Distributed or Viewpoint-based Ontologies in the Kasimir System

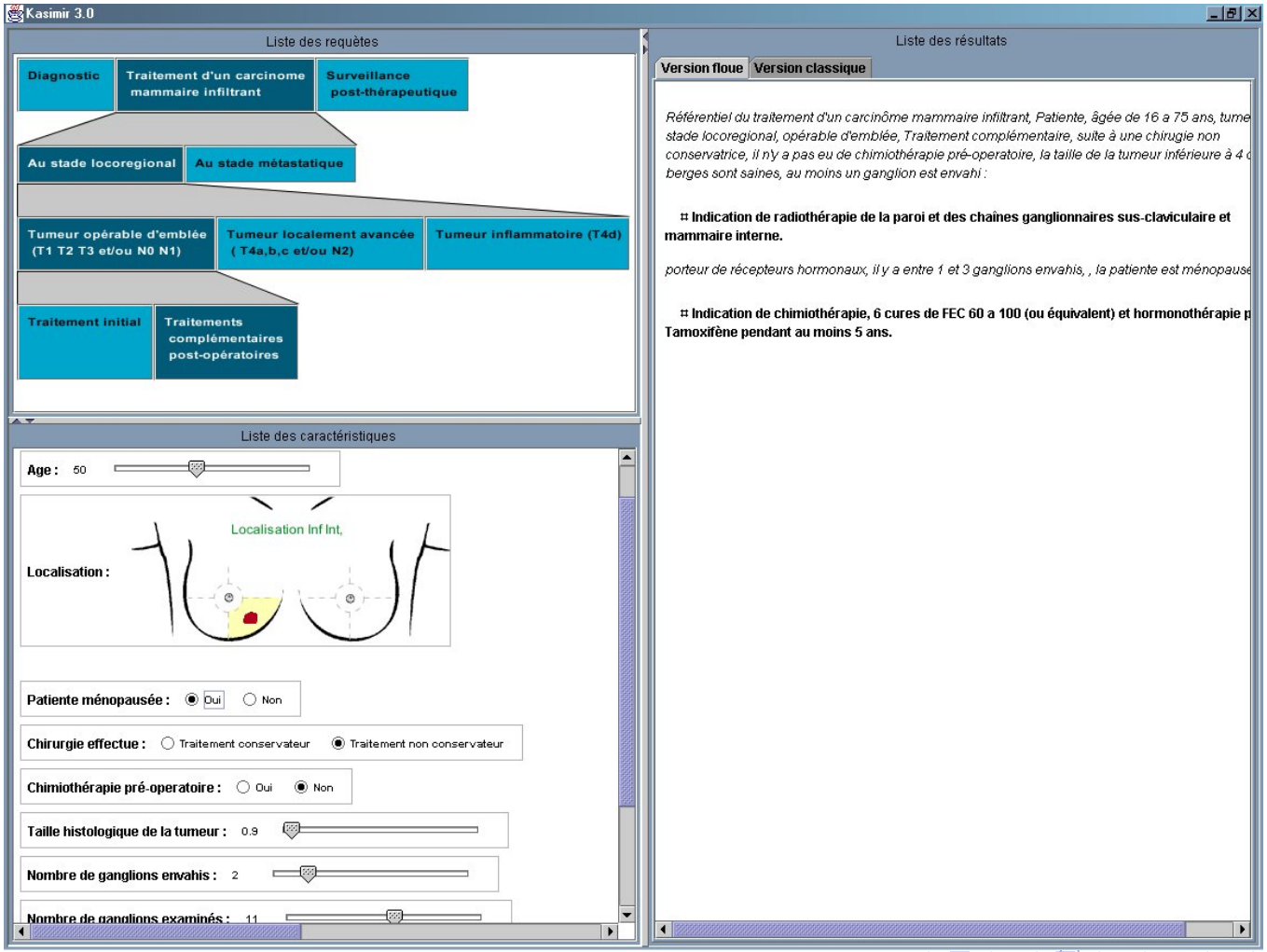
Amedeo Napoli,
LORIA – Équipe Orpailleur
CNRS – INRIA – Nancy Université
BP 239, 54506 Vandoeuvre les Nancy, France
Amedeo.Napoli@loria.fr -- http://www.loria.fr/

Journées GDR STIC Santé – 18 novembre 2008
Ontologies médicales : utilité et place des ontologies fondationnelles ?

