PHD IN THEORIES, METHODOLOGIES AND ADVANCED APPLICATIONS FOR COMMUNICATION, COMPUTER SCIENCE AND PHYSICS

XI CYCLE – NEW SERIES

APRIL 2013

Hybrid approaches based on Computational Intelligence and Semantic Web for distributed Situation and Context Awareness

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Roadmap

- Introduction
- Theoretical and Technological Foundations
- Proposed Approaches and Research Objectives
- Architectural Overviews and Application Scenarios
- Conclusions

Introduction
- Some Definitions
- Research Trend
- Research Focus, Significance and Objectives

Theoretical and Technological Foundations
- Situation/Context Awareness and Semantic Sensor Web
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- SPARQL
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Proposed Approaches & Research Objectives
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- SbESA
- CAPSD

Architectural Overviews and Application Scenarios
- Situation Awareness & Airport Security
- Situation Awareness & Smart Grids
- Context Awareness & Healthcare

Conclusions

Some Definitions

Situation Awareness
- *is the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their status after some variable has changed, such as time, or some other variable, such as a predetermined event.*
- *It is also a field of study concerning the perception of the environment critical to decision-makers in complex, dynamic areas.*

Context Awareness
- *refers to the idea that computers can both sense, and react based on their environment.*
  - *Devices may have information about the circumstances under which they are able to operate and based on rules, or an intelligent stimulus, react accordingly.*
- *Specifically, it is considered a process to support user applications to adapt interfaces, tailor the set of application-relevant data, increase the precision of information retrieval, discover services, make the user interaction implicit or build smart environments.*

Research Trend

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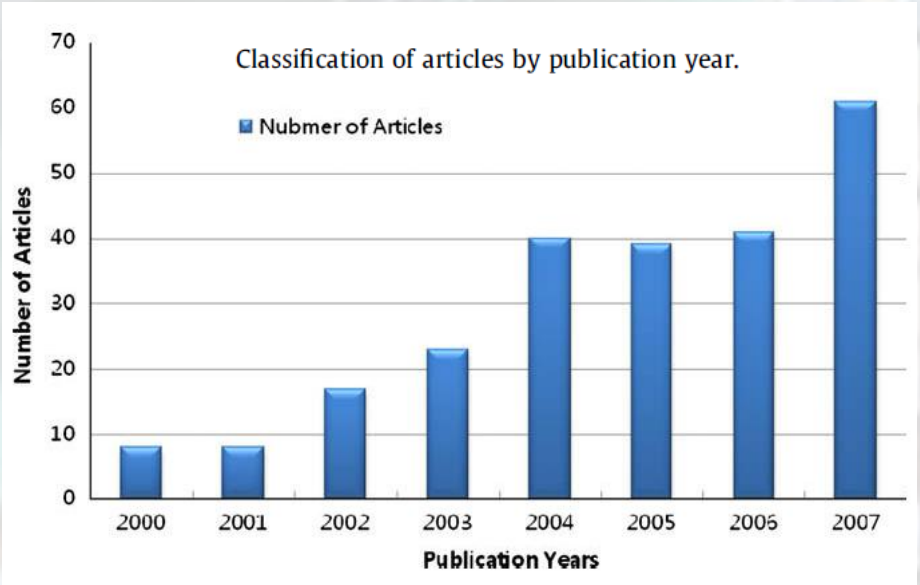
Classification of articles based on the journal.

Journal articles	Number of articles
IEEE Pervasive Computing	23
Personal and Ubiquitous Computing	10
IEEE Internet Computing	6
Wireless Personal Communications	5
IEEE Intelligent Systems	5
Mobile Networks and Applications	5
IEEE Transactions on Software Engineering	4
The Others	139
Expert Systems with Applications	10
Computer Communications	6
Journal of Systems and Software	6
Pervasive and Mobile Computing	5
World Wide Web	5
IEEE Wireless Communications	5
Interacting with Computers	4
Total	237

Classification of articles by publication year.

Online database	Number of articles
IEEE Xplore	74
Science Direct	60
Springer Link Online Libraries	57
Ingenta Journals	18
ACM Digital Library	16
Wiley InterScience	9
EBSCO (Electronic Journal Service)	3
Total	237



Hong J.Y., Suh E. H., Kim S.J.: Context-aware systems: A literature review and classification. (2009) Expert Systems with Applications, 36 (4), pp. 8509-8522

Research Focus, Significance and Objectives

Introduction
Theoretical and Technological Foundations
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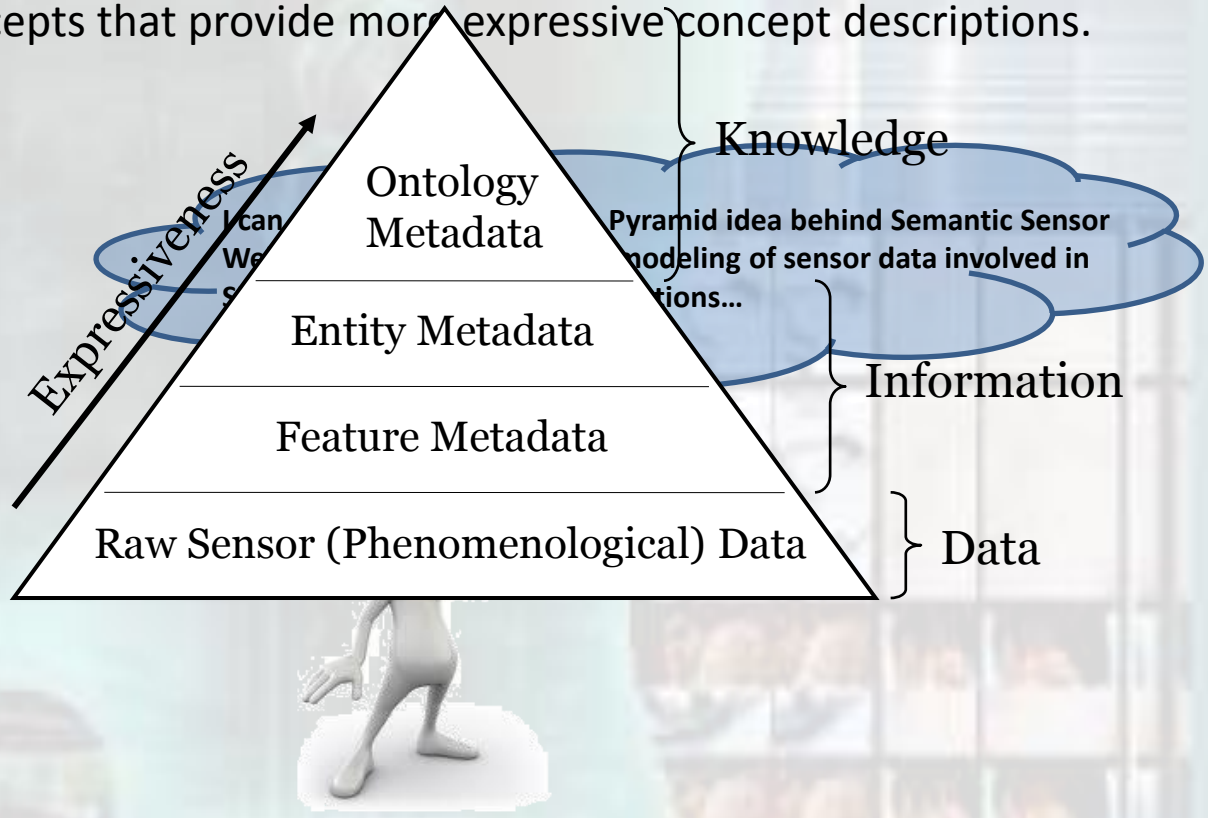
Conclusions

- The research studies in Situation/Context Awareness have highlighted that the main issues related to these areas are:
  - ✓ the need to support the acquisition and aggregation of dynamic environmental information from the field;
  - ✓ the lack of formal approaches to knowledge representation and processing;
  - ✓ the lack of automated and distributed systems to support the reasoning through software special purpose.
- In this research we propose approaches for distributed Context and Situation Awareness and proposes to apply them in order to achieve some related research objectives such as:
  - ✓ computational intelligence methodologies and techniques;
  - ✓ Knowledge Representation;
  - ✓ multi-agent distributed paradigm.
  - ✓ Semantic Reasoning;
  - ✓ Pattern Recognition;
  - ✓ Information Retrieval.

Situation/Context Awareness and Semantic Sensor Web

- **Semantic Sensor Web**
  - ✓ the idea is to add semantic annotations to existing standard Sensor Web languages in order to provide semantic descriptions and enhanced access to sensor data;
  - ✓ this is accomplished with model-references to ontology concepts that provide more expressive concept descriptions.



Ontology-based Situation Theory

- In ST (introduced by Barwise and Perry, 1983), information about a situation is expressed in terms of infons.
  - ✓ Infons are written as

$$\sigma_i \equiv\ll R, a_1, \ldots, a_n, \varphi \gg$$

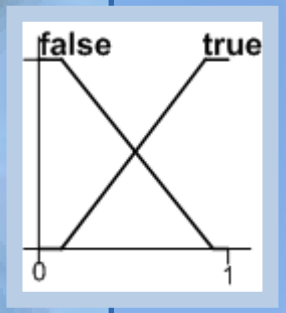
- To capture the semantics of situations, ST provides a relation between situations and infons.
  - ✓ This relationship is called the supports relationship and relates a situation with the infons that ‘‘are made factual’’ by it.
  - ✓ Given an infon **σ** and a situation **s** the proposition “**s** supports **σ**” is written as

$$\mathbf{s} \models \boldsymbol{\sigma}.$$

- A formalization of Barwise’s situation semantics in terms of an ontology, with some parts using mathematics and rules, has been named STO (M. Kokar, C. J. Matheus, K. Baclawski, 2009).

