Semantically Steered Clinical Decision Support Systems

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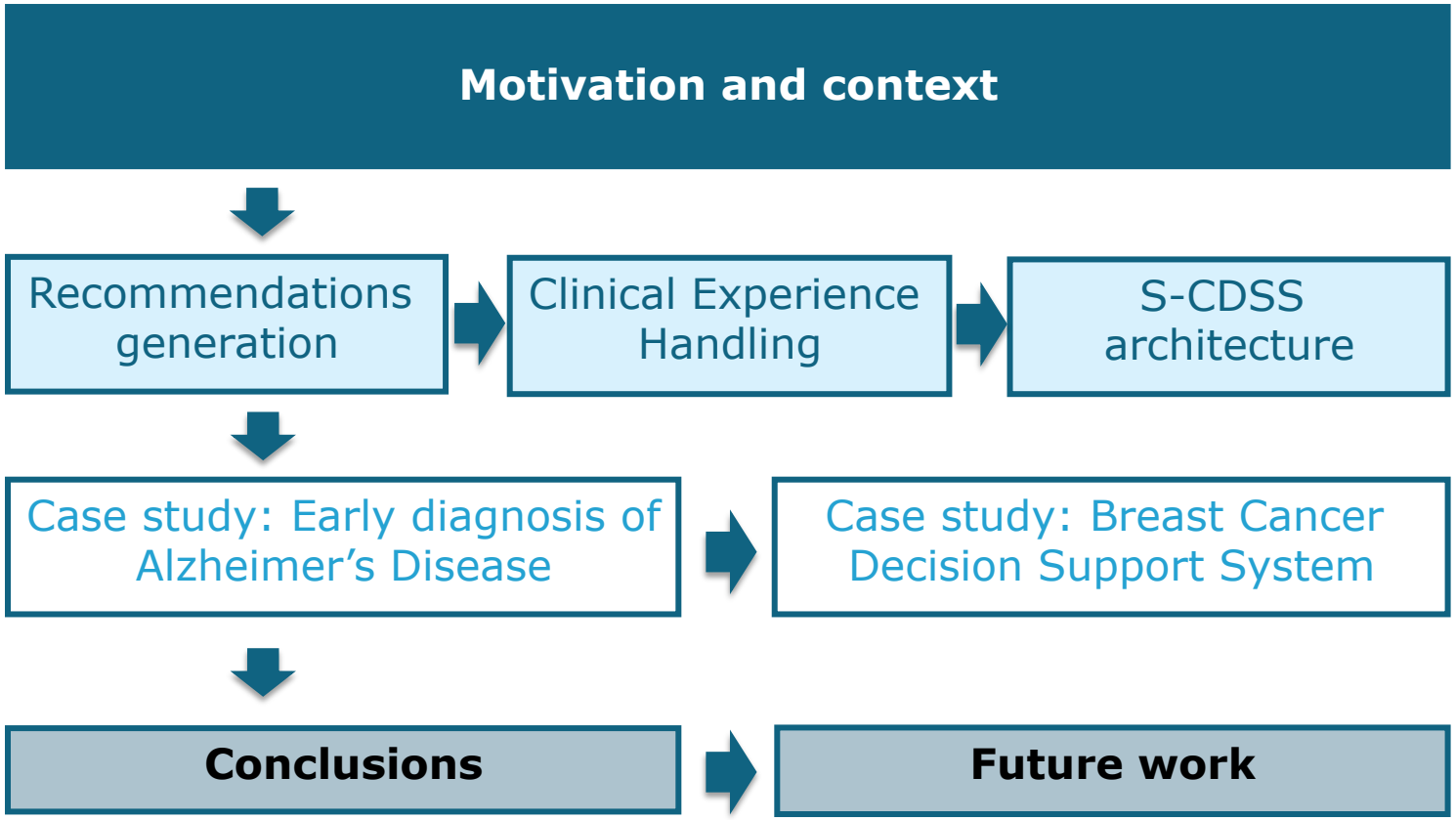
Contents and structure



Semantically Steered Clinical Decision Support Systems

- Medicine and **decision making**
  - **Human** factor and success
  - Medical **errors**
  - High **cost**
  - **Preventable**

- Clinical Decision Support Systems (CDSS)

> "**Active** intelligent systems that use **patient clinical data** to generate case specific **advice**".

Semantically Steered Clinical Decision Support Systems

Challenges of Clinical Decision Support Systems (CDSS)

1. Computerization of CDSS

- Traditional decision support recommendations
  - Medical books and journals
  - Specialized conferences
  - Clinical protocols and guidelines
  - Clinical working groups meetings

- Problem
  - Requires high effort for knowledge retrieval

Semantically Steered Clinical Decision Support Systems

Challenges of Clinical Decision Support Systems (CDSS)

1. Computerization of CDSS
2. **Timely advice**

- Recommendations provided at
  - the **place** and **time**
  - when they are **needed**

- Need of
  - Making recommendations available
  - Fast reasoning process of recommendations generation

Semantically Steered Clinical Decision Support Systems

Challenges of Clinical Decision Support Systems (CDSS)

1. Computerization of CDSS
2. Timely advice
3. **Maintainability and extensibility**

- When new knowledge is fed to the system
  - Easy to maintain
  - Easy to extend
- Medical knowledge is continuously changing
  - Frequently found new discoveries
  - New techniques proved validity
- Affordable solution needed
- New knowledge provided by
  - Medical and scientific community
  - **Experience** of medical experts

Semantically Steered Clinical Decision Support Systems

Challenges of Clinical Decision Support Systems (CDSS)

1. Computerization of CDSS
2. Timely advice
3. Maintainability and extensibility
4. **Clinical workflow integration**

- Decision support integrated into the clinical workflow
  - Minimization of time consumption during the introduction of patient data and results.
  - Assist clinicians during all different tasks of their daily duties
    - » Not only during specific activities.

Semantically Steered Clinical Decision Support Systems

Challenges of Clinical Decision Support Systems (CDSS)

1. Computerization of CDSS
2. Timely advice
3. Maintainability and extensibility
4. Clinical workflow integration
5. **Architecture for CDSS**

- Sharing and reusing of clinical decision support
- Needed:
  - Expressivity
  - Modularity
  - Reasoning Capabilities

Semantically Steered Clinical Decision Support Systems

This work was **driven** by the hypothesis that **semantics** and **experience**-based technologies can **enhance** CDSS making them **successful** in real clinical environments.

Semantically Steered Clinical Decision Support Systems

How can clinical experience be modeled, acquired and reused in the context of clinical decision making?

Is it possible to develop a semantic steered clinical decision support system that allows the handling of the collective experience of a medical organization?

Semantically Steered Clinical Decision Support Systems

- Objectives
  - To propose a methodology for the recommendations generation process.
  - To propose a methodology for the automatic evolution of a ruleset, based on the acquired decisional events.
  - To present a generic model for clinical tasks in the context of clinical decision making.
  - To present a generic architecture for S-CDSS that fits in the clinical task model.
  - To present a framework for the management of the clinical experience of a medical organization.

Contents and structure

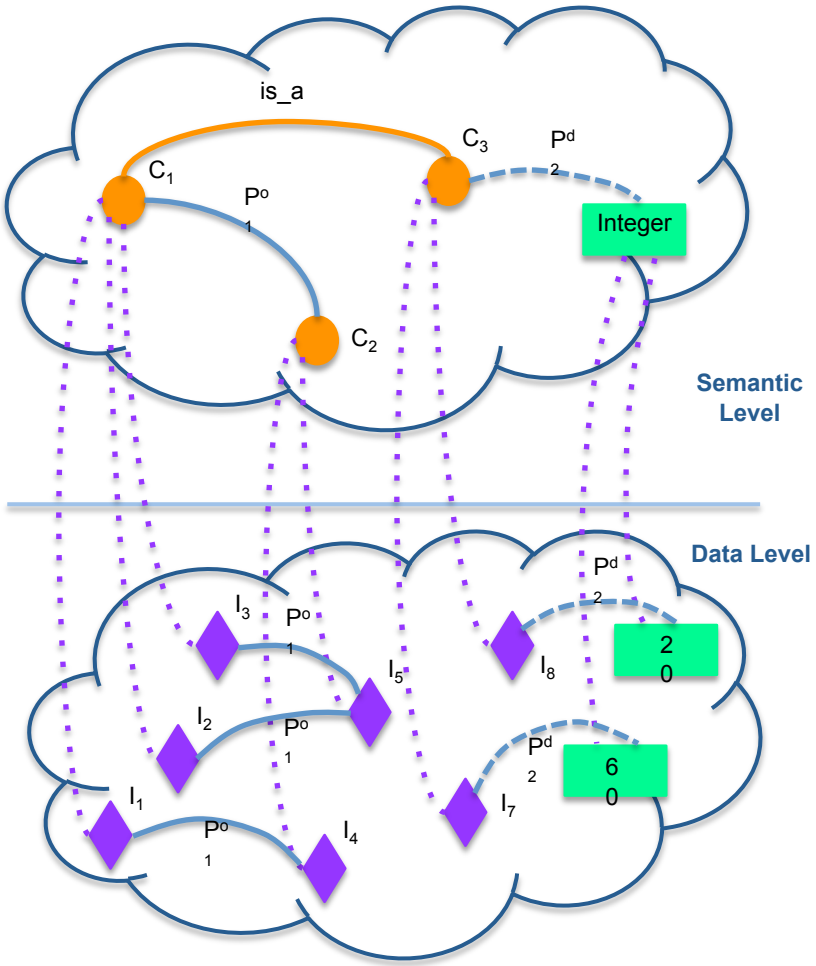
Motivation and context

Recommendations generation

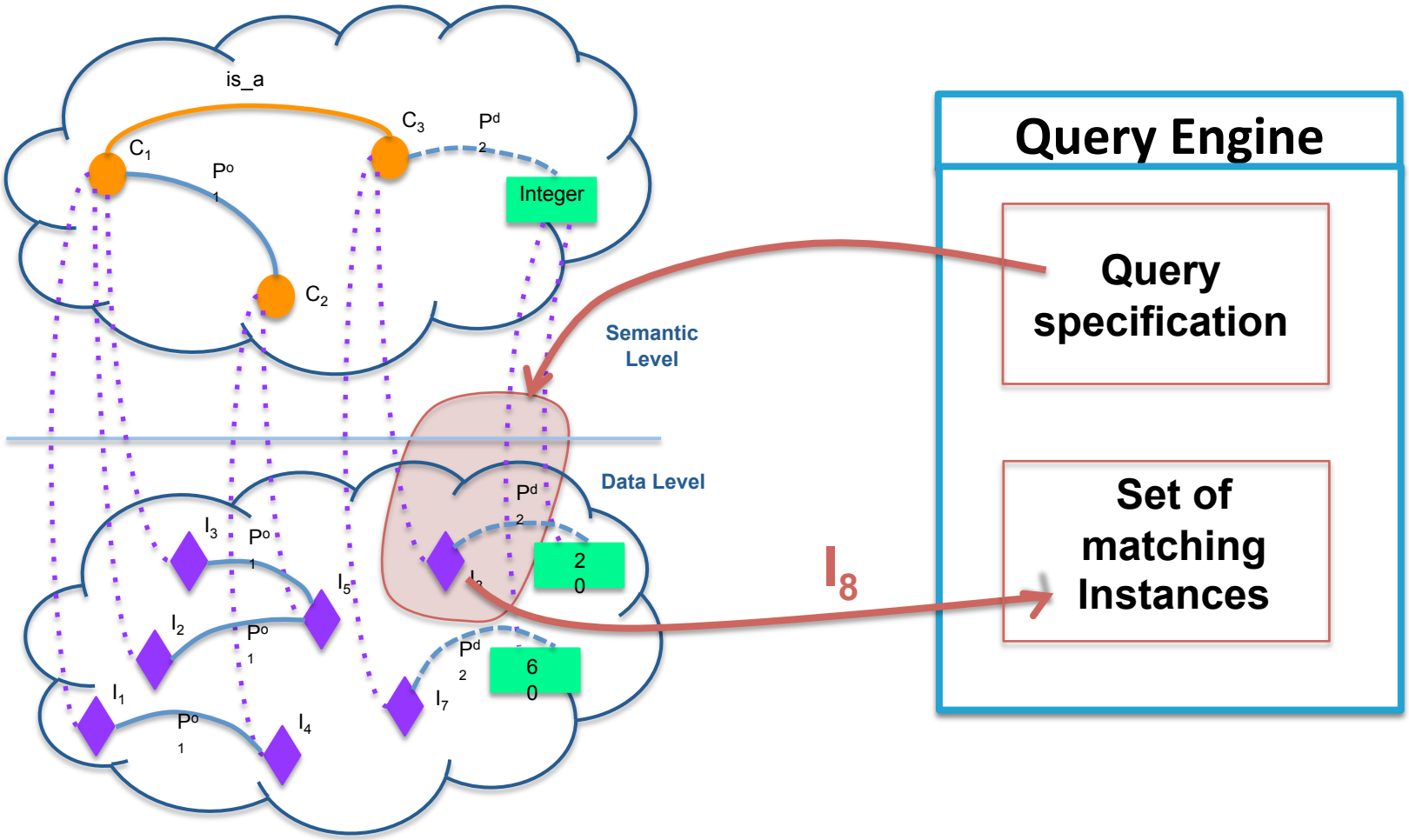
Recommendations generation

- **Recommendations are…**
  - a set of alternative options
  - Ranked and presented to system users with their proofs
- Knowledge-based approach needed
- Reasoning system