The Kasimir system

- The main tasks of the Kasimir system are decision support and knowledge management for the treatment of cancer.
- For a given cancer localization, a treatment is based on a protocol similar to a medical guideline.
- The Kasimir system is based on Semantic Web technology and includes modules for the editing of treatment protocols, visualization, maintenance, and knowledge discovery.

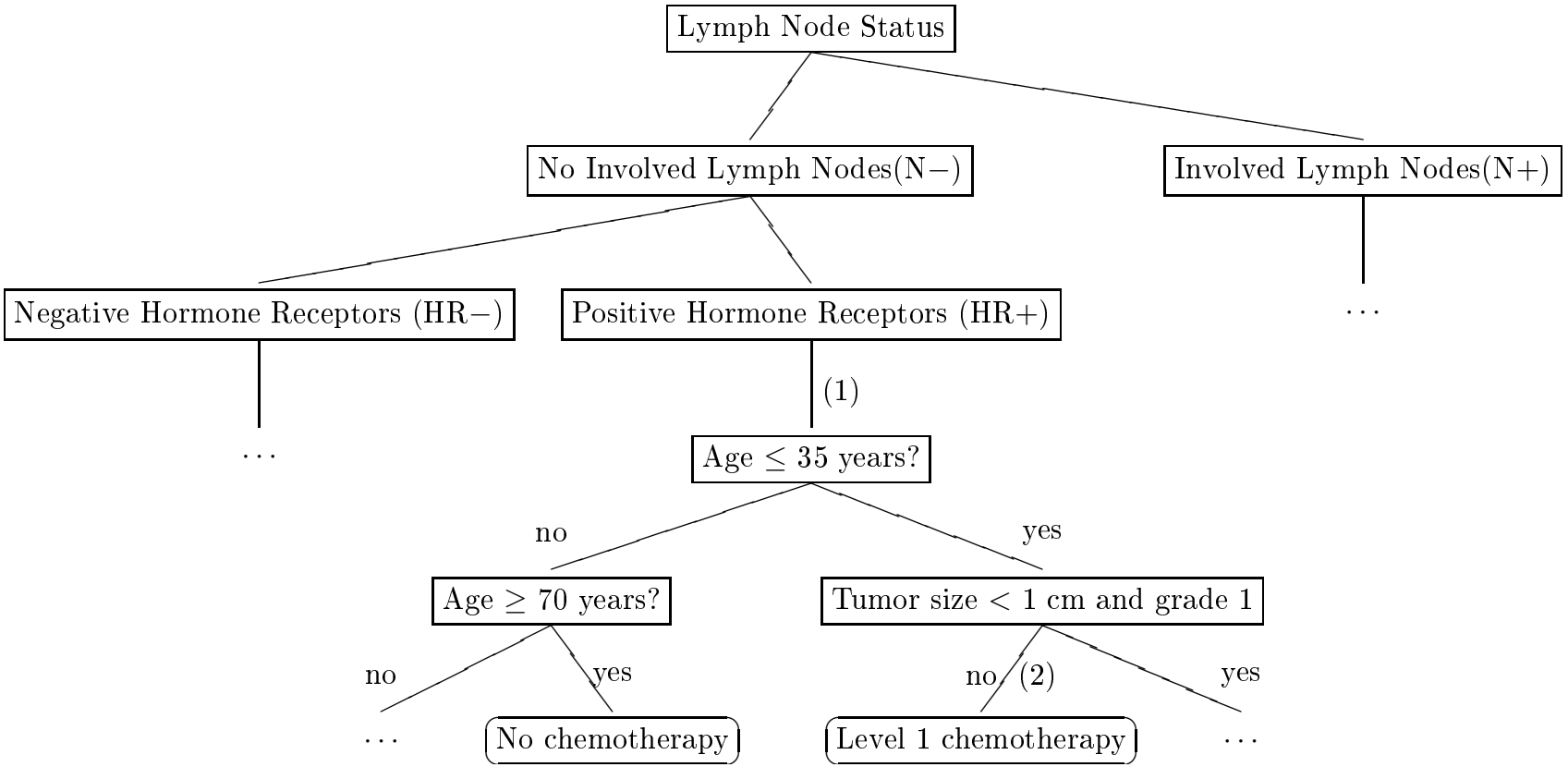
The Kasimir system



Protocols in the Kasimir system

- A protocol contains "standard knowledge units for decision support in oncology" and is structured as a kind of decision tree.
- The protocol is considered as a set of rules $\{\mathtt{R}_i\}_i$ of the form $\mathtt{R}_i = (\mathtt{P}_i \longrightarrow \mathtt{D}_i)$ where $\mathtt{P}_i$ represents a class of cancer patients and $\mathtt{D}_i$ represents a set of therapeutic decisions.
- Most of the time (about 60 to 70% of the cases), the protocol is straightforwardly applied; the remaining out-of-protocol cases are examined by the breast therapeutic decision committee for adapting the protocol and decision.

An example of protocol (breast cancer)



The representation of protocols

- The representation of a decision protocol for associating a treatment recommendation to a patient description is based on a domain ontology.
- A cancer patient is considered as a person and as a medical case.
- A medical case is, in turn, considered as a problem case to be solved, or for which a solution has to be found, i.e. a cancer patient has a tumor for which a treatment has to be recommended.