From a Fuzzy Extension of Situation Theory to Fuzzy Situation Theory Ontology

- I propose a fuzzy extension of semantics related to Situation Theory, namely, Fuzzy Situation Theory Ontology (FSTO).
  - ✓ FSTO meta-model for SA can evolve in a natural way towards the approximation and uncertainty modeling.



Thus, in my interpretation, the polarity of an *infon* σ_i supporting a situation s_j can be one of the terms defining a linguistic variable expressing infon's truth. For instance, let us say

$$(InfonTruth, \Im(G), [0..1], G, M)$$

- G is the grammar generating terms in $\Im(G)$
- M is the semantic rule which associates each linguistic value with its meaning.

The definition of the context free grammar G involves $(true, false)$ as primary terms, a finite number of hedges $(more\ of\ less,\ quite,\ really, \ldots)$ whose evaluation in M is performed by means of concentration and dilation, the connectives and and or, and the negation not.

From a Fuzzy Extension of Situation Theory to Fuzzy Situation Theory Ontology

- I propose a fuzzy extension of semantics related to Situation Theory, namely, Fuzzy Situation Theory Ontology (FSTO).
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As a result, an infon σ_i supporting a situation s_j is written as:

$$\sigma_{i,s_j} \equiv \ll R_i, a_1, a_2, \dots, a_n, \tau_{\sigma_{i,s_j}} \gg with\ \tau_{\sigma_{i,s_j}} \in \Im(G)$$

stating that $R_i(a_1, a_2, \dots, a_n)\ is\ \tau_{\sigma_{i,s_j}}$ in s_j.

By adopting this modeling approach, the semantic of *support* proposition $\models$ can be stated as

$$s_j \models_{ext} \{\sigma_{i,s_j}\} \iff \forall\, i :\ R_i(a_1, a_2, \dots, a_n)\ is\ \tau_{\sigma_{i,s_j}}$$

This interpretation lead us to define a modeled situation occurrence as the evaluation of a corresponding fuzzy control rule:

IF $R_1(a_{1,1}, a_{1,2}, \dots, a_{1,n_1})\ is\ \tau_{\sigma_{1,s_j}}$

AND …

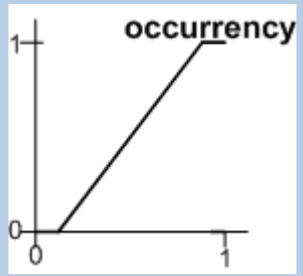
AND $R_i(a_{i,1}, a_{i,2}, \dots, a_{i,n_i})\ is\ \tau_{\sigma_{i,s_j}}$ THEN

$s_j\ is\ occurring$

otherwise formalized as:

$$\mu_{occ}(s_j) = \bigwedge_i \mu_{\tau_{\sigma_{i,s_j}}}[R_i(a_{i,1}, a_{i,2}, \dots, a_{i,n_i})]$$

where $\wedge$ is a suitable t-norm operator and *Occurrency* is a fuzzy set.



SPARQL

Introduction
Theoretical and Technological Foundations
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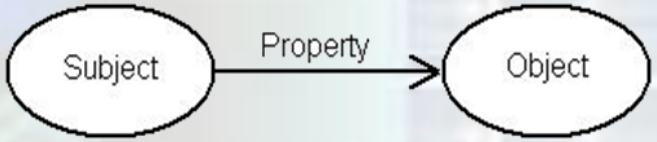
Conclusions

- SPARQL (pronounced “sparkle”, a recursive acronym for SPARQL Protocol and RDF Query Language) is an RDF query language, that is, a query language for databases, able to retrieve and manipulate data stored in Resource Description Framework format.
  - ✓ Querying RDF Graph
  - ✓ Set of triples



- SPARQL sintax is similar to SQL
  - SPARQL allows users to write unambiguous queries

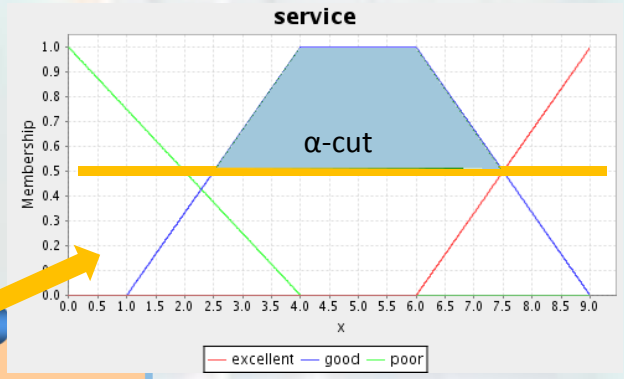
SPARQL QUERY

```
PREFIX cd: <http://example.org/cd/>
        SELECT ?title ?year
        FROM  <http://cd.com/listacd.ttl>
        WHERE {
                ?title cd:year ?year.
                FILTER (?year > 2000).
        }
```

f-SPARQL

query f-SPARQL

result transformation



f-SPARQL

```
#top-k FQ# WITH 10
FCL service:<./fcl/service.fcl>
SELECT ?individual ?evaluation ?Fqscore
FROM <file:./ontology/service.rdf>
WHERE {
        ?individual<http://www.corisa.it/service#evaluation>
        ?evaluation WITH 1.
        FILTER ( ?evaluation  > sevice:evaluation:good WITH 0.5 ) .
}
```

query SPARQL

query result

SPARQL

```
SELECT ?individual ?evaluation ?Fqscore
FROM <file:./ontology/service.rdf>
WHERE {
    ?individual<http://www.corisa.it/service#evaluation> ?evaluation .
    FILTER (( ?evaluation  > 2.5 ) && (?evaluation < 7.5)) .
```

f-SPARQL extension

Fuzzy Clustering and Classification of Ontology Concept Instances

CoMSA

- Introduction
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- Conclusions

Approaches

Research Objectives

- Knowledge Representation
- Semantic Reasoning
- Pattern Recognition
- Information Retrieval

CoMSA

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- Theoretical and Technological Foundations
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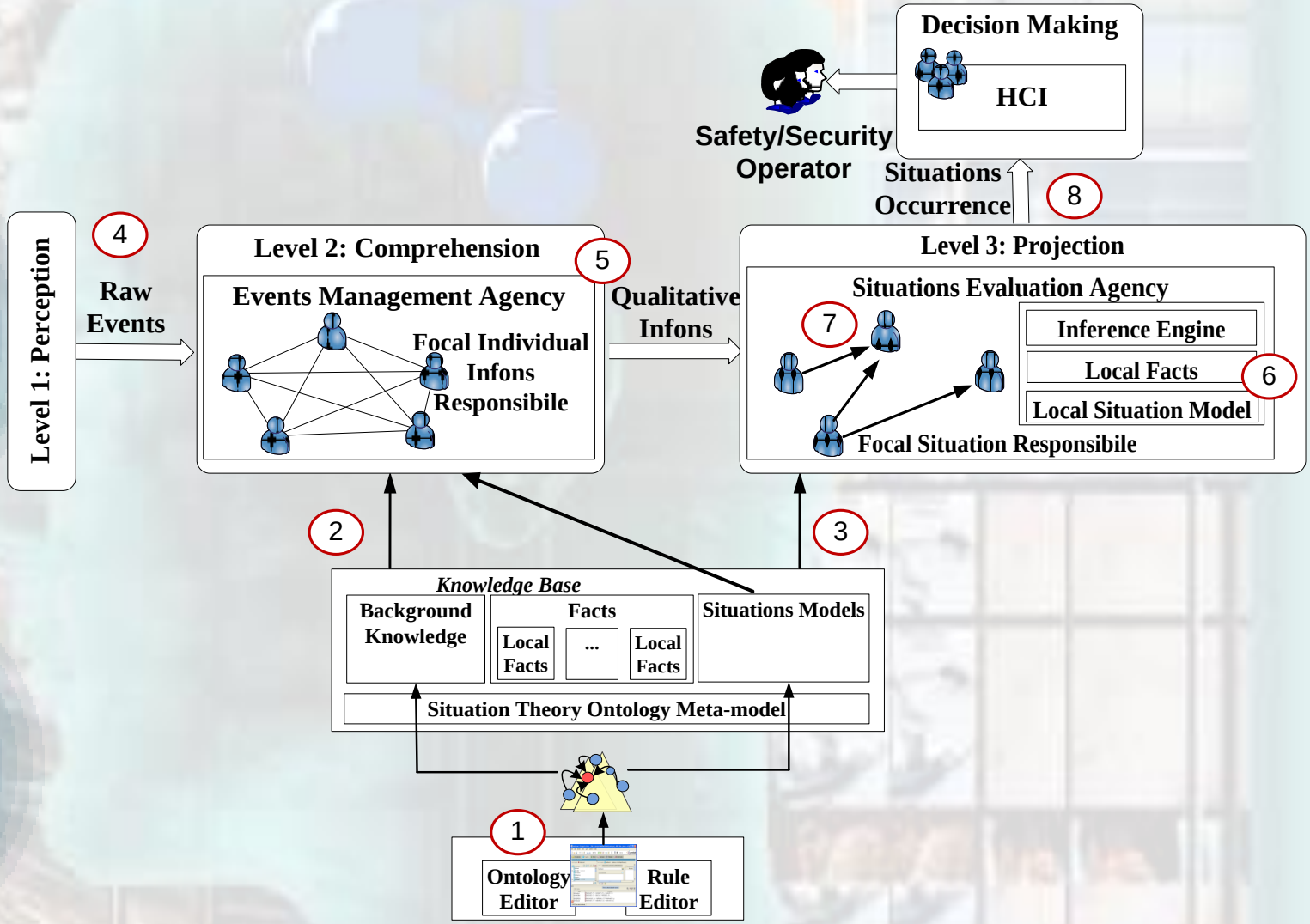
- Conclusions



