology: MM and Environment