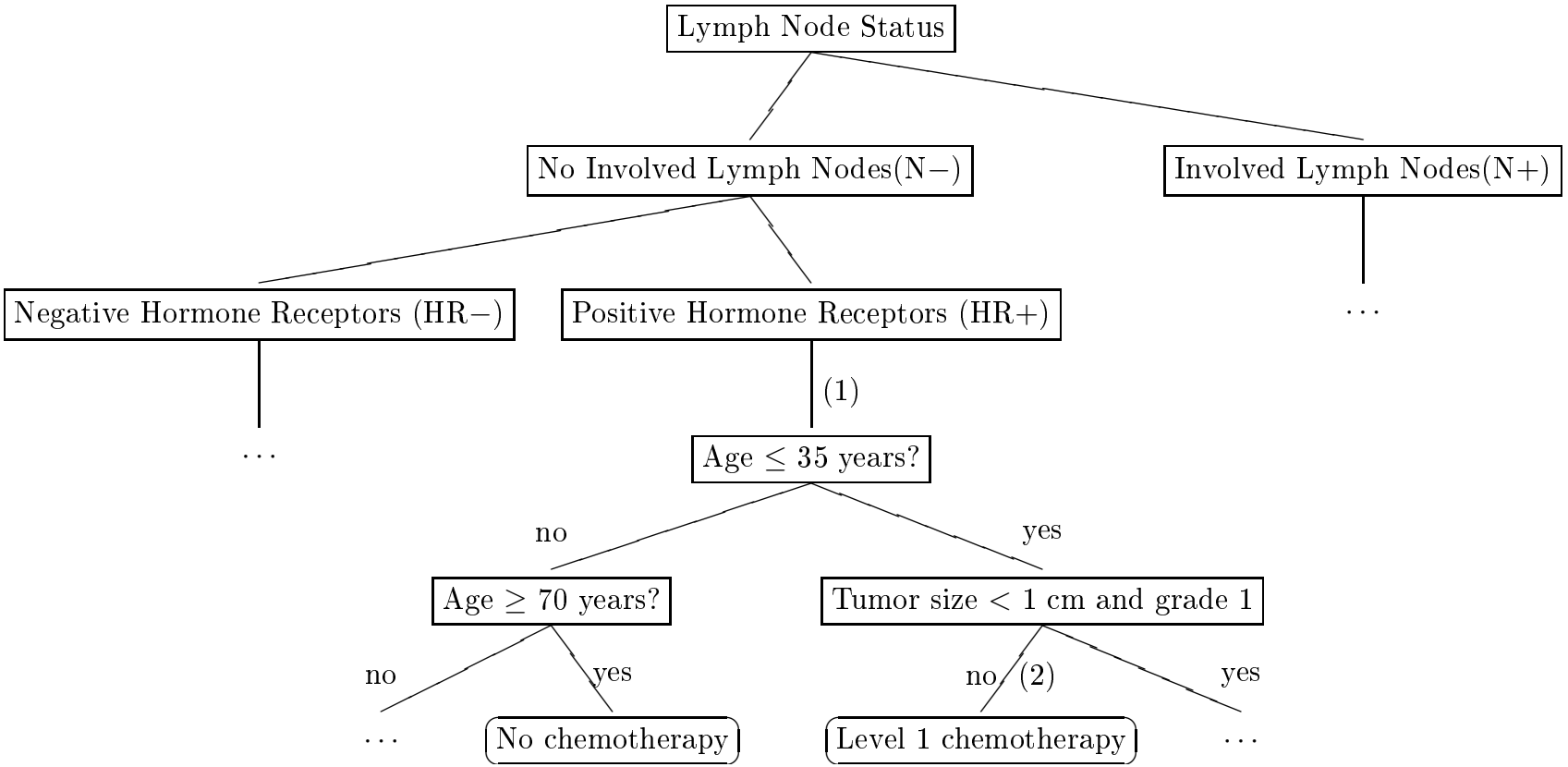
Problem, solutions, and axioms

- Problems are represented by the `ProblemCase` concept.
- Solutions are represented by the `SolutionCase` concept.
- A problem-solution axiom relate specific problems to specific solutions.

$$\texttt{TumorPatient} \equiv \texttt{Person} \sqcap \texttt{MedicalCase} \sqcap \exists \texttt{hasTumor}.\texttt{Tumor}$$
$$\texttt{MedicalCase} \sqsubseteq \exists \texttt{hasRecommendation}.\texttt{Treatment}$$

$$\texttt{MedicalCase} \sqsubseteq \texttt{ProblemCase}$$
$$\texttt{hasRecommendation} \sqsubseteq \texttt{hasSolution}$$
$$\texttt{ProblemCase} \sqsubseteq \exists \texttt{hasSolution}.\texttt{SolutionCase}$$

An example of protocol (breast cancer)



The representation of protocols using DLs

$$\texttt{C1} \equiv \texttt{TumorPatient} \sqcap \exists \texttt{hasInvolvedLymphNodes}.\{\texttt{false}\} \sqcap \exists \texttt{hasPositiveHormoneReceptors}.\{\texttt{true}\}$$

$$\texttt{C2} \equiv \texttt{C1} \sqcap \exists \texttt{hasAge}.\, <_{35} \sqcap \neg(\exists \texttt{hasTumor}.(\exists \texttt{hasSize}.\, <_1 \sqcap \exists \texttt{hasGrade}.\, =_1))$$

$$\texttt{C2} \sqsubseteq \exists \texttt{hasRecommendation}.\texttt{Level1Chemotherapy}$$

Viewpoints in Oncology

- Oncology has to be regarded as a complex domain where several specialties are involved.
- For each specialty, different characteristics of the patient are taken into account for setting on a specific treatment within the whole treatment process.
- The protocol for breast cancer treatment is based on four main sub-protocols –viewpoints– focusing on a particular phase of the treatment: preoperative chemotherapy, surgery, radiotherapy, and complementary treatment.