Situation Awareness and Airport Security

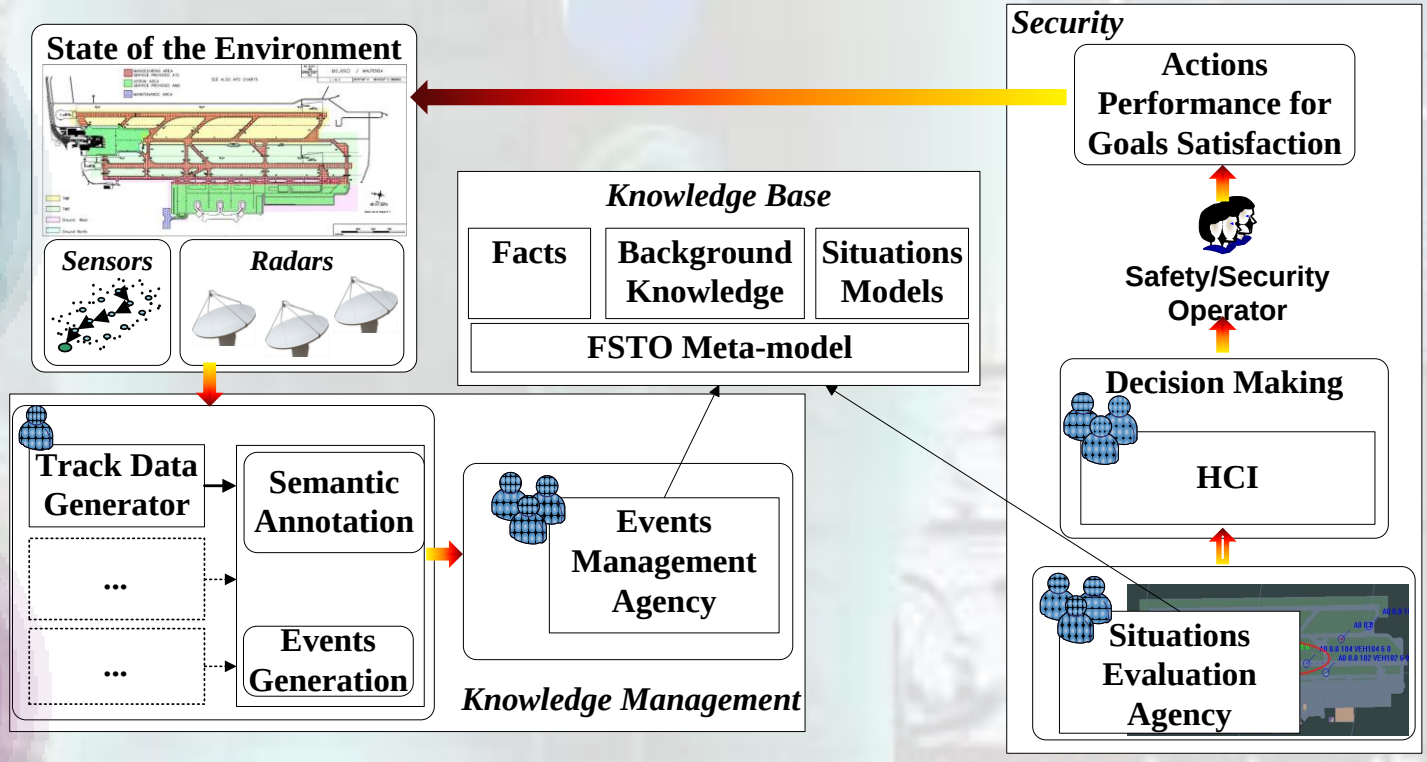
Introduction
Theoretical and Technological Foundations
Proposed Approaches and Research Objectives
Architectural Overviews and Application Scenarios
Conclusions

- New types of threats (terrorism, organized crime, etc.) can make risky the normal conduction of airport operations.

- So, it is necessary to achieve a common enhanced situation awareness involving:
  - ✓ Relevant data sharing;
  - ✓ Qualitative data sharing;
  - ✓ Collaborative decisions.

- **Specific Goal**:
  - ✓ support security operators in the detection of critical situations in the internal areas of the airport;
    - Intelligent Decision Support System;
    - **CoMSA**.