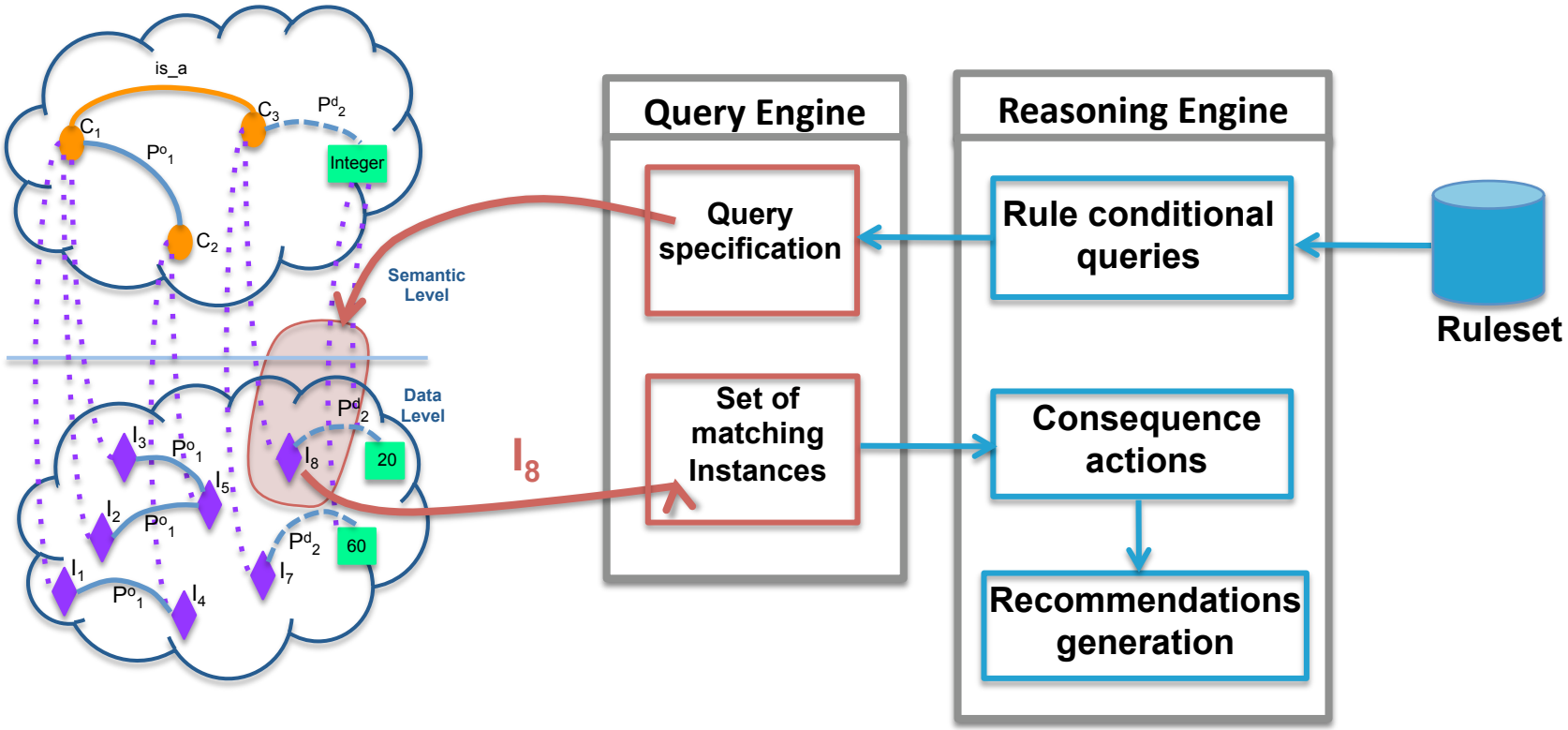
Recommendations generation



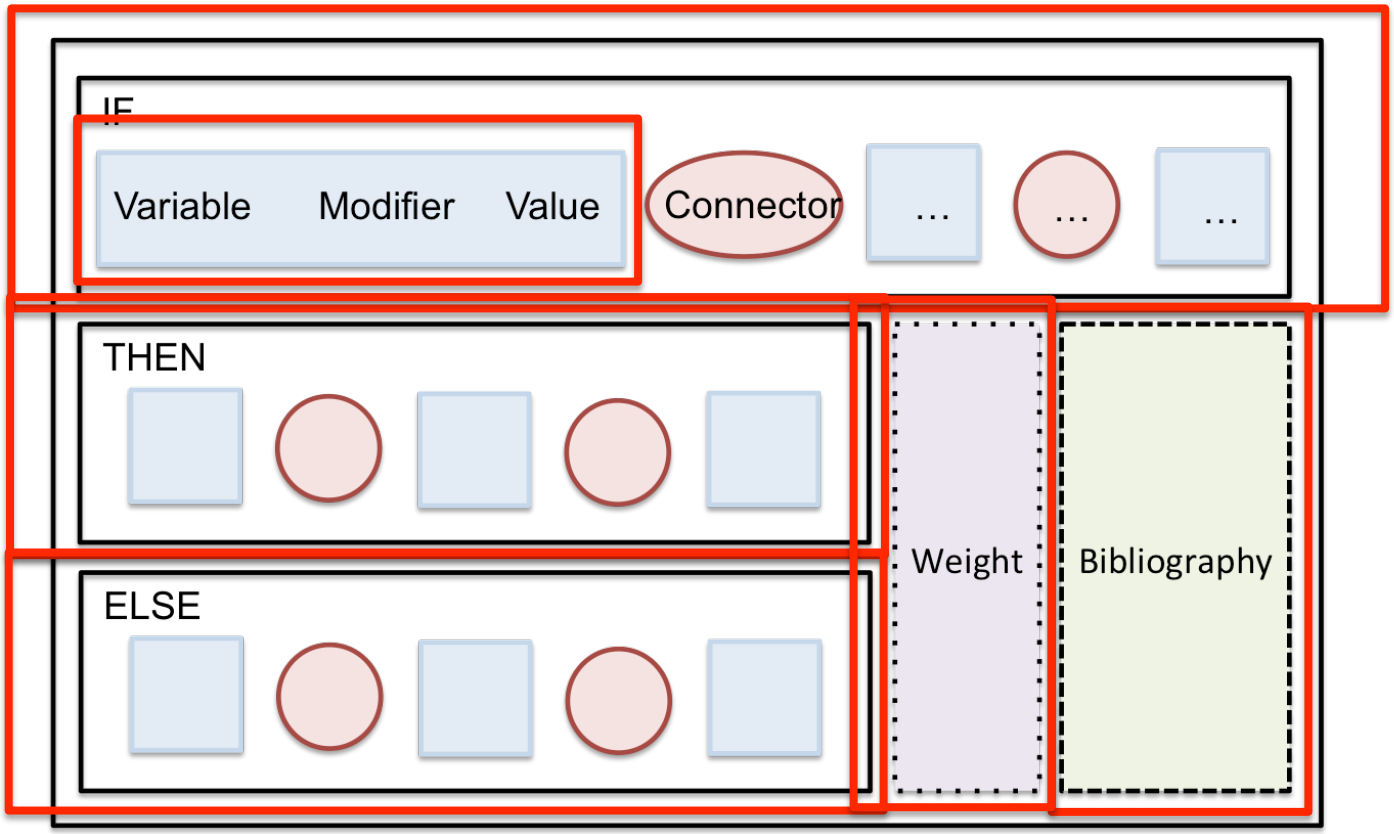
Recommendations generation



Recommendations generation



Recommendations generation



If ((CLASS GeneralSurgery with the PROPERTY GeneralSurgery_InterventionType EQUALS TO Conservative))
then (CLASS Radiotherapy with the PROPERTY Radiotherapy_ProtocolName EQUALS TO MAMA-50)