DDLs for representing multiple viewpoints

- The representation of viewpoints within the Kasimir system is based on distributed description logics (DDLs).
- The representation of the protocol is modularized, i.e. it is reified as a multi-viewpoint representation in DDLs.
- DDLs and namely C-OWL are extensions of DLs allowing the representation of contexts, i.e. local contextualized ontologies, which are semantically related through mappings.
- The C-OWL formalism provides means for local representation and reasoning within a viewpoint, and global reasoning across several viewpoints through mappings, leading to decentralized reasoning.

Contexts in DDLs

- In a DDL, the knowledge about a domain is distributed over a set of contexts. A context O_i is an ontology, with a proper language and a proper interpretation.
- A mapping $\mathcal{M}_{ij}$ between contexts O_i and O_j is expressed through a set of bridge rules from O_i to O_j allowing to declare a correspondence between the interpretation domains of the two contexts.
- In this way, knowledge units in O_i can be interpreted and reused in (terms of) O_j.

Representation of oncology viewpoints using DDLs

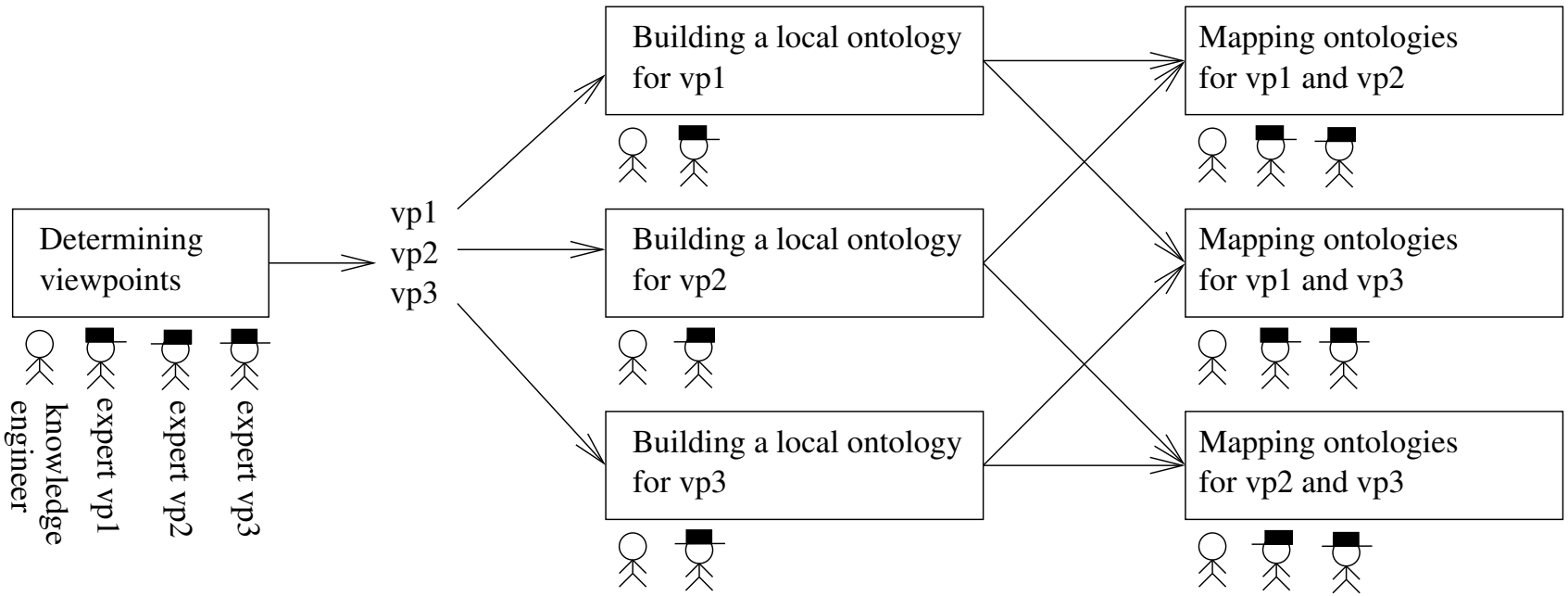
- Modeling and formalizing a multiple viewpoint representation within a DDL is a decentralized task, i.e. there is no need to set up a consensus, but, dually, to distinguish viewpoints.