Architectural Overview

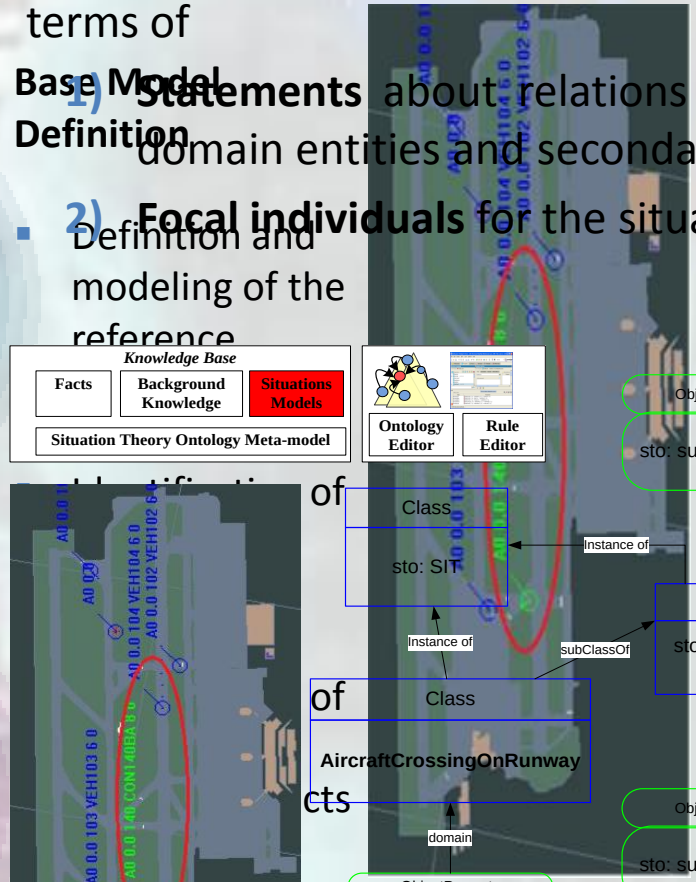


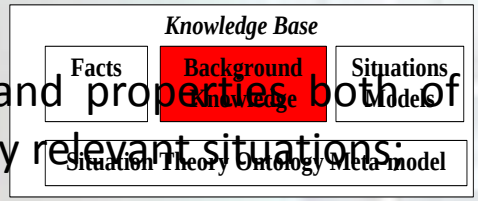
Ontological Modeling - Knowledge Base

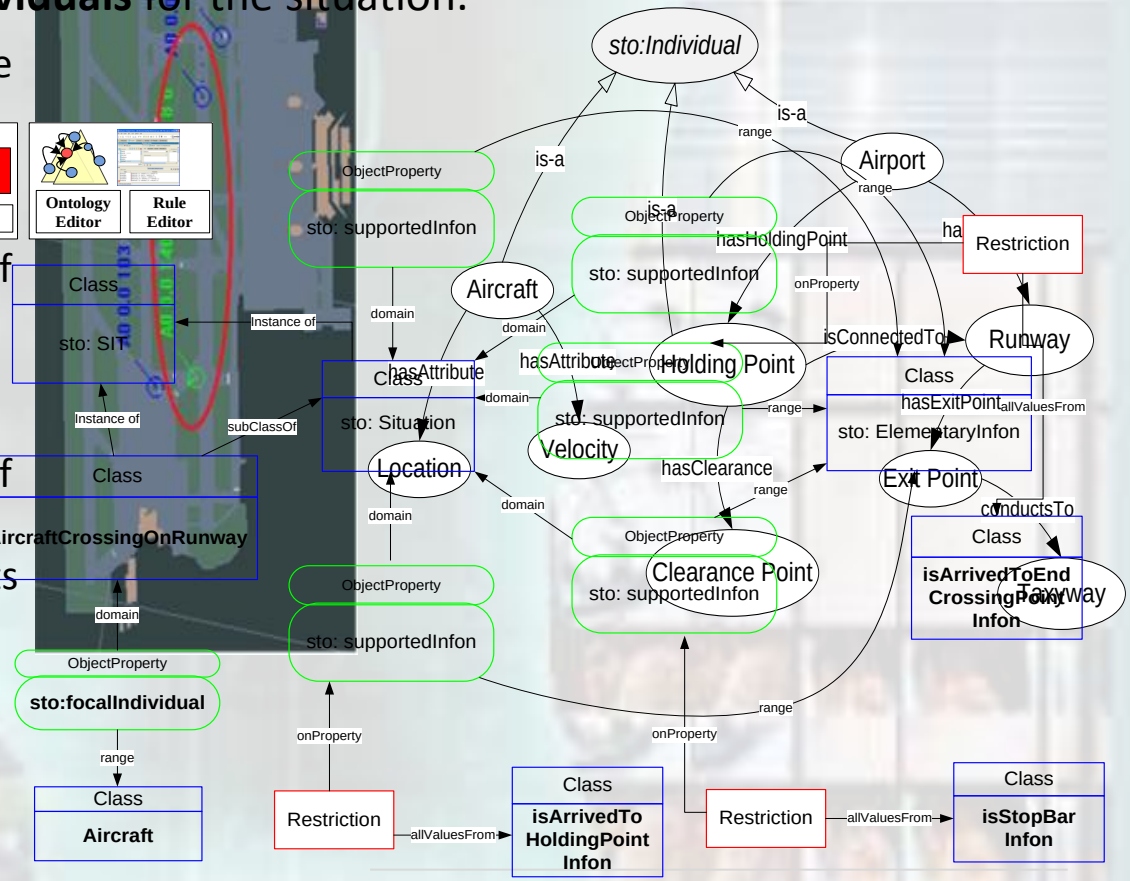
- **Generation of Situational Models**: modeling of the situations in terms of
  1) **Statements** about relations and properties both of observed domain entities and secondary relevant situations;
  2) **Focal individuals** for the situation.

Base Model Definition

- Definition and modeling of the reference
- Identification of
- of
- cts



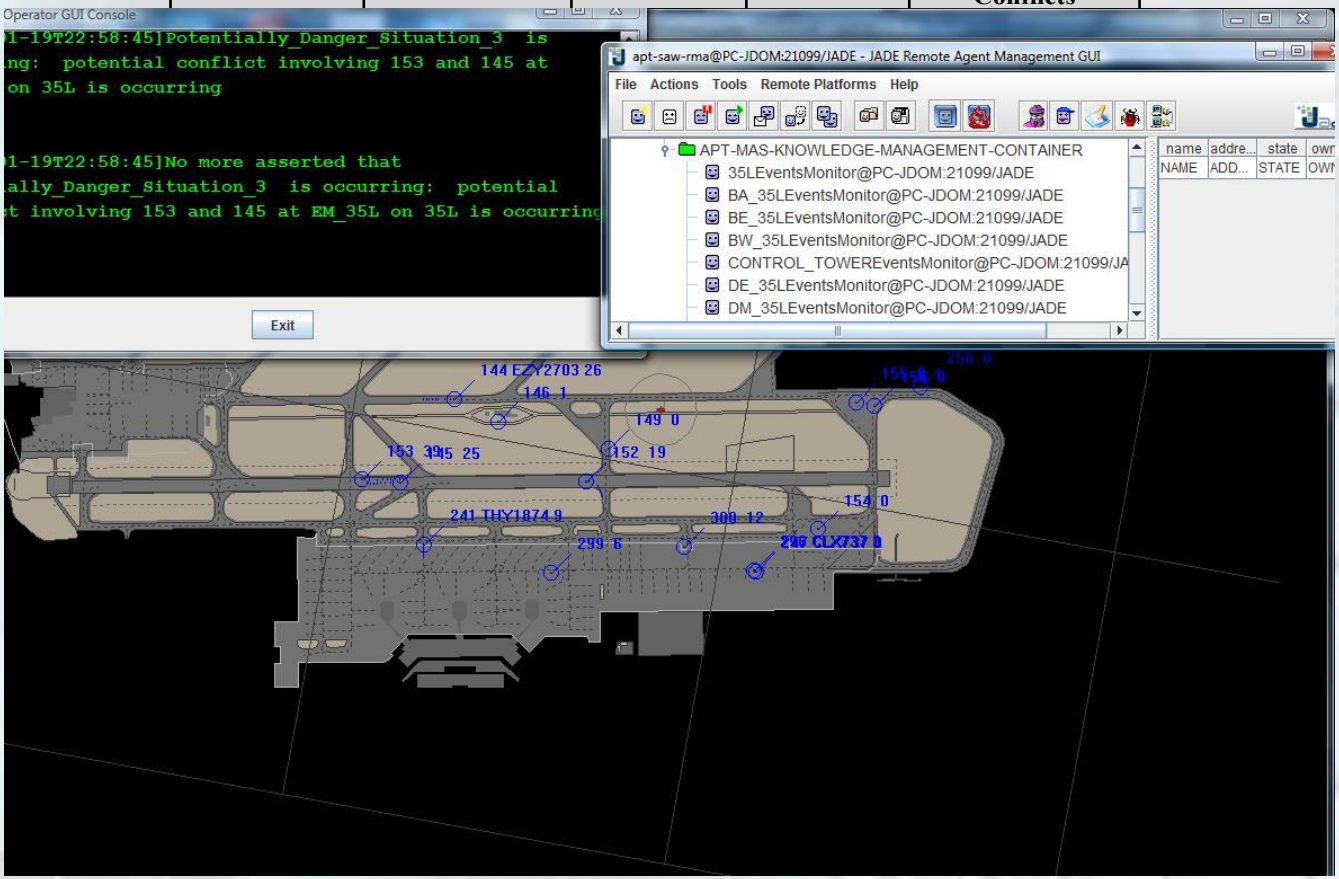




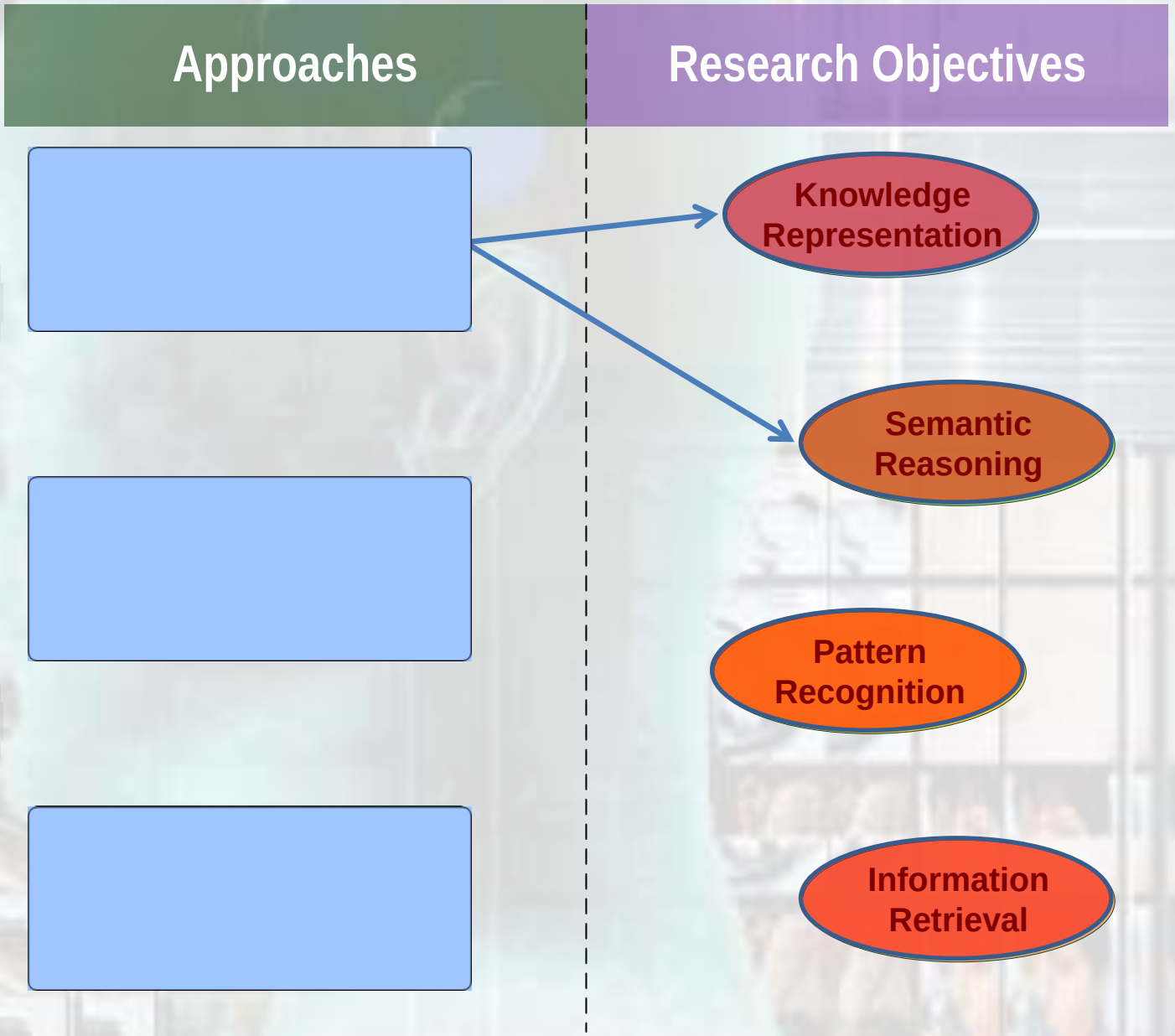
Simulation Results

- **SIMULATOR**: ASAS (Airport Security Agents System)