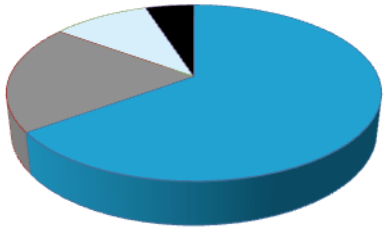
Recommendations generation

REQUEST

- Patient
- Decisional category

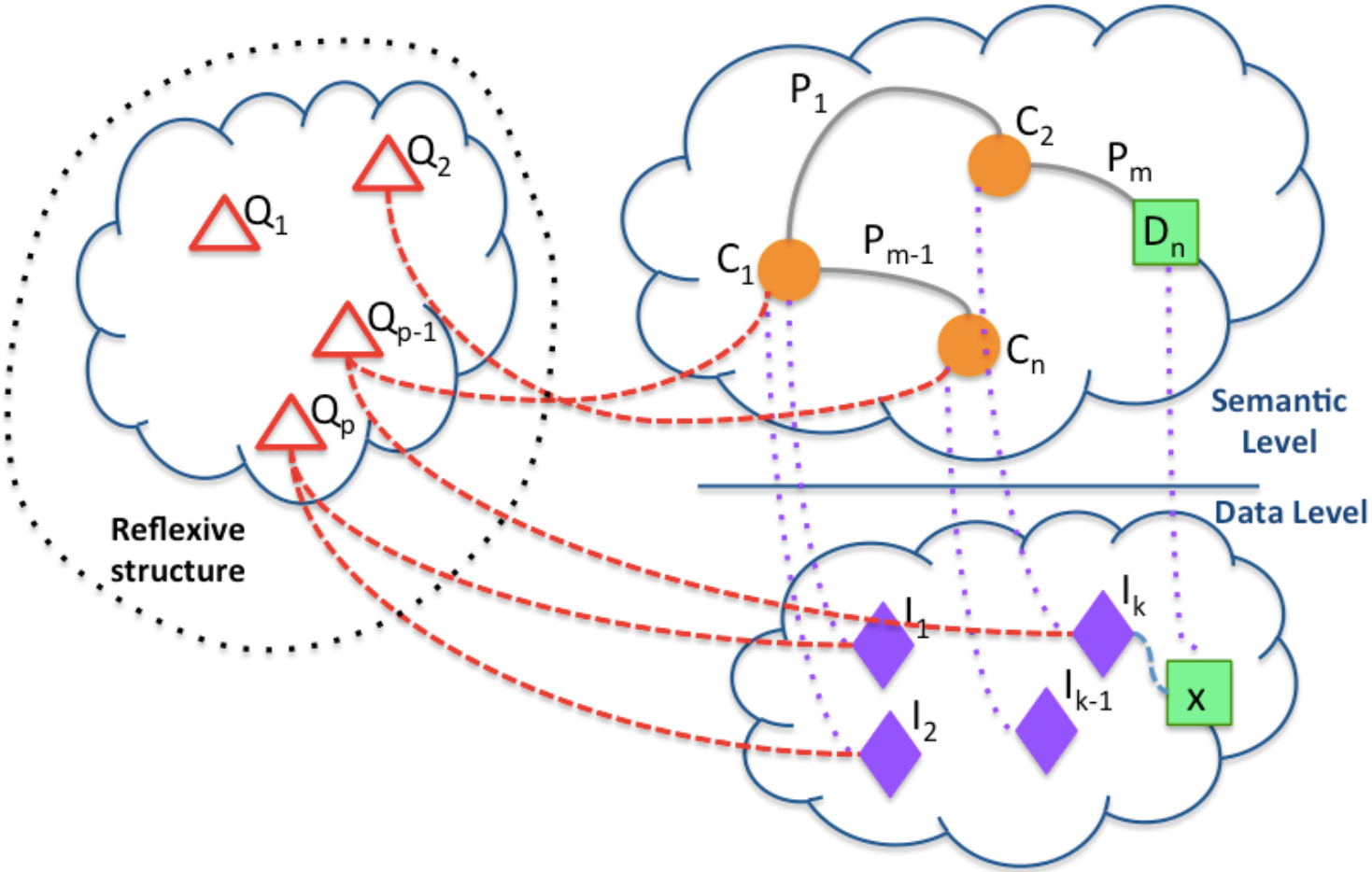
Reasoning system

RECOMMENDATIONS

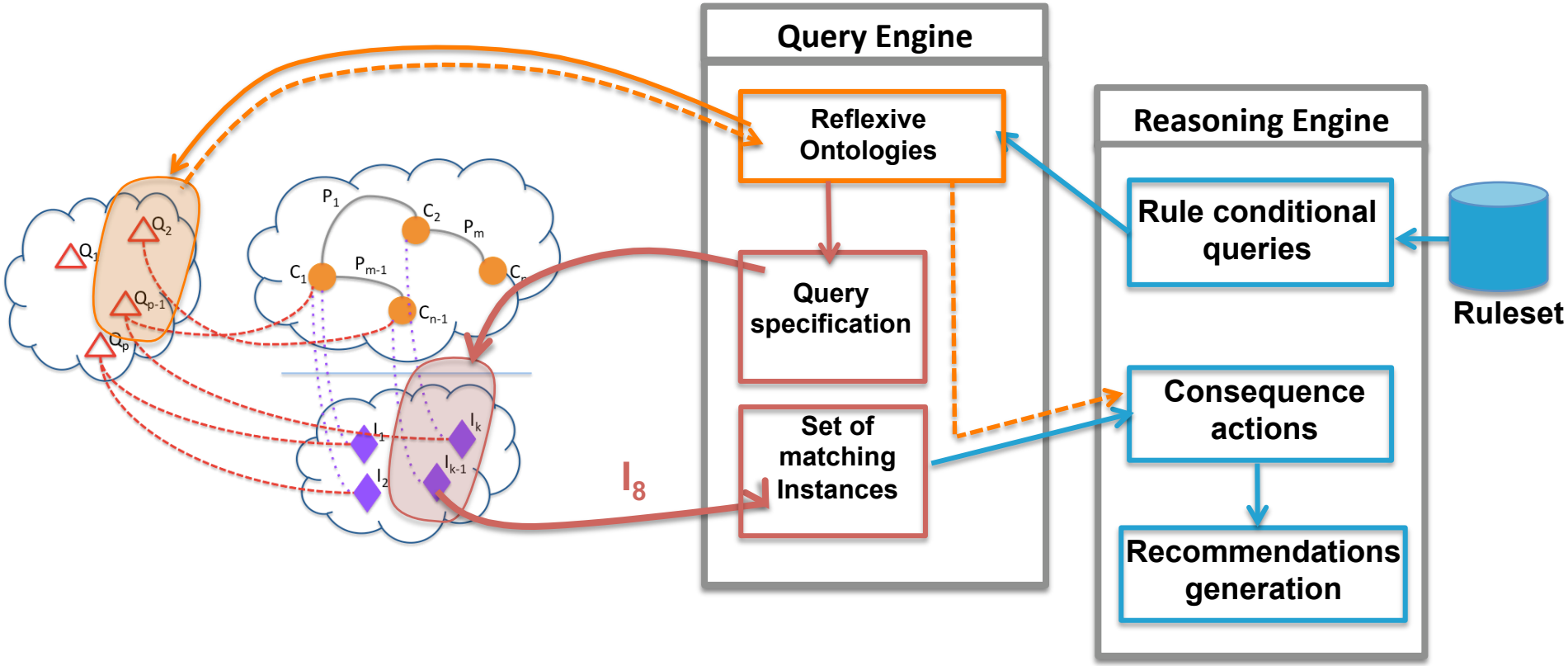


Opt-1	65% -	Rule 1
Opt-2	20% -	Rule 2,3
Opt-3	10% -	Rule 5
Opt-4	5% -	Rule 12

Fast querying: Reflexive Ontologies



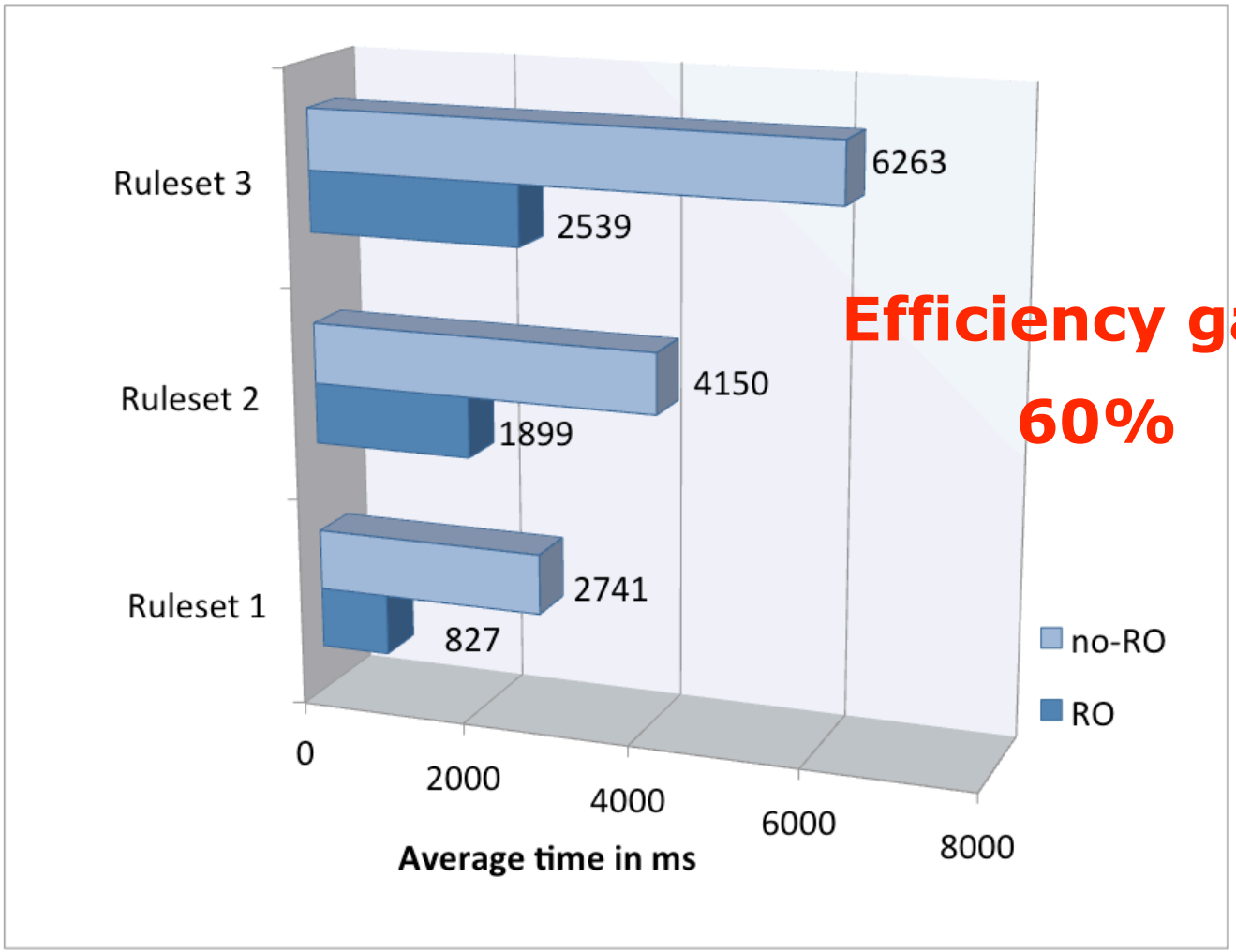
Fast querying: Reflexive Ontologies



Speed up in the medical domain: same questions are repeated frequently

Fast querying: Reflexive Ontologies

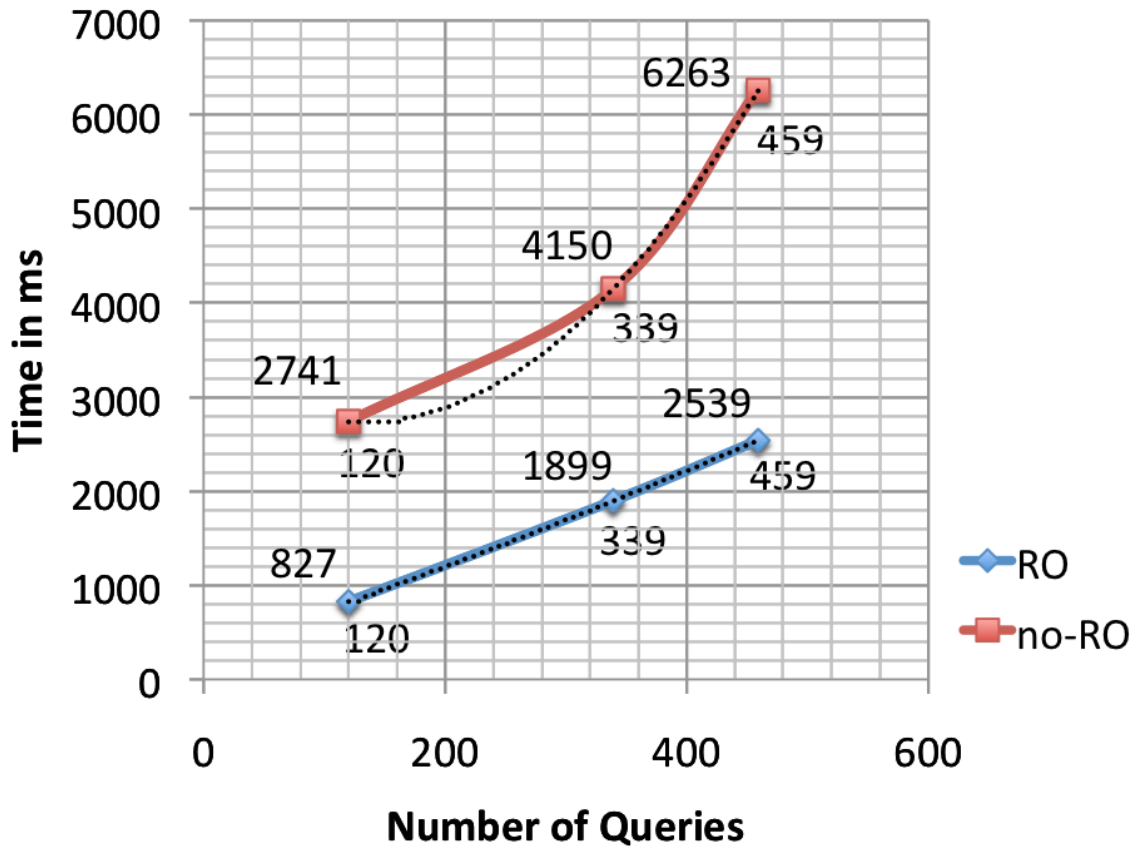
- Performance of Reflexive Ontologies



Efficiency gain 60%

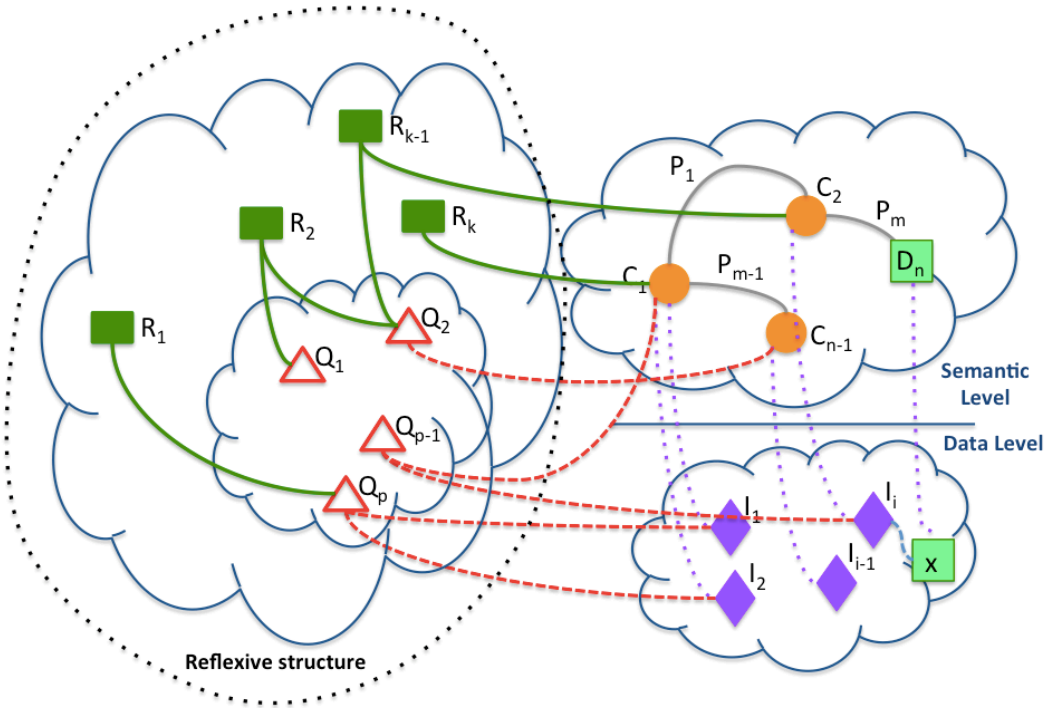
Fast querying: Reflexive Ontologies

- Performance of Reflexive Ontologies



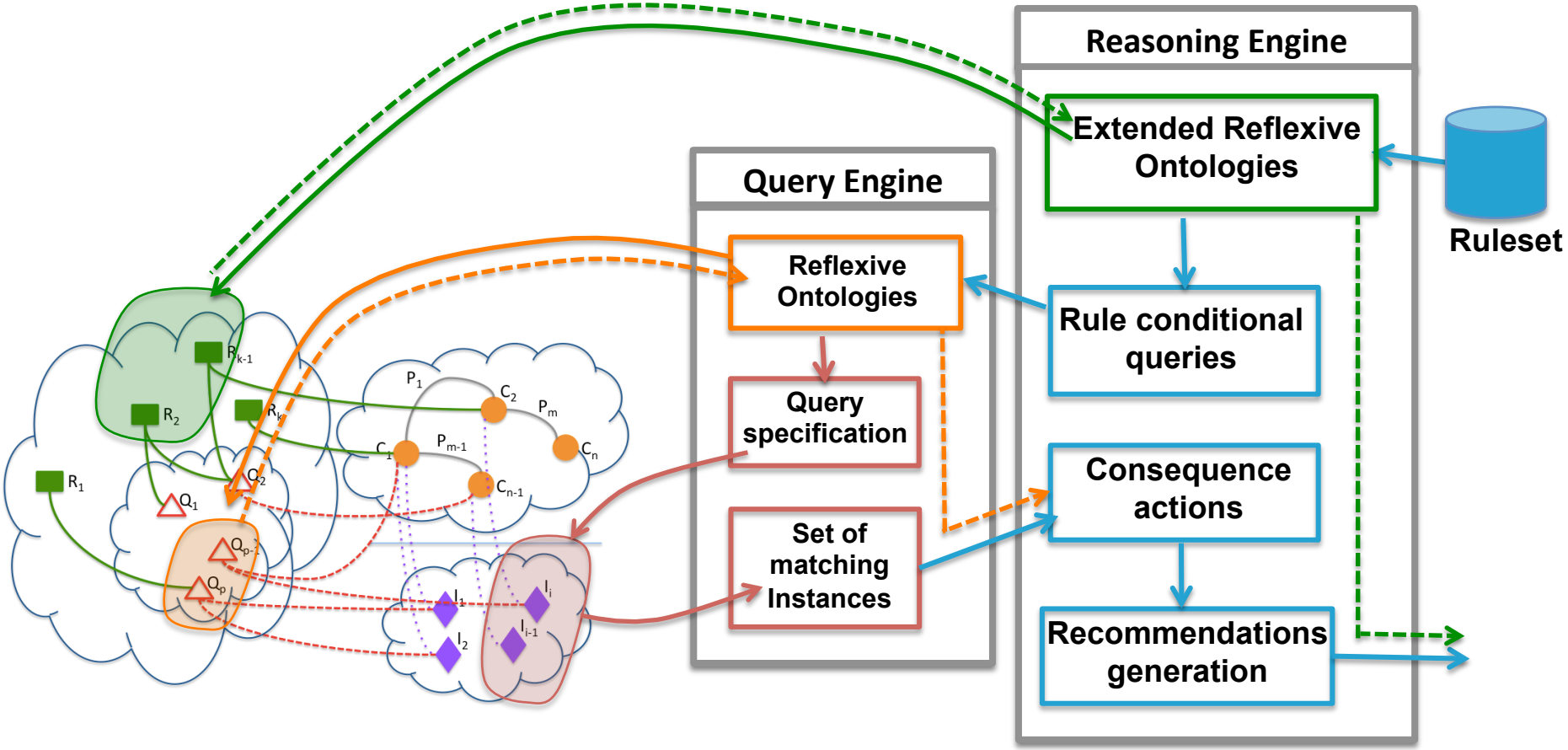
Extended Reflexive Ontologies

- Reflexive ontology containing also
  - Rules
  - The matching recommendations for each set of individuals



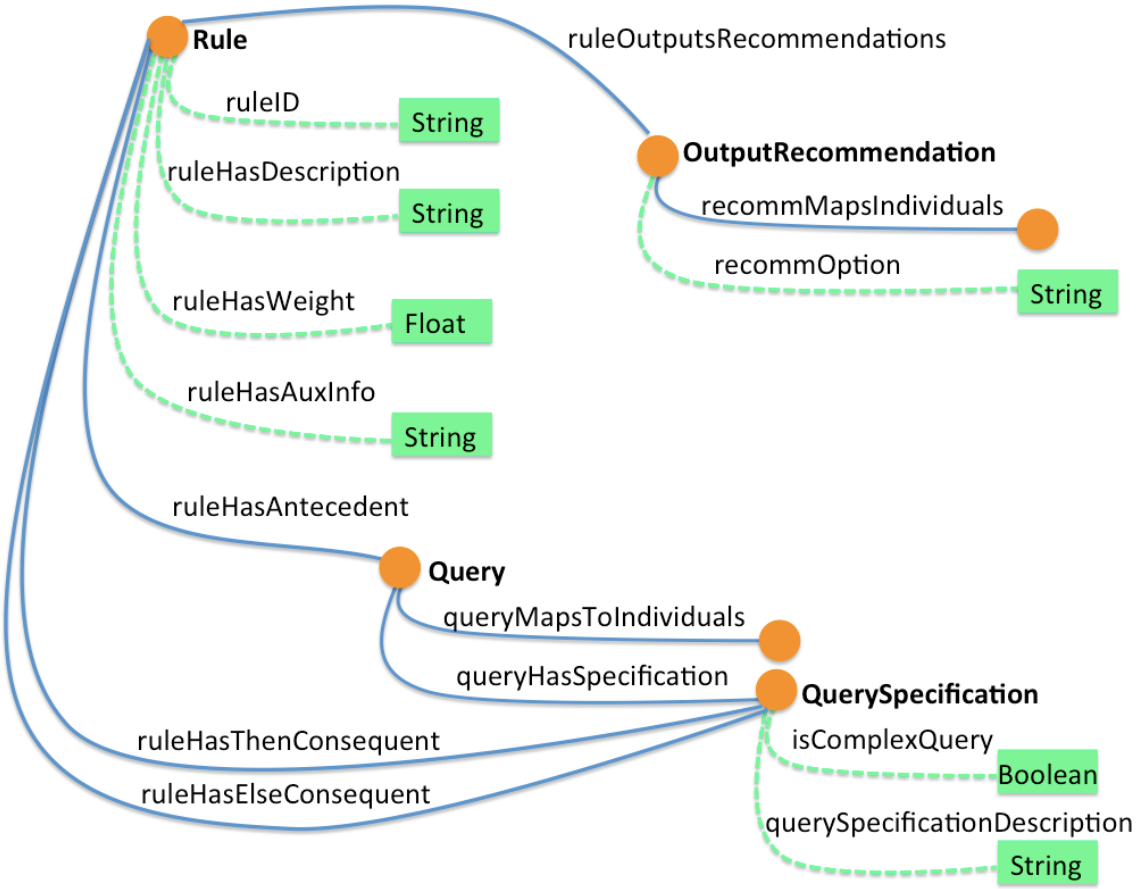
- Speed up of the reasoning process
  - Previously made rules do not need to be calculated again

Extended Reflexive Ontologies



Extended Reflexive Ontologies

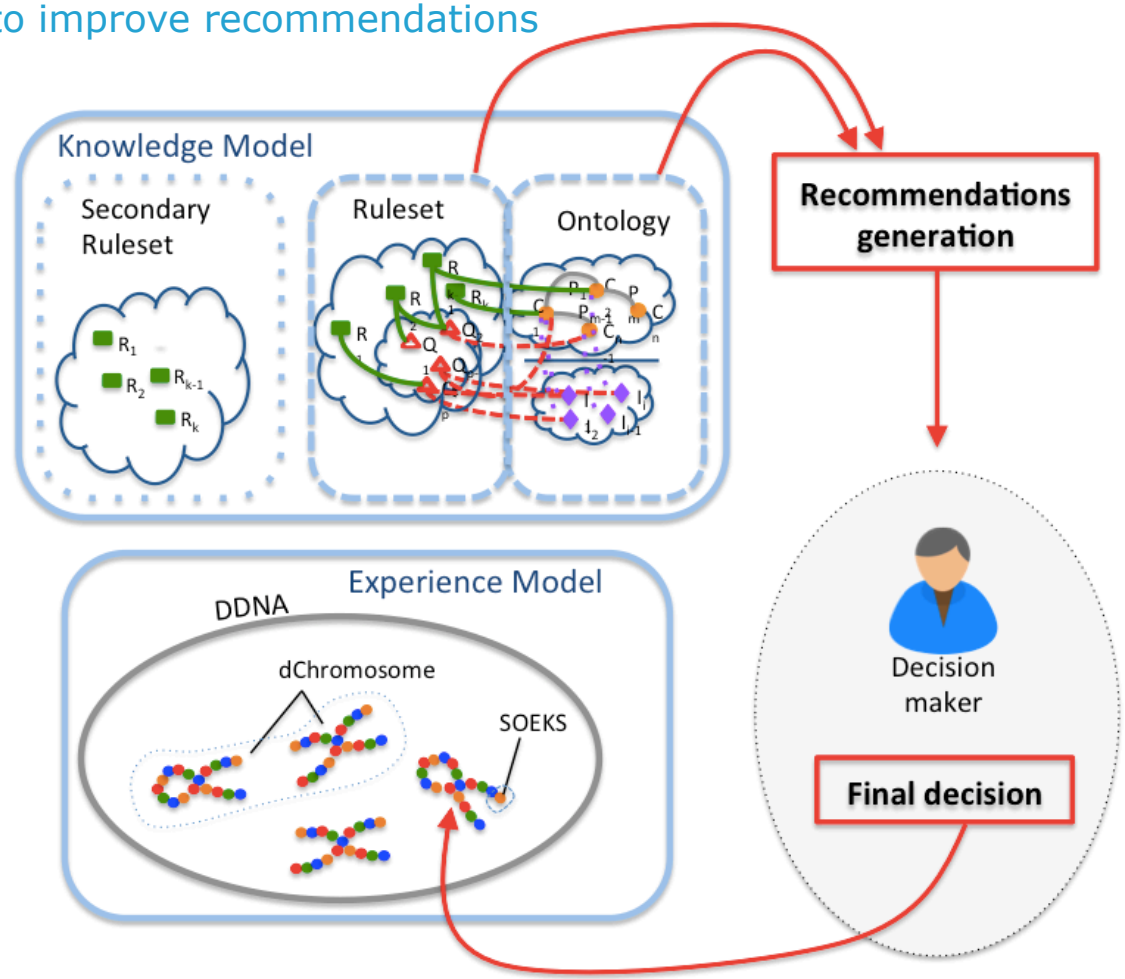
- Implementation of Extended Reflexive Ontologies