(1) determine the relevant viewpoints in the domain,

(2) build a local ontology for every viewpoint, and

(3) establish mappings between local ontologies, reifying correspondences between viewpoints.

Determining viewpoints: example



Determining viewpoints

- A large and complex domain is often organized according to various sub-domains, e.g. services, tasks, working groups, communities, providing a division into viewpoints.
- In the same way, the protocol for breast cancer treatment is considered to be composed of four main treatment phases (daily used by physicians): presurgical chemotherapy (*pc*), surgery (*s*), radiotherapy (*r*), and complementary treatment (*ct*: hormonotherapy or chemotherapy).
- These four treatment phases are interrelated: the decision taken for a particular phase depends on decision units lying in another one.

Building a local ontology

- Building a local ontology consists in formalizing a context in DDL corresponding to a viewpoint.
- A local ontology includes the knowledge units considered to be useful within the current viewpoint, independently from the other viewpoints, i.e. a context in DDL formalizing a local ontology only implements knowledge units relevant to the viewpoint.

Examples of axioms in a local ontology (1)

- In surgery, a patient with a directly operable and non multifocal tumor has to be treated with a partial ablation of the breast.

$$\mathtt{s{:}C} \equiv \mathtt{TumorPatient} \sqcap \exists \mathtt{hasTumor}.\,(\mathtt{OperableTumor} \sqcap \exists \mathtt{hasFocus.SimpleFocus})$$

$$\mathtt{s{:}C} \sqsubseteq \exists \mathtt{hasRecommendation.PartialAblation}$$

Examples of axioms in a local ontology (2)

- In radiotherapy, the considered characteristics are related to the recommended surgery, to the localization of the tumor in the breast, the size, and the presence of malignant cells in the lymph nodes.

$$\begin{aligned}
\mathtt{r{:}C} \equiv\ & \mathtt{TumorPatient} \\
& \sqcap \exists \mathtt{hasRecommendedSurgery.PreservingAblation} \\
& \sqcap \exists \mathtt{hasInvolvedLymphNodes.}\{\mathtt{false}\} \\
& \sqcap \exists \mathtt{hasTumor.}(\exists \mathtt{hasLocalization.InferoInternal})
\end{aligned}$$

$$\begin{aligned}
\mathtt{r{:}RadiotherapyBreastAndEIMC} \equiv\ & \mathtt{Irradiation} \\
& \sqcap \exists \mathtt{hasZone.Breast} \\
& \sqcap \exists \mathtt{hasZone.EIMC}
\end{aligned}$$

$$\mathtt{r{:}C} \sqsubseteq \exists \mathtt{hasRecommendation.RadiotherapyBreastAndEIMC}$$

Examples of axioms in a local ontology (3)

- The choice of a complementary treatment is guided by characteristics such as the status of the hormone receptors, the number of involved lymph nodes, the age of the patient, the size of the tumor, and the grade (1, 2, or 3).

$$\begin{aligned} \texttt{ct:C} \equiv\ & \texttt{TumorPatient} \\ & \sqcap \exists \texttt{hasAge}.\ \leq_{35} \\ & \sqcap \exists \texttt{numberInvolvedLymphNodes}.\{0\} \\ & \sqcap \exists \texttt{hasPositiveHormoneReceptors}.\{\texttt{true}\} \\ & \sqcap \neg \exists \texttt{hasTumor}.(\exists \texttt{hasGrade}.\ =_1 \sqcap \exists \texttt{hasSize}.\ <_1) \end{aligned}$$

$$\texttt{ct:C} \sqsubseteq \exists \texttt{hasRecommendation.Level1Chemotherapy}$$