Test Case	No. Sweep Radar	Duration (min.)	Max No. Traces	Ground Truth: No. Anomalies and Conflicts



CoMSA Research Objectives



Approaches

CoMSA Approach

Key elements

Semantic Sensor Web

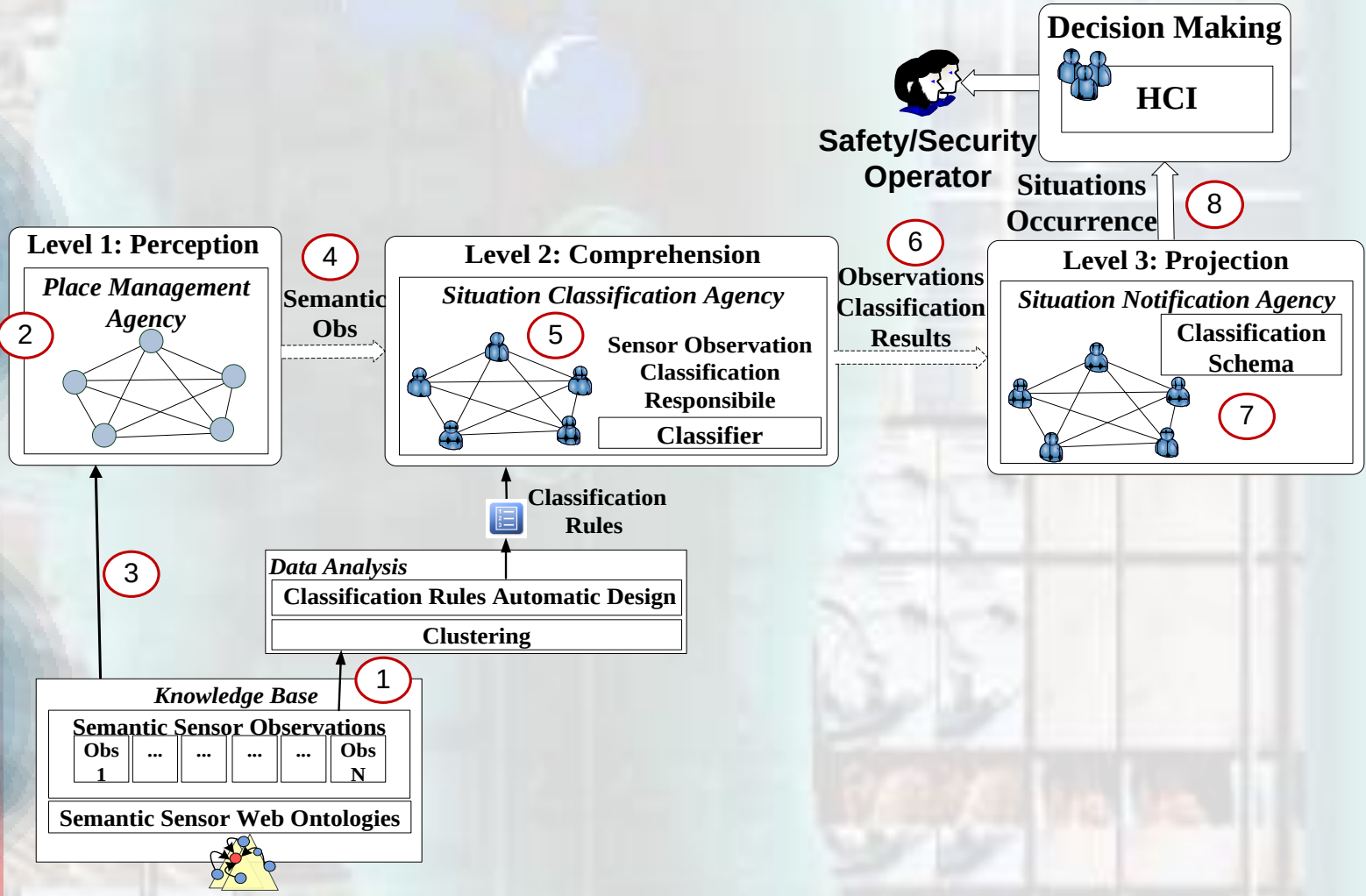
Fuzzy Situation Theory Ontology

Multi Agent Paradigm

Research Objectives

- Knowledge Representation
- Semantic Reasoning
- Pattern Recognition
- Information Retrieval

SbESA



Situation Awareness and Smart Grids

Introduction
Theoretical and Technological Foundations
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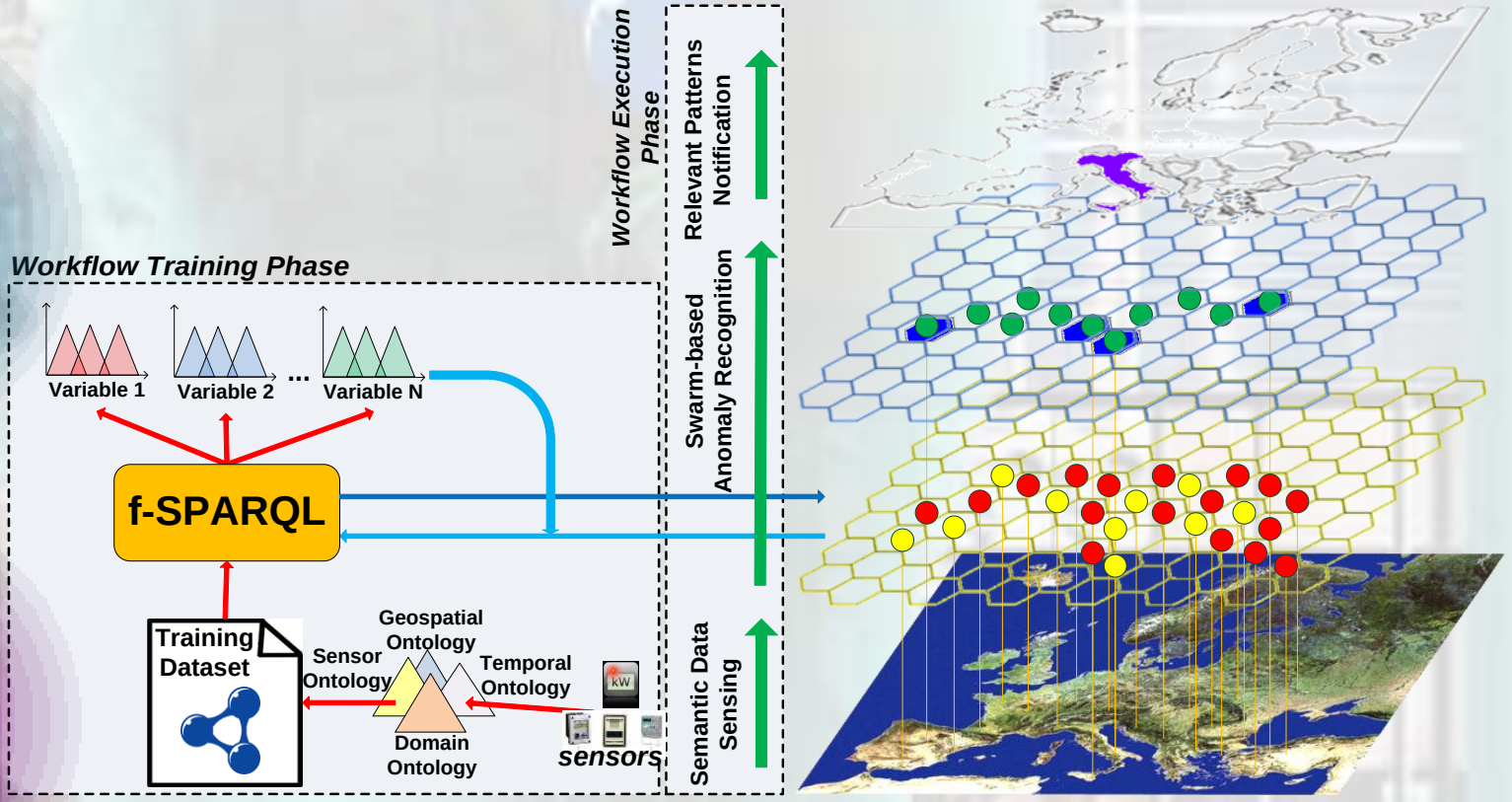
Conclusions

- Smart Grids paradigm is expected to support the evolution of traditional electrical power systems.
- In particular, the constant growth of grid complexity and the need for supporting rapid decisions require paradigms:
  - ✓ more scalable and flexible;
  - ✓ proactive;
  - ✓ self-healing.