Contents and structure

Clinical Experience handling

- Final decision
  - Reusable to improve recommendations



Clinical Experience handling

Ruleset evolution

1. Rule weight evolution

Combine 2 criteria:

- **QUANTITY**: number of times a rule matches the conditions
- **QUALITY**: number of times when recommendation becomes a final decision

$$W_k(\alpha) = \frac{\sum_m \sum_t \left(\boxed{x_{mtk}} - \boxed{\alpha_{mt}}\boxed{e_{mtk}}\right)}{\sum_m \sum_t \sum_k \left(x_{mtk} - \alpha_{mt} e_{mtk}\right)}$$

Clinical Experience handling

Ruleset evolution

2. Fine tuning of rules (rule conditional query clauses)

- **Activation count:** Total amount of times that a query clause is active in a rule that matches conditions

$$\mu_{kl} = \sharp \left\{ \mathbb{S}_t \mid M\left(A_k, \mathbb{S}_t\right) \& M\left(q_{kl}^s, \mathbb{S}_t\right), q_{kl}^s \in A_k \right\}$$

- **Agreement count:** Total of times that being a query clause active in a rule that matches conditions, the recommendation = final decision

$$\rho_{kl} = \sharp \left\{ \mathbb{S}_t \mid M\left(A_k, \mathbb{S}_t\right) \& M\left(q_{kl}^s, \mathbb{S}_t\right) \& \left(S_k = f_t\right), q_l^s \in A_k \right\}$$