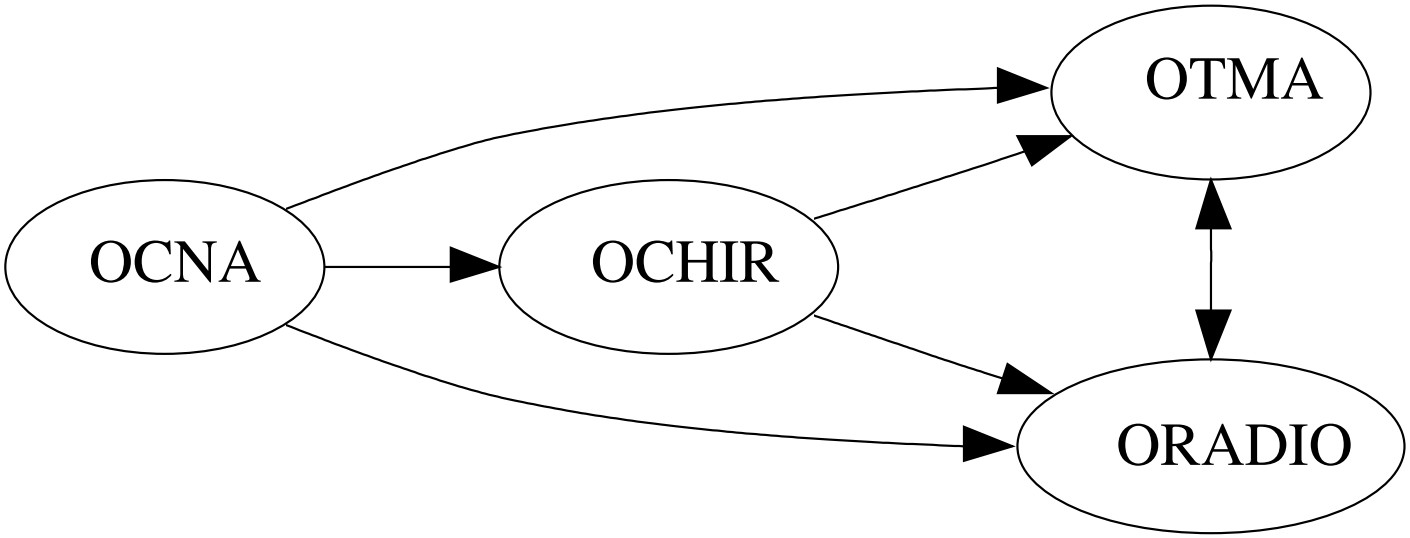
Mapping ontologies

- The relations existing between viewpoints are materialized through mappings between local ontologies.
- An important question concerns the knowledge units that can be shared and reused from a given viewpoint in another viewpoint.
- Thus, it is important to make precise the correspondences between viewpoints, indicating how a given context may take advantage of knowledge units in another context.

Mapping ontologies in oncology

- In oncology, a local ontology represents knowledge related to a specialty playing a role in a particular phase of the treatment.
- Surgery is the central phase of the treatment and takes place after presurgical chemotherapy: then, decisions in surgery follow decisions in presurgical chemotherapy accordingly.
- Radiotherapy and complementary treatment aim at complementing surgery (for eliminating remaining involved cells with radiotherapy, chemotherapy, or hormonotherapy). Thus, the decision in these two viewpoints depends on the surgery viewpoint.

Examples of mapping between ontologies in oncology



Making precise bridge rules between ontologies (1)

- Bridge rules are used either for sharing knowledge between the viewpoints or for representing the influence of a decision in a particular viewpoint on the decision in another viewpoint.
- Decisions in radiotherapy and in complementary treatment both rely on the status of the lymph nodes –either involved or not–, even if this information unit is represented differently in O_r and O_{ct}:

$$\texttt{r:}\exists\texttt{hasInvolvedLymphNodes.}\{\texttt{false}\} \xrightarrow{\sqsubseteq} \texttt{ct:}\exists\texttt{numberInvolvedLymphNodes.}\{0\}$$

$$\texttt{r:}\exists\texttt{hasInvolvedLymphNodes.}\{\texttt{true}\} \xrightarrow{\sqsubseteq} \texttt{ct:}\exists\texttt{numberInvolvedLymphNodes.} \geq_1$$