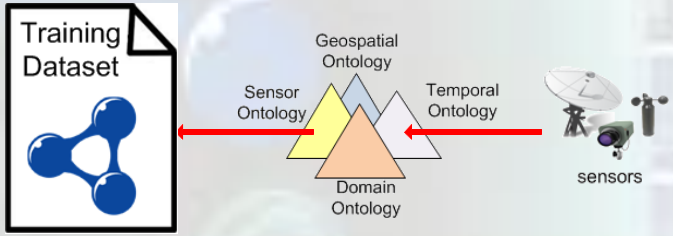
- **Specific Goal**:
  - ✓ support the evolution of traditional electrical power systems toward web energy networks composed by distributed and cooperative energy resources;
    - A situation aware distributed and cooperative monitoring system.
    - **SbESA**.

Architectural Overview

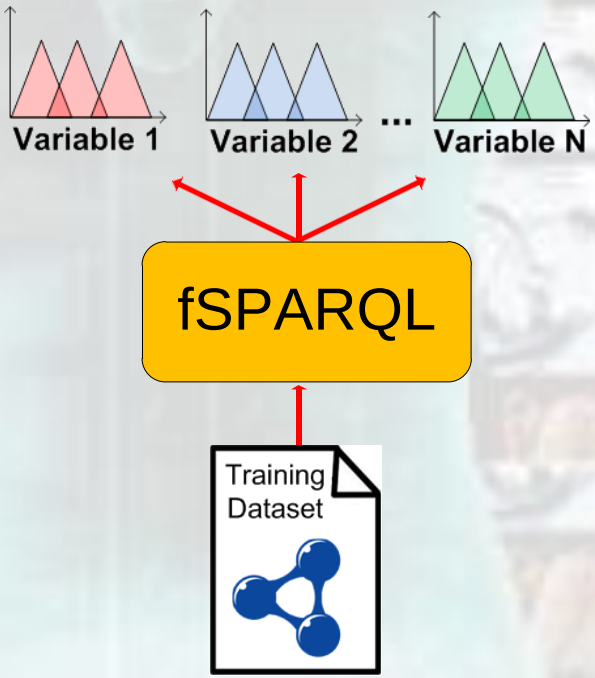


Workflow Training Phase

- Building of training dataset

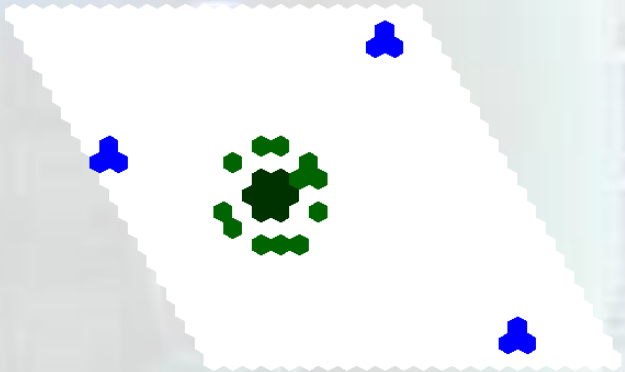


- Clustering of sensor observations
  - identification of events that may occur in the system

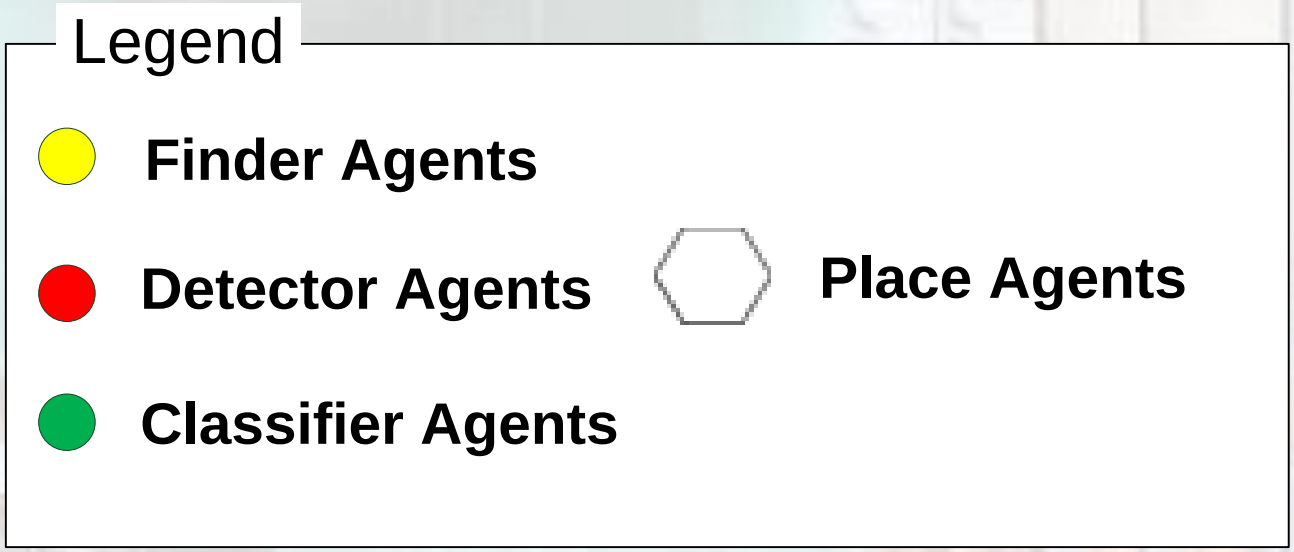


Workflow Execution Phase

- Swarm behavior exploiting ant foraging metaphor

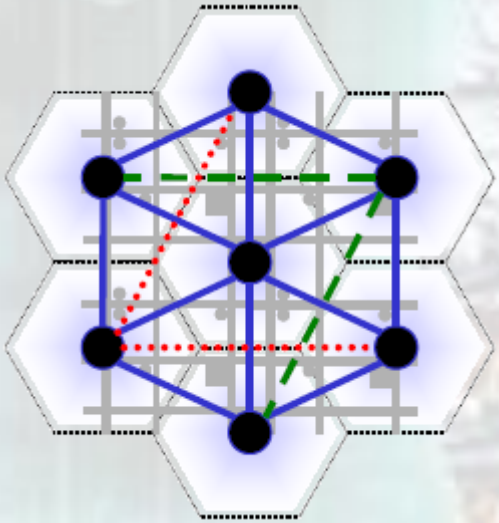


- It foresees the employment of four populations of agents



Workflow Execution Phase – Place Agents

- These agents provide infrastructure services in order to manage the pheromone properties (such as concentration, evaporation, and propagation) on each node of the network.
- They also implement pheromone's logics as well as operations of data sensing.
- Moreover, they provide topological information and manage the interactions between neighboring agents.



Workflow Execution Phase – Finder Agents

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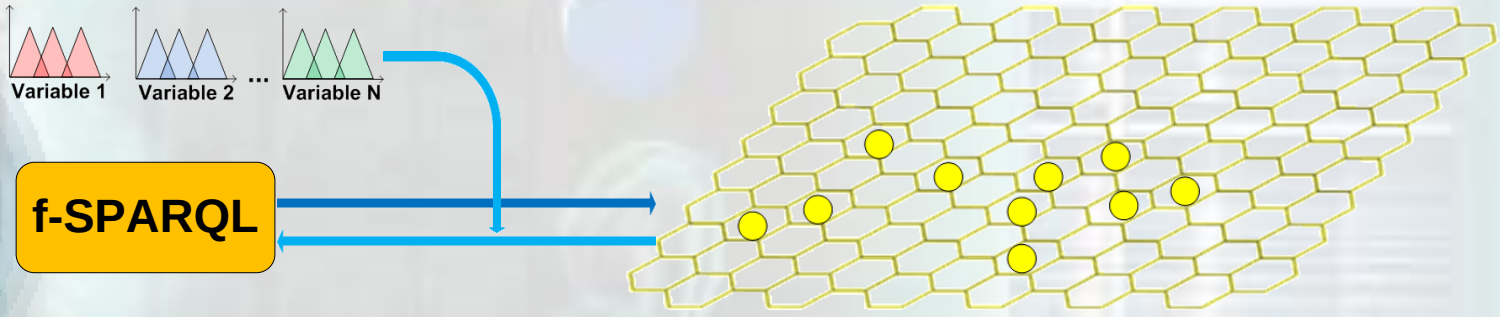
Conclusions

- These agents move in the environment in a totally random way, trying to estimate clusters density, which can be interpreted as a measure of not anomaly for clusters.



- Each Finder Agent maintains a vector with as many cells as clusters;

	Vector
Cluster1	15
Cluster2	18
Cluster3	1

+

Cell Data
0.1
0.3
0.6

=

New Vector
15.1
18.3
1.6

- Then, Finder Agents on the same cell will periodically exchange among themselves the information contained in their arrays, with the aim to refine the search.