- **Ratio**: Error prone query clauses

$$\frac{\rho_{kl}}{\mu_{kl}} > \text{Threshold}$$

Clinical Experience handling

Ruleset evolution

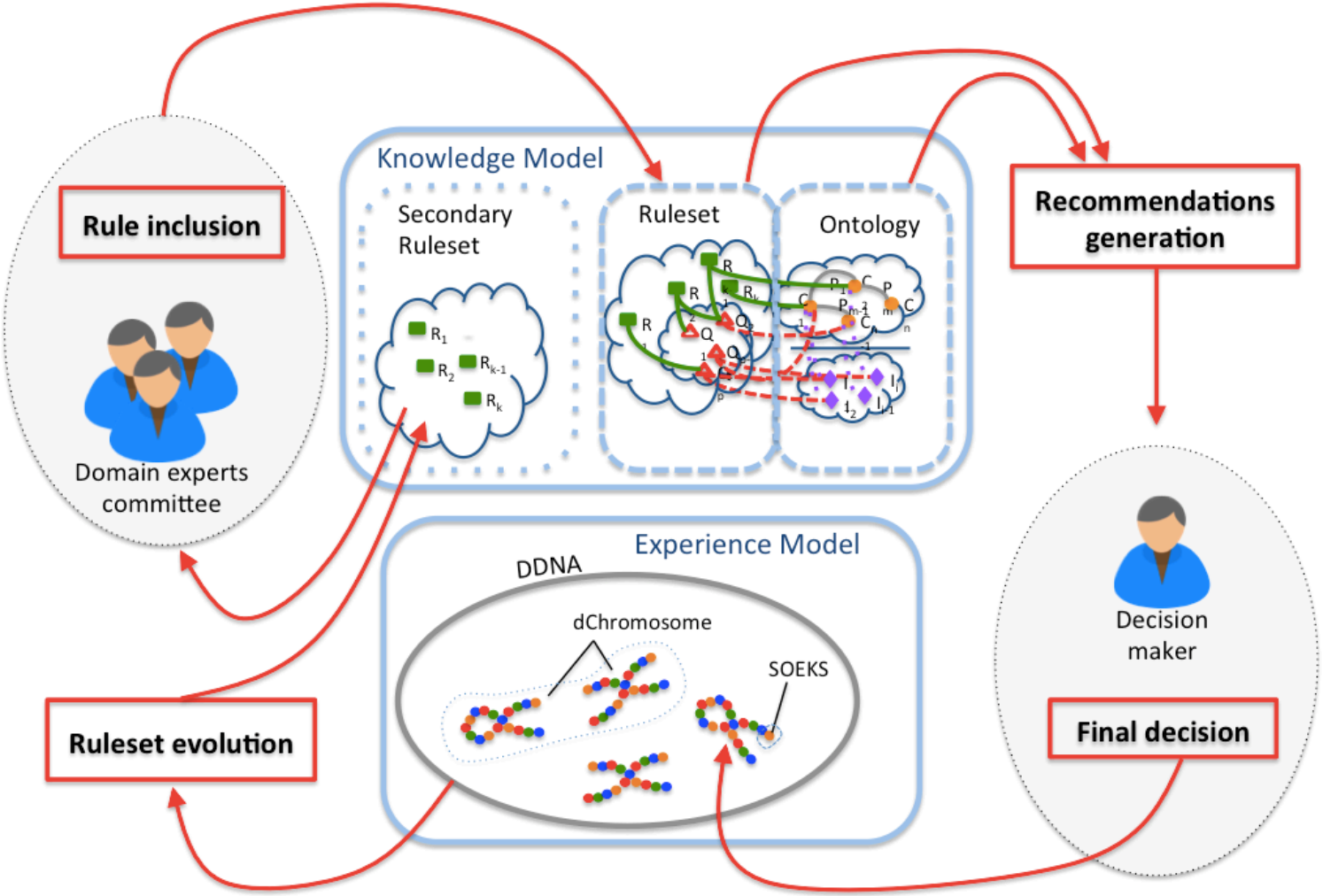
3. New rule generation

- **Final decision:** validate the set of variables that are relevant
  - **Include**
  - **Remove**

- Generate a new rule
  - **Antecedent** (IF): new set of relevant values
  - **Consequent** (THEN): final decision