Making precise bridge rules between ontologies (2)

- A decision in radiotherapy depends on the recommended treatment in surgery, either preserving, i.e. a partial ablation preserving the essential part of the breast, or not preserving.

$$\texttt{s}:\exists\texttt{hasRecommendation}.\texttt{PartialAblation} \xrightarrow{\sqsubseteq} \texttt{r}:\exists\texttt{hasRecommendedSurgery}.\texttt{PreservingAblation}$$

DDL Reasoning for decision support in oncology

- Solving a problem in a multi-viewpoint framework with CBR is a decentralized process.
- Inferences occur locally in each viewpoint represented by a context in DDL, taking advantage of bridge rules for reusing the knowledge and inferences from the other viewpoints.
- As a result, a decentralized solution is composed of partial solutions from each viewpoint considered during the problem-solving process.
- No choice is done and the decentralized solution is given as a whole to the physician for effective and actual reuse. n

Representation and reasoning with viewpoints (1)

- In the Kasimir system, the protocols are patient-centered and based on patient description, with axioms relating a patient description to a decision.
- Descriptions are represented within DL and DDL formalisms, and inferences are based on satisfiability and subsumption.
- The decentralized approach is based on viewpoints or local ontologies represented by contexts.
- In terms of knowledge engineering and knowledge management, the maintenance of a set of contexts is simpler: knowledge units are only locally updated.

Representation and reasoning with viewpoints (2)

- A protocol can be seen as a decision tree and can be represented as such within a DL formalism.
- The problem-solving process relies on problem-solution axioms relating a medical case description to a treatment description.
- The features implemented for decision support in oncology are of general interest and may be reused in other domains where similar problems are raised.

A bottom-up approach for designing a knowledge base

- The standard approach is usually a top-down process, where a general and global representation covering the larger part of the domain knowledge is built.
- By contrast, the building of a contex-based ontology is bottom-up.
- It consists in considering local knowledge in local viewpoints and then to combine the different viewpoints through mappings.
- The resulting decentralized ontology covers the domain in a global way and is made up of local ontologies that may be used for their own.

Distributed reasoning within the Kasimir KB

- DDLs provide a framework for implementing distributed reasoning mechanisms, where a specialized reasoner is associated to a given context (as in Drago).
- Global reasoning can be carried out through P2P communications: the complexity and the resources used are distributed among the local reasoners, that can be activated on different or distant machines.
- This is a way of tackling the problem of scalability of reasoning in a complex real world application.

Architecture and implementation

- The Kasimir system is embedded within a semantic portal for knowledge management and decision support in oncology.
- Several protocols are formalized, on different health-care tasks such as diagnosis, treatment, surveillance, and different cancer localizations, such as breast, prostate, colon.
- The architecture of the Kasimir semantic portal relies on a knowledge server, implemented as a set of Web services and embedding a DL and DDL reasoners (Jena API, Pellet, and Drago).

Conclusion

- The Kasimir system is aimed at knowledge management and decision support in oncology.
- It implements medical decision protocols using DL and DDL formalisms, based on original characteristics regarding representation, reasoning, and viewpoints.
- In addition, A CBR process embedded within a DL framework is used for solving adaptation problems.
- Efforts are currently carried out for designing discovery of adaptation knowledge: both reuse of expert knowledge and knowledge discovery in databases (e.g. CabamakA).

People, organizations, and Kasimir

- At LORIA: Mathieu d'Aquin, Fadi Badra, Sébastien Brachais, Benoît Bresson, Julien Cojan, Jean Lieber, Thomas Meilender, Amedeo Napoli, Laszlo Szathmary, ...
- Laboratoire d'Ergonomie du CNAM, Centre Alexis Vautrin, Associations Oncolor et Hermès, ...
- Thanks!...