	Vector FA_A
Cluster1	15.1
Cluster2	18.3
Cluster3	1.6

Vector FA_B
10
10
1

→

Vector FA_A & FA_B
12.55
14.15
1.3

Workflow Execution Phase – Detector Agents

- These agents cooperate in a stigmergic way (i.e. through the release of pheromone) and their aim is to identify local anomalies;
  - ✓ Detector Agents, on their side, firstly contact a Finder Agent present in the same place in order to get the density vector.

$$densitydegree_{cluster\ r_i} = \frac{density_{cluster\ i}}{\sum_{j=1}^{n} density_{cluster\ j}}$$

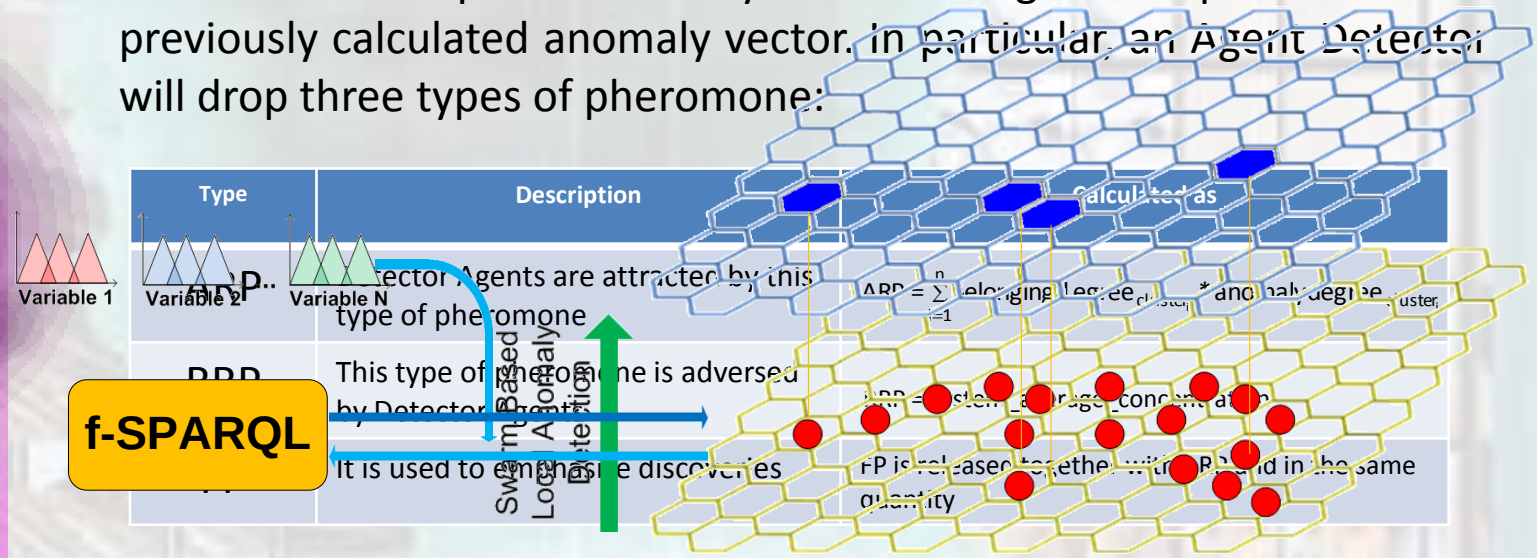
$$anomalydegree_{cluster\ r_i} = max_{0 \le j \le n} \left\{ densitydegree_{cluster\ r_j} \right\} - \left\{ densitydegree_{cluster\ r_i} \right\}$$

	FA Vector
Cluster1	12.55
Cluster2	14.15
Cluster3	1.6

DA Density Vector
0.45
0.5
0.05

DA Anomalies Vector
0.05
0
0.45

- The release of pheromone by Detector Agents depends on the previously calculated anomaly vector. In particular, an Agent Detector will drop three types of pheromone:



Workflow Execution Phase – Classifier Agents

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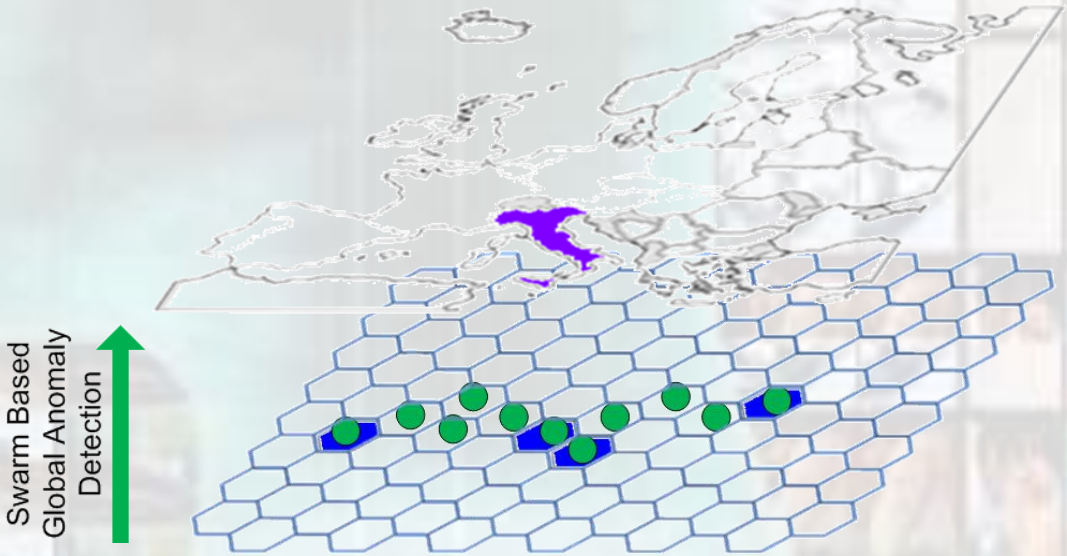
- They classify anomaly sensor observations detected in the previous phase highlighting the most important ones.
  - ✓ They release Classification Pheromone (CP), which spreads and evaporates slowly.
  - ✓ The population of Classifier Agents moves into the environment following FP trails released by Detector Agents and according to their classification scheme, which can be local or distributed.
- The concentration of CP, released on the nodes, will depend on both the concentration of FP and the confidence that the Classifier Agents have in having found a pattern;
  - ✓ confidence increases as its classification scheme proves to be exact.