Clinical Experience handling

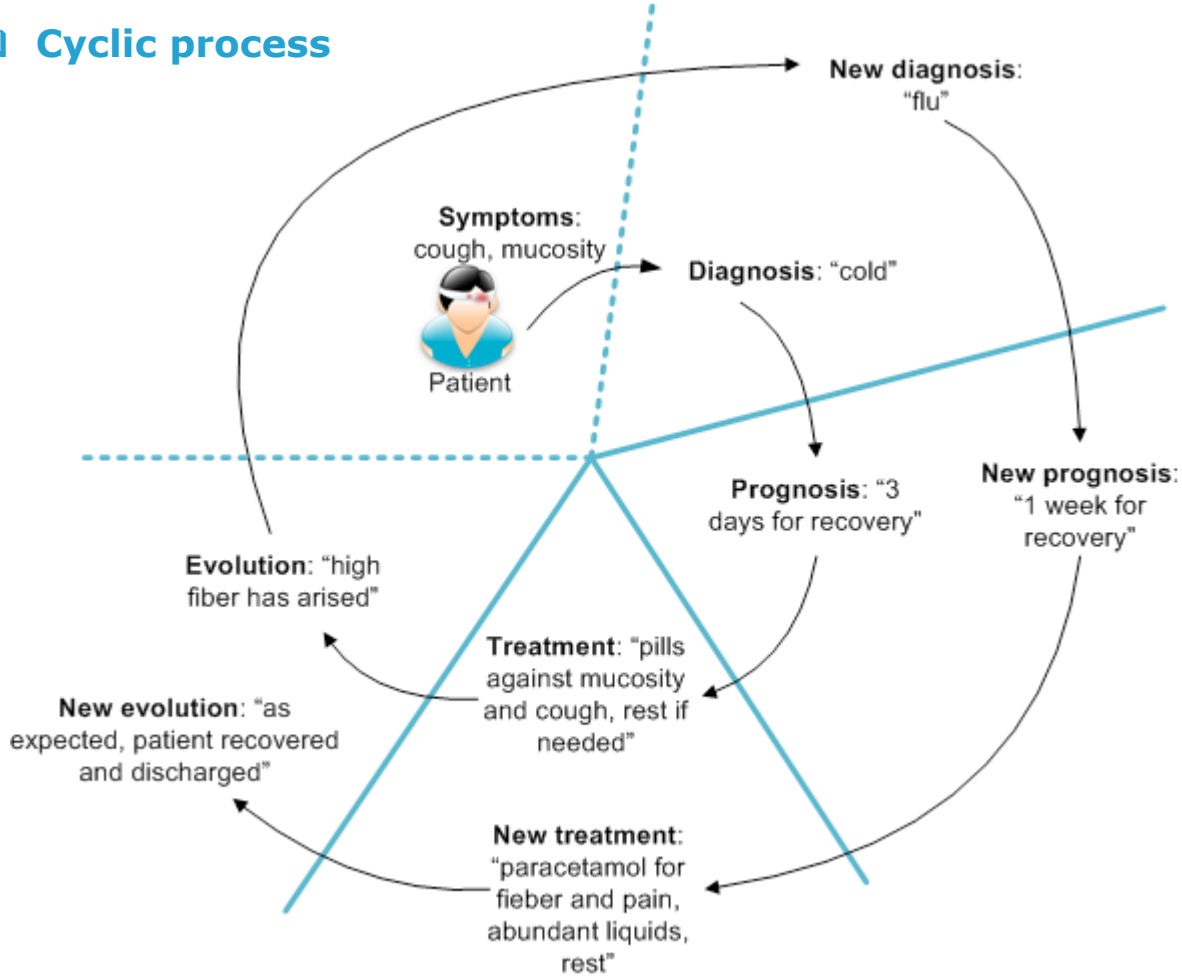
Experience consolidation



Contents and structure

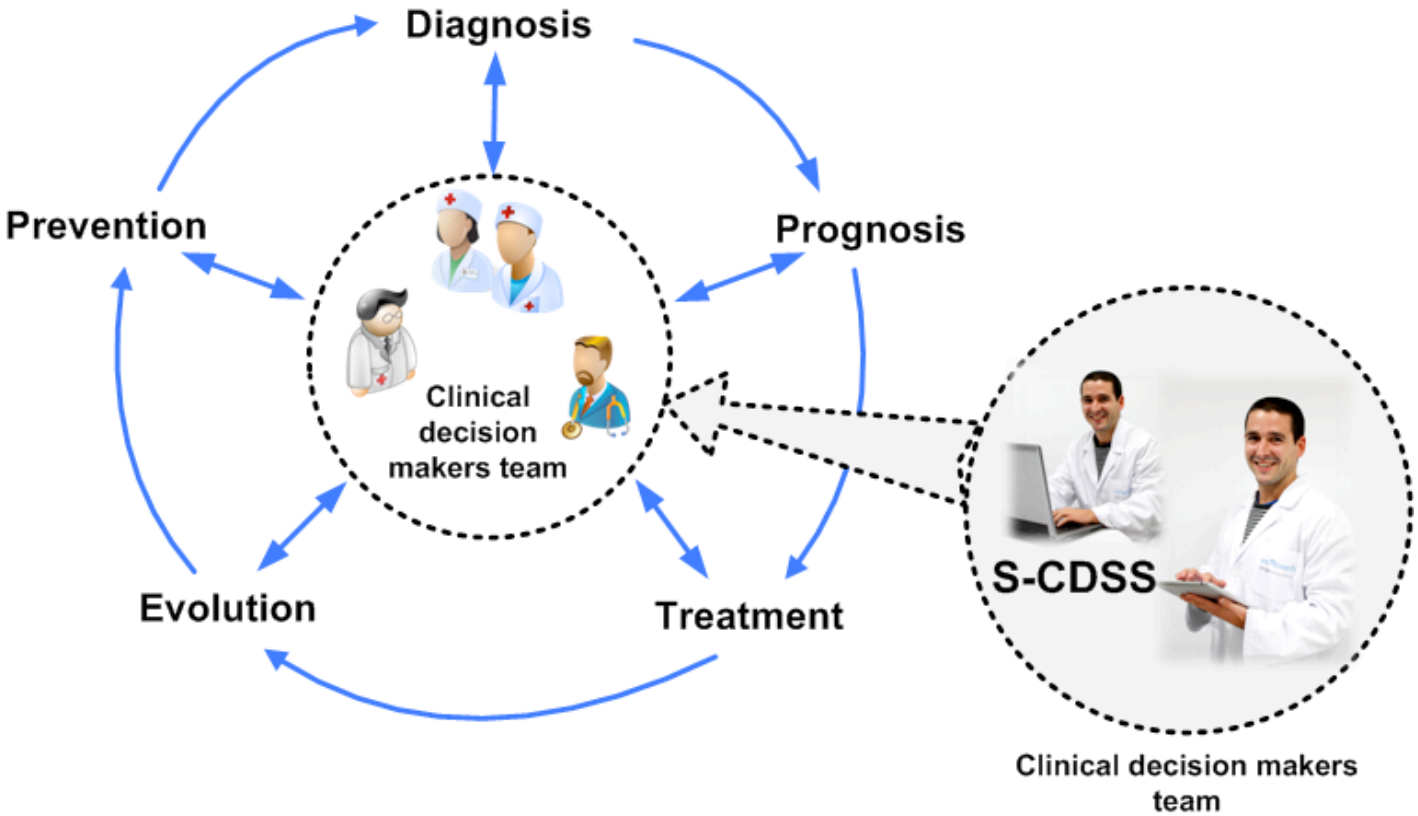
S-CDSS architecture

- Clinical Task Model
  - **Cyclic process**

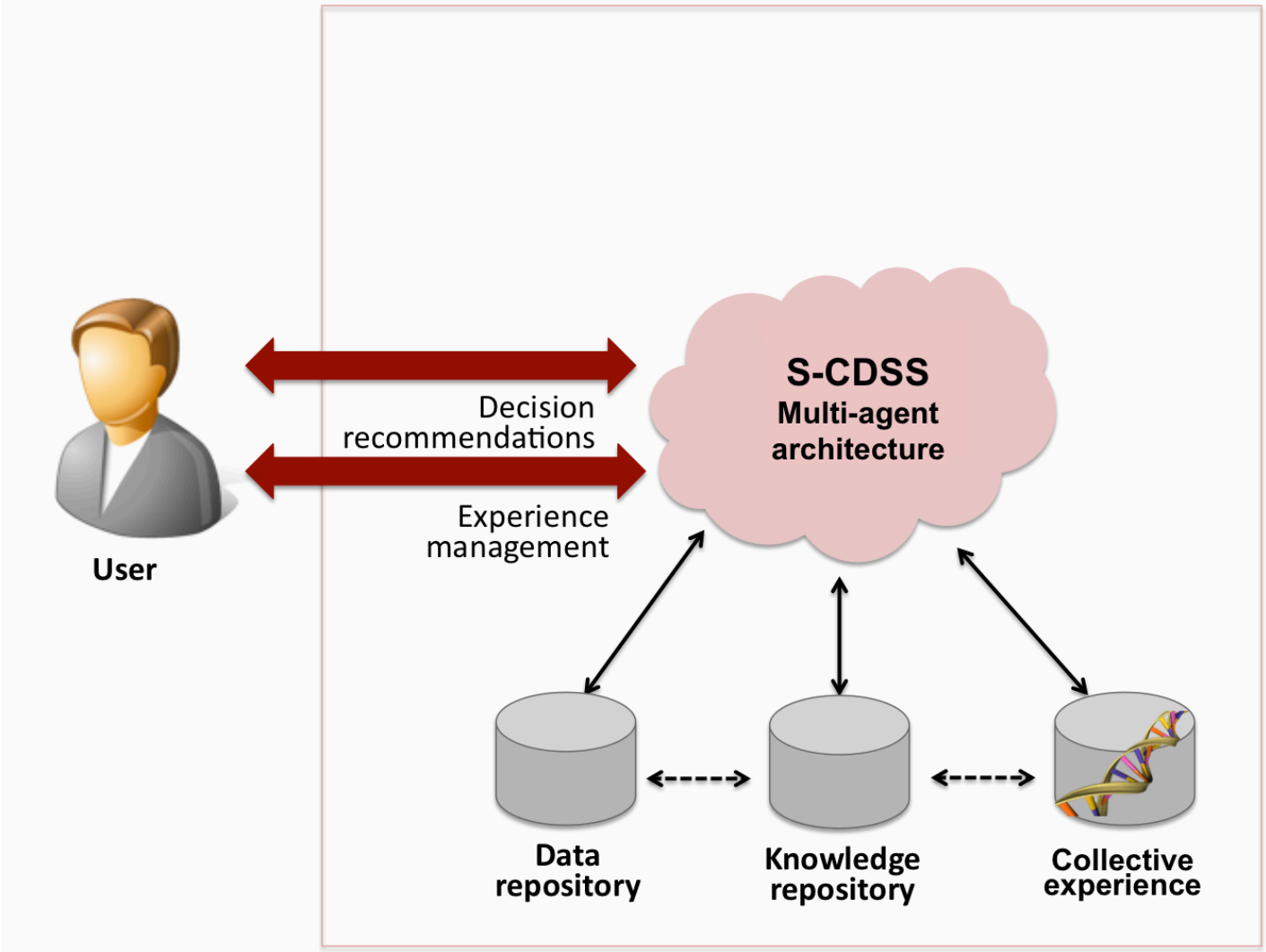


S-CDSS architecture

- Clinical Task Model
  - Cyclic process
  - **Federated management**

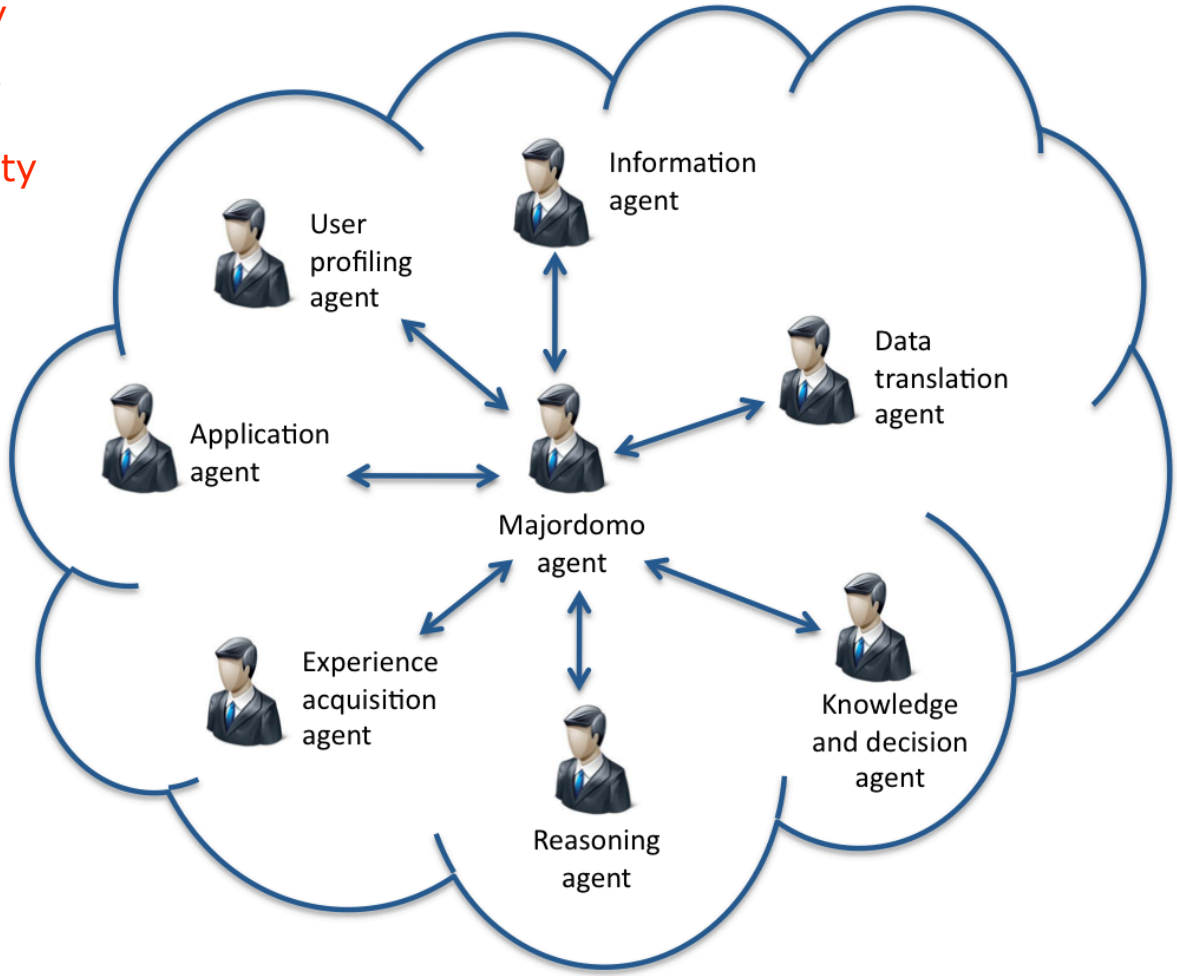


S-CDSS architecture



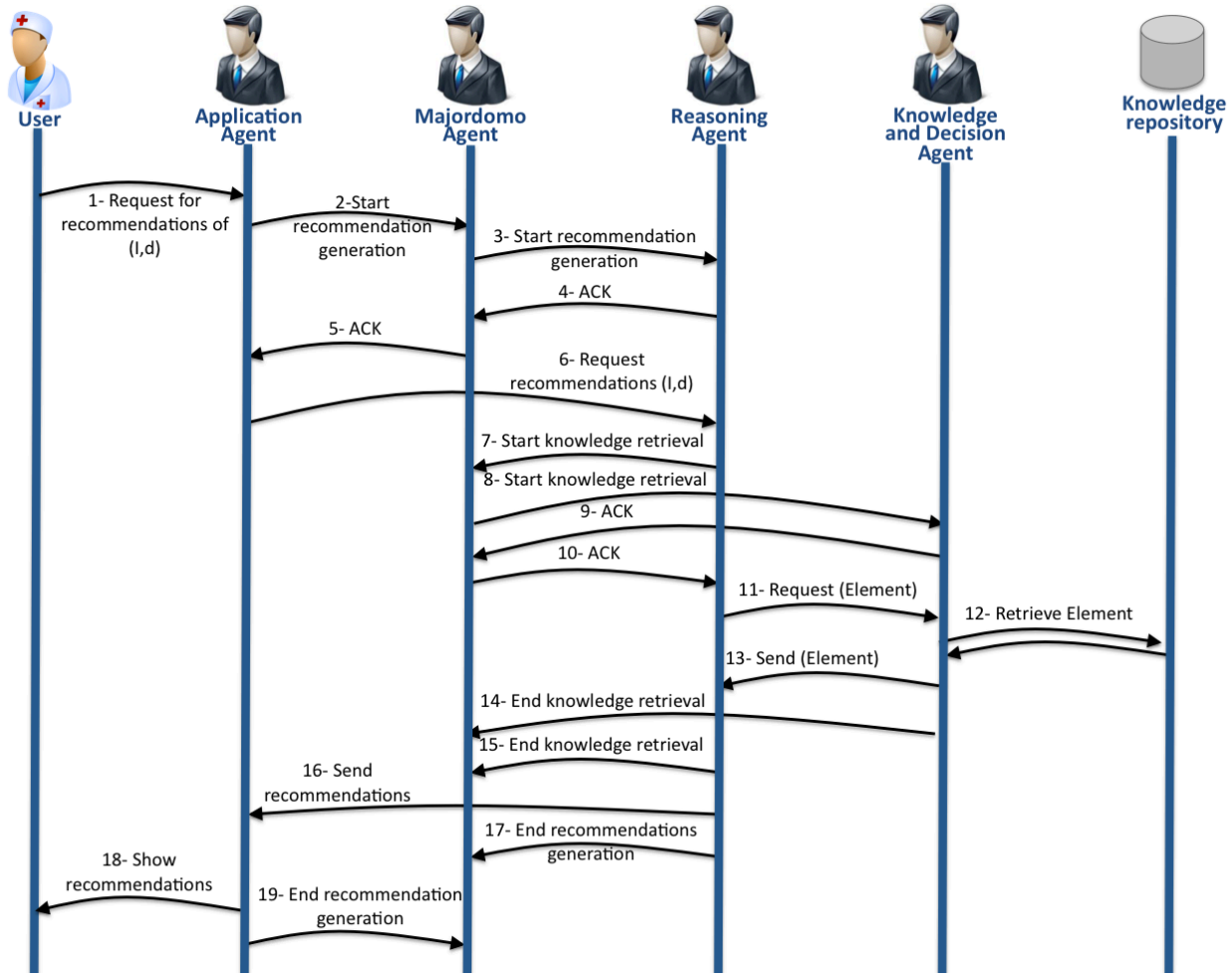
S-CDSS architecture

- Multi-Agent System
  - Modularity
  - Scalability
  - Extensibility



S-CDSS architecture

- Sequence diagram



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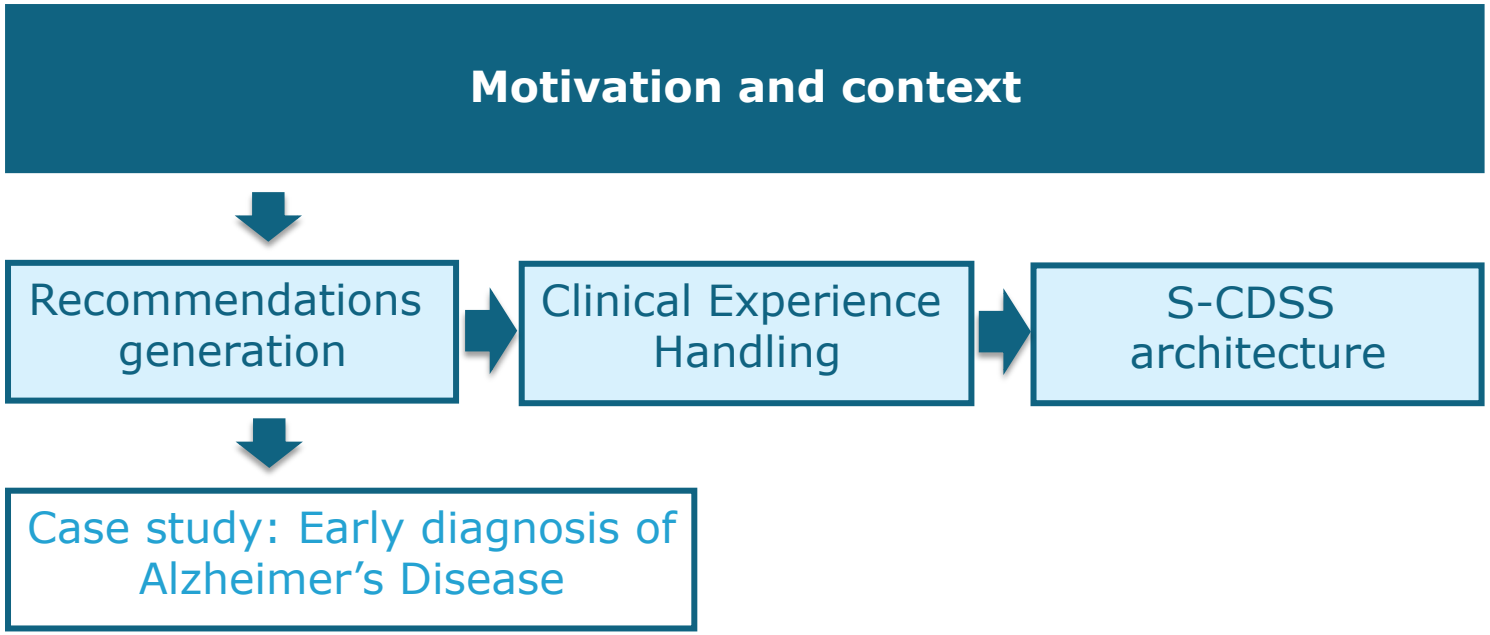