Simulation Results

- Introduction
- Theoretical and Technological Foundations
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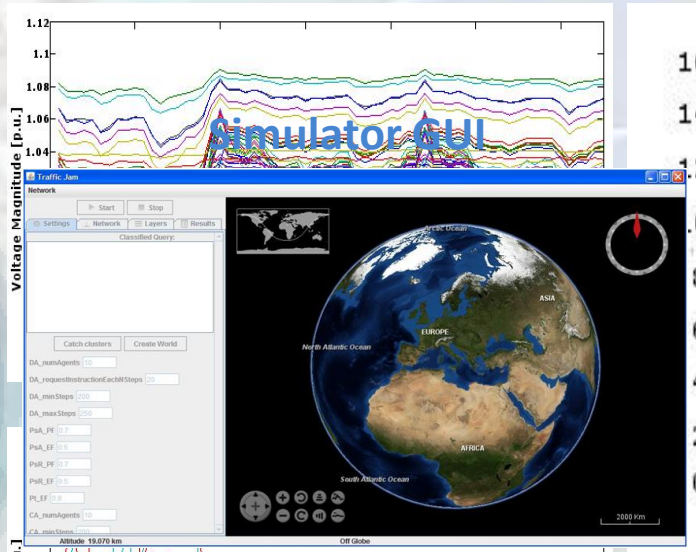
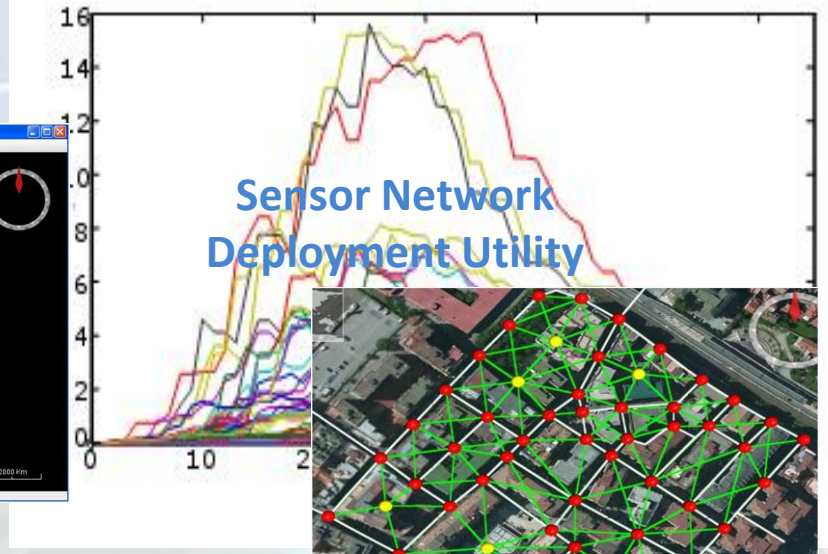
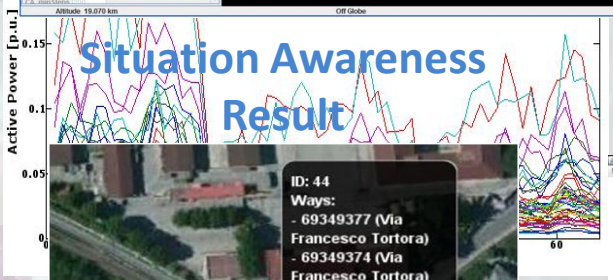
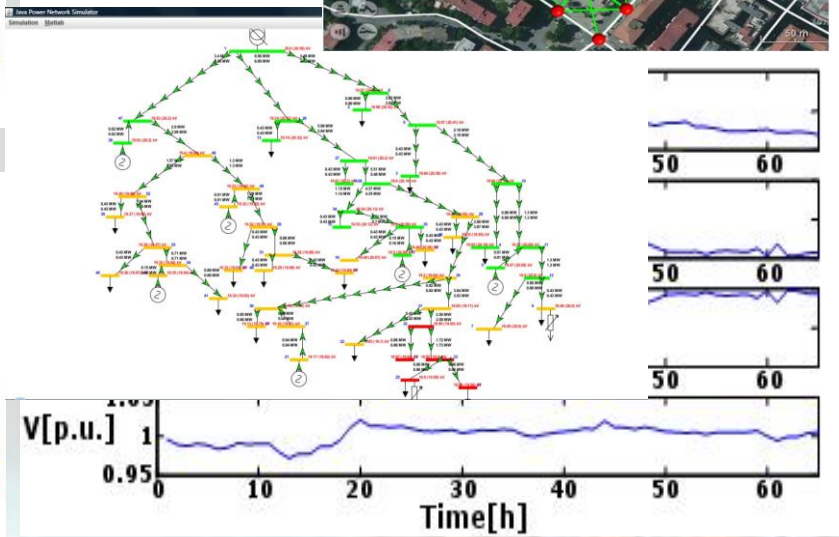
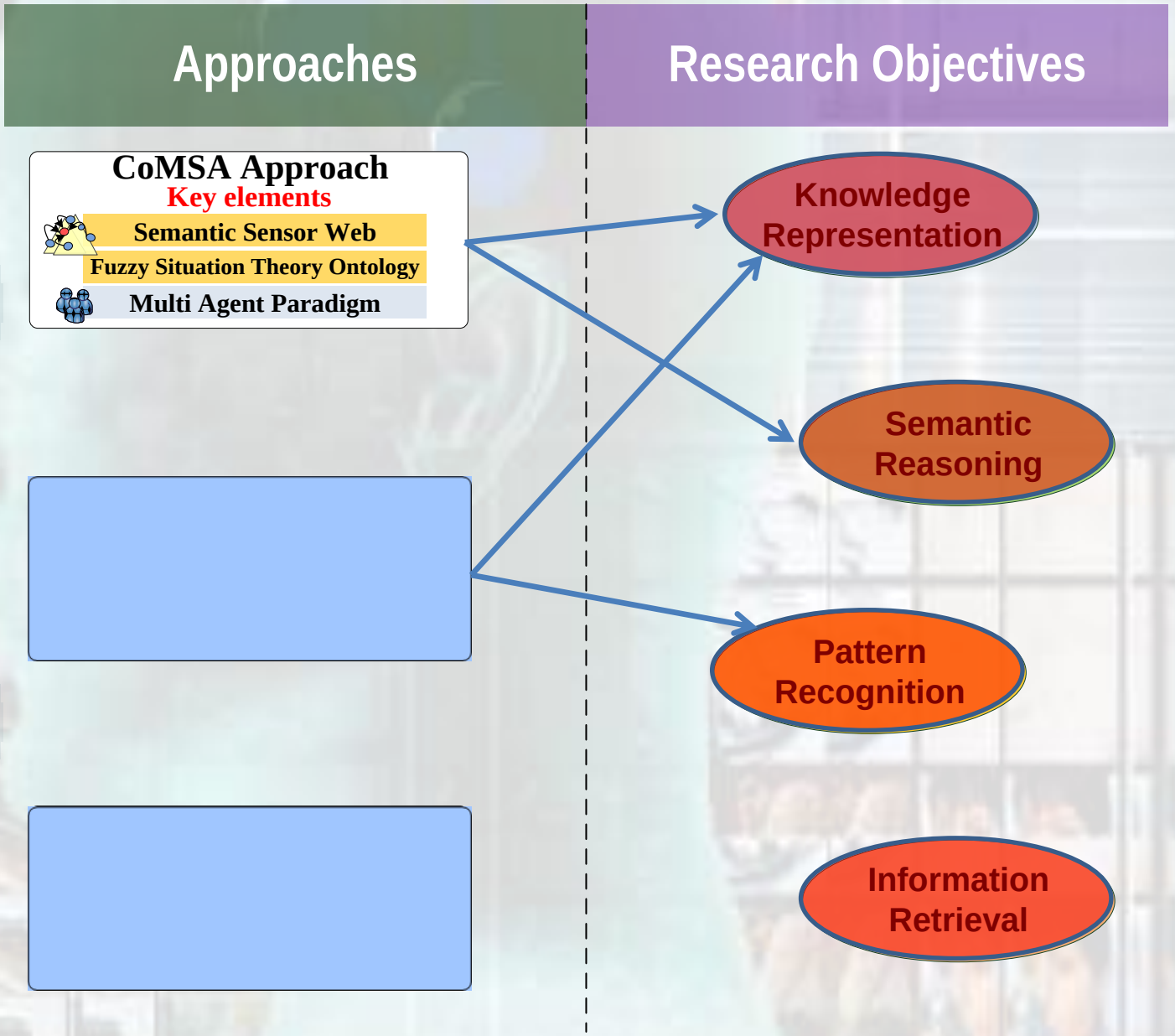








SbESA Research Objectives



CAPSD

- Introduction
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Approaches

CoMSA Approach

Key elements

- Semantic Sensor Web
- Fuzzy Situation Theory Ontology
- Multi Agent Paradigm

SbESA Approach

Key elements

- Semantic Sensor Web
- Fuzzy Clustering & Classification
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Research Objectives

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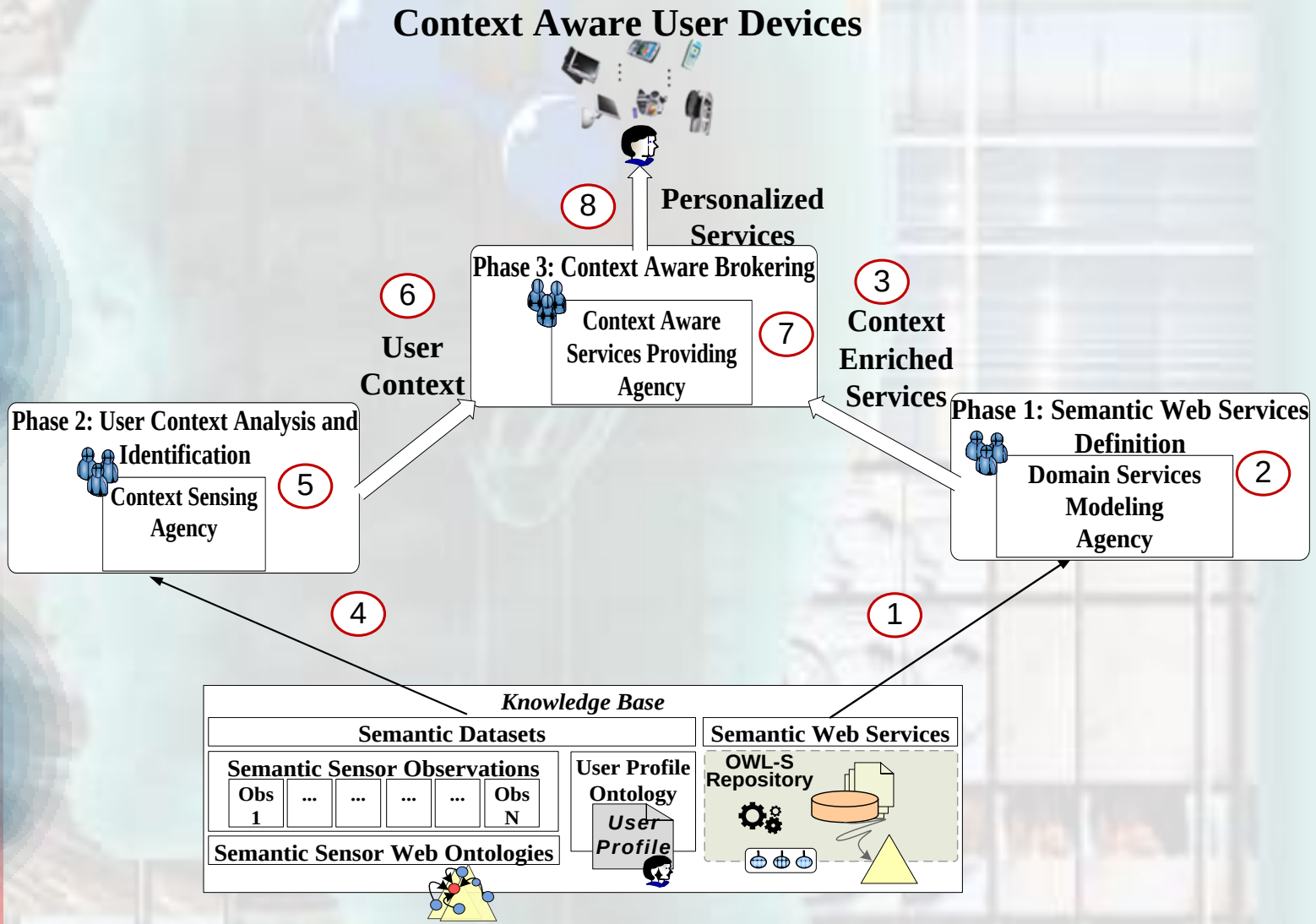
- Semantic Reasoning
- Pattern Recognition
- Information Retrieval



Context Awareness and Healthcare

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