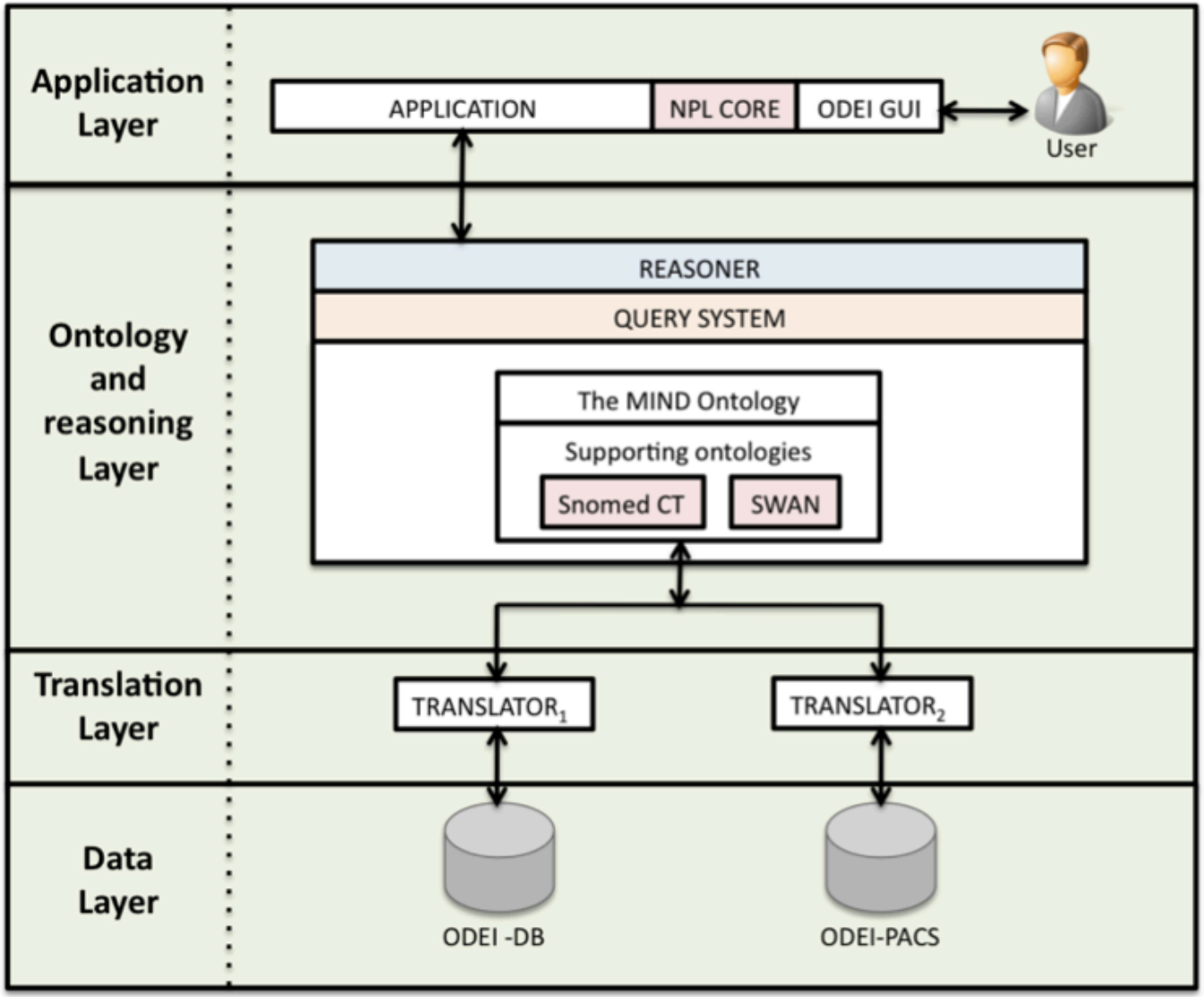
Early diagnosis of Alzheimer's Disease

- Research project MIND

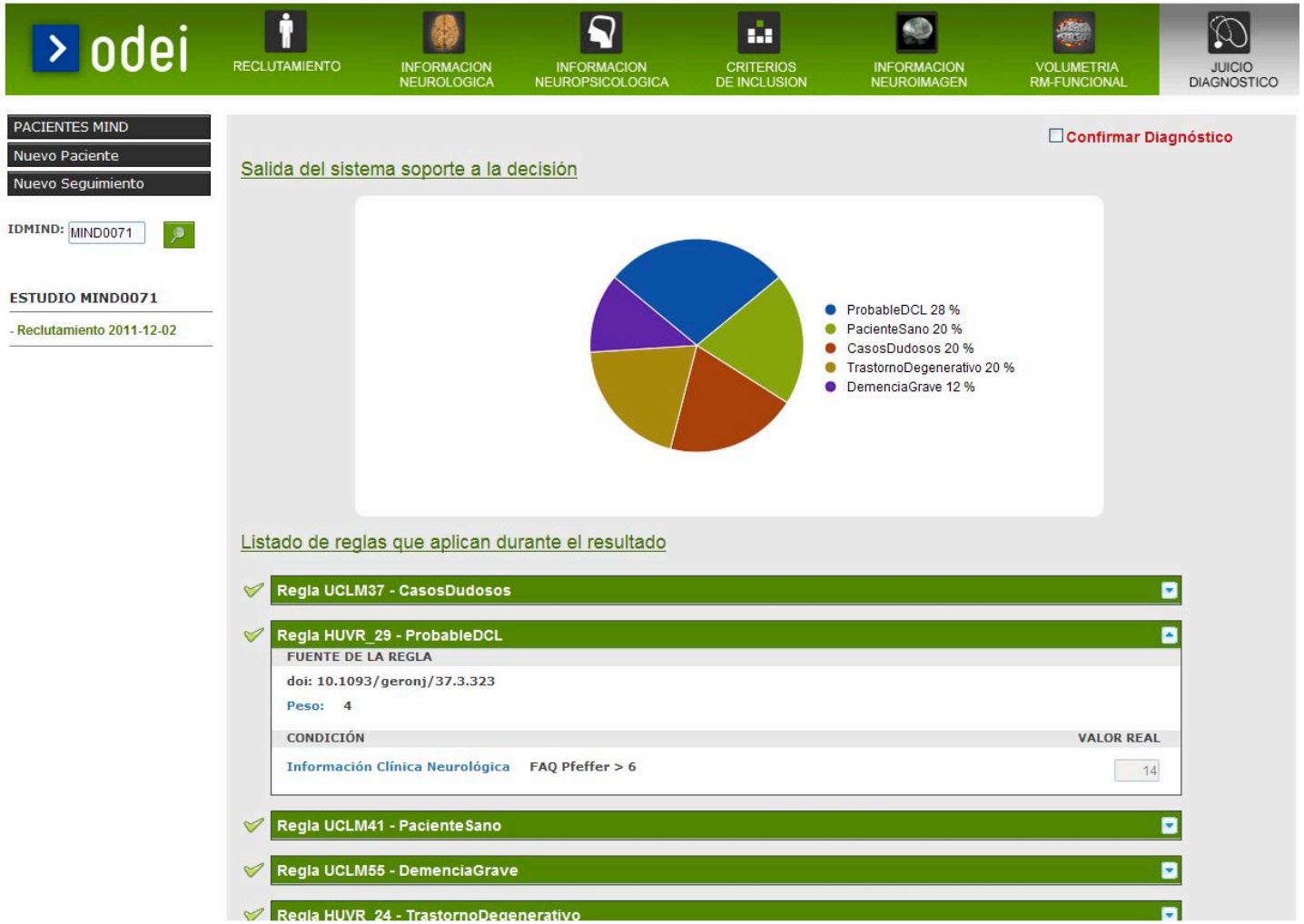
- Alzheimer's Disease
  - Neurodegenerative
  - Cause and mechanisms still unknown
  - Challenges:
    - Discovery of new knowledge
    - Knowledge handling

- CDSS for early diagnosis

Early diagnosis of Alzheimer's Disease



Early diagnosis of Alzheimer's Disease



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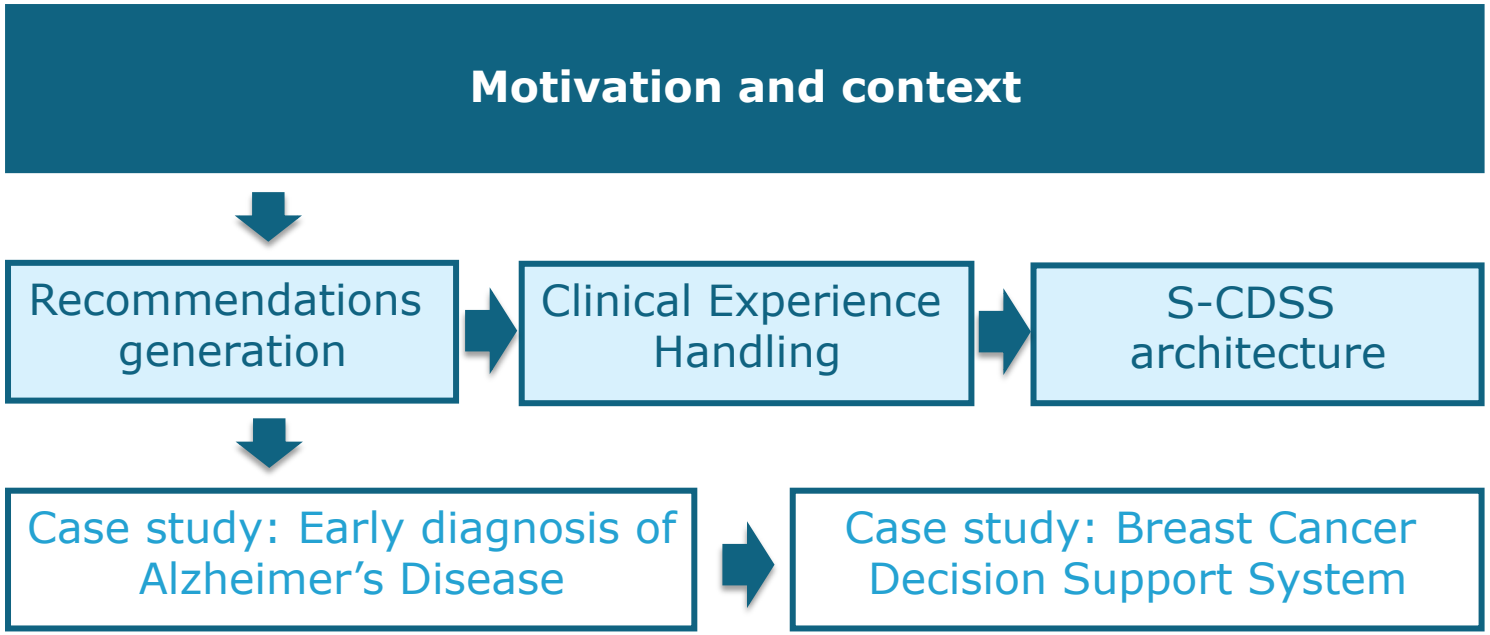


Breast Cancer Decision Support System

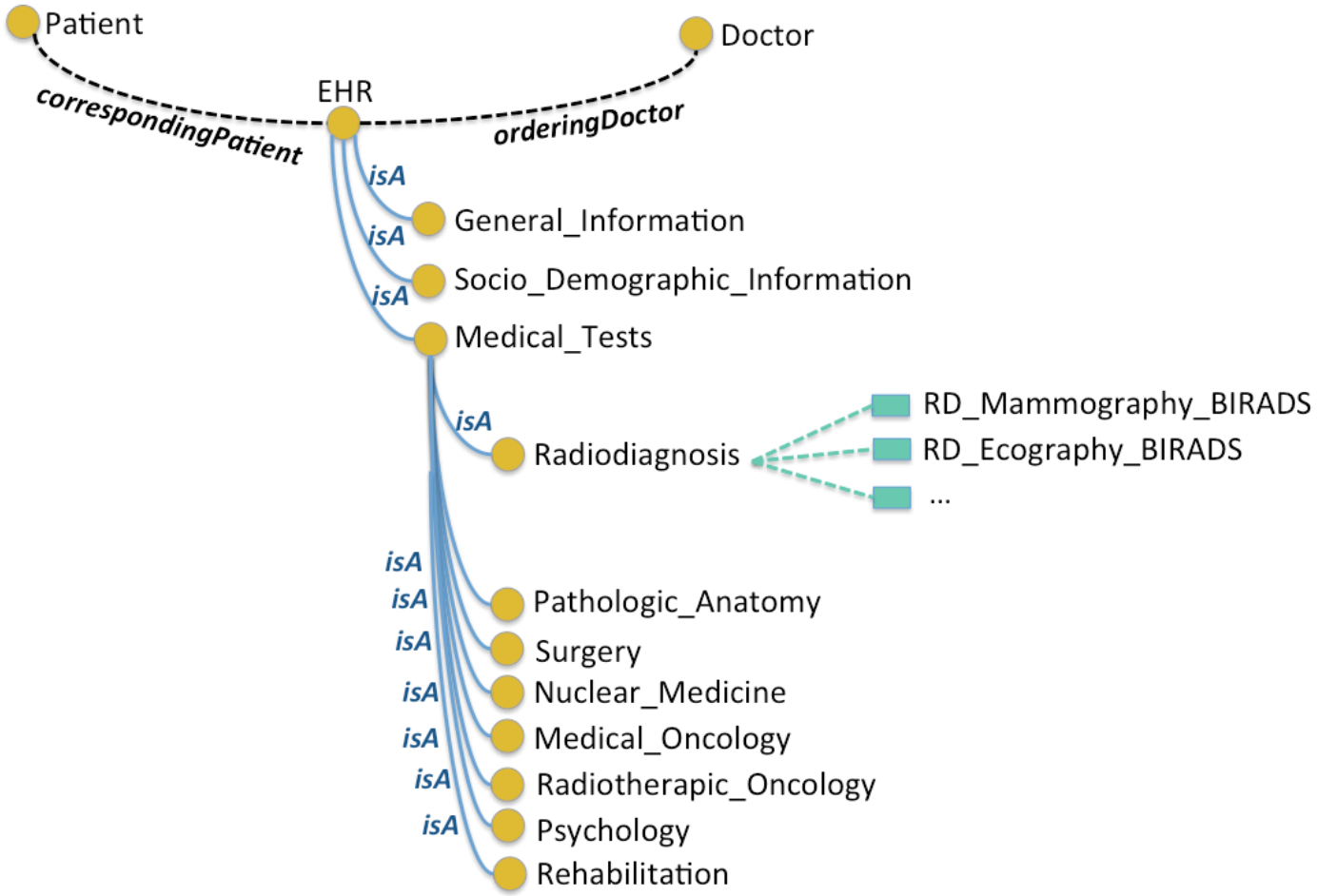
- Project LIFE

- Breast cancer
  - ❑ Multidisciplinary
  - ❑ Challenges
    - Personalized therapies
    - Knowledge maintenance

- S-CDSS for breast cancer functional unit
    - Radiology (diagnosis)
    - Nuclear medicine
    - Pathologic anatomy
    - Surgery
    - Medical Oncology
    - Radiation Oncology
    - Psychology
    - Rehabilitation

Breast Cancer Decision Support System

- LIFE Ontology



Breast Cancer Decision Support System

- Implementation (demo video)

clinicXperience

Patient
Overview
Recommendations

Rules
Visualization
Evolution
Advanced Evolution
Fine tuning

Rule ID
RT0001

Rule description

Parameter	Modifier	Value
PathologicAnatomy_SurgicalPiece_Size	=	T0
PathologicAnatomy_SurgicalPiece_Size	=	T1mic
PathologicAnatomy_SurgicalPiece_Size	=	T1a
PathologicAnatomy_SurgicalPiece_Size	=	T1b
GeneralSurgery_InterventionType	=	Conservative
Radiotherapy_hypersensitivity	=	Yes
PathologicAnatomy_SurgicalPiece_LymphNodes	=	0

Radiotherapy_ProtocolName

MAMA-50

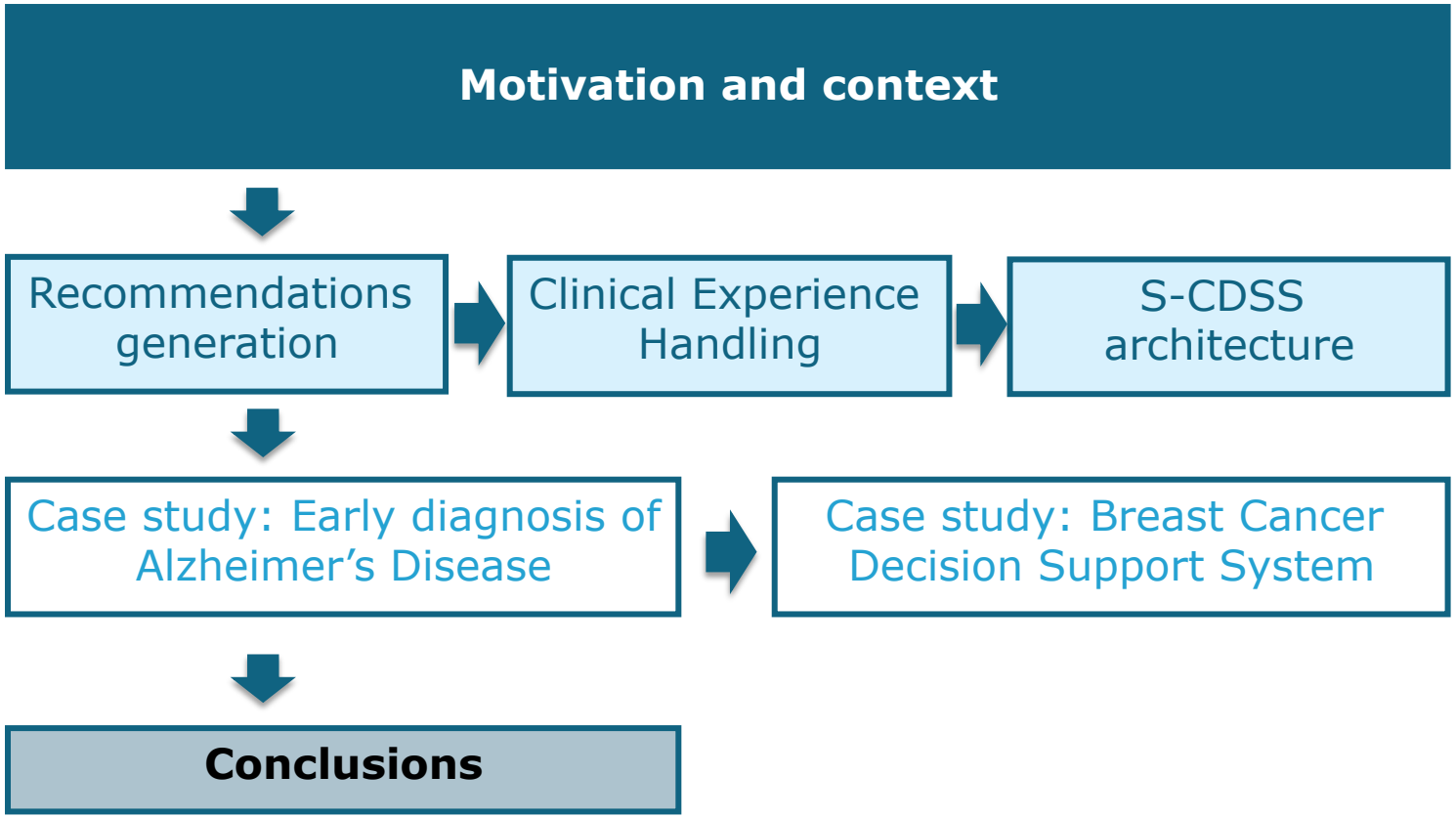
Bibliography

doi:10.1186/bcr1981

Rule change recommendations, according to error associated values

Parameter	Value	Errors	Percentage
PathologicAnatomy_SurgicalPiece_Size	T1mic	5	100.0

Contents and structure



Conclusions

- Research question and objectives accomplishment

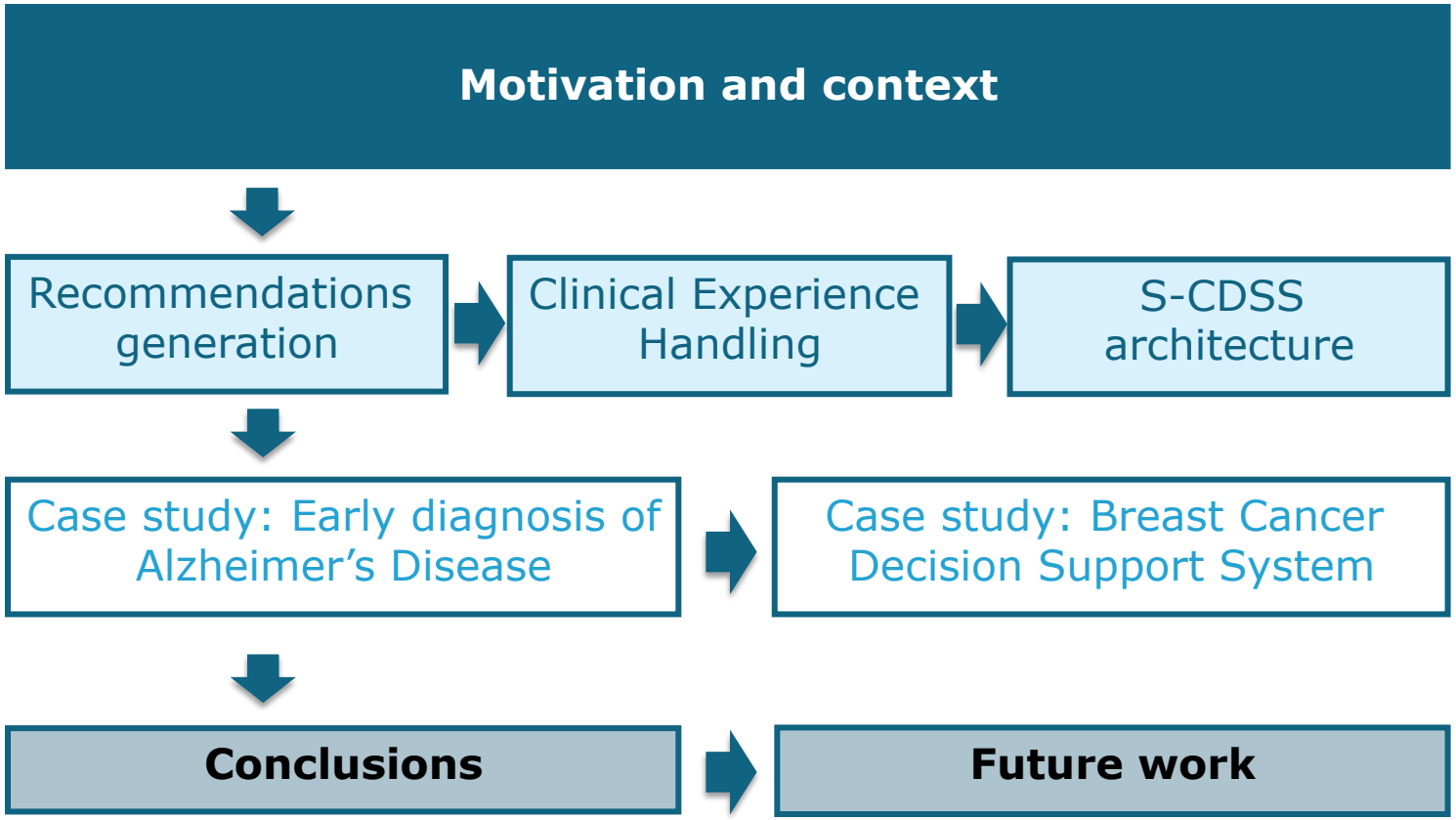
  - We have demostrated that clinical experience can be modeled, acquired and reused in the context of clinical decision making.

  - In order to allow the handling of the colective experience within a medical organization, we have proposed and developed
    - a theoretical framework
    - its specific recommendations
    - associated methodologies
    - practical tools

Conclusions

- We presented a methodology for the generation of decision recommendations.
- We presented a methodology for the acquisition and consolidation of decisional events in the system.
- In particular, we have provided a methodology for the automatic evolution of a ruleset based on the acquired decisional events.
- The integration of such contributions into a CDSS allowed us to present an innovative architecture for Semantically steered CDSS (S-CDSS).
- The architecture fits in the Clinical Task Model (CTM), a generic model for clinical tasks which we also presented.
- We have achieved an operational implementation of such architecture and methodologies in the framework of two case studies: early diagnosis of AD and breast cancer treatment.

Contents and structure



Future work

- Short term
  - Design more refined algorithms in order to extract implicit knowledge from the reflexive structure
  - Evaluate the performance of RO in different domains and use cases
- Mid term
  - Perform a formal evaluation of our architecture in a real clinical environment
- Long term
  - Study how to develop decision traceability in the clinical domain
  - Develop automatic knowledge retrieval tools to provide knowledge maintenance
  - Integrate the proposed S-CDSS with hospital EHR
    - EHR semantization

Thank you for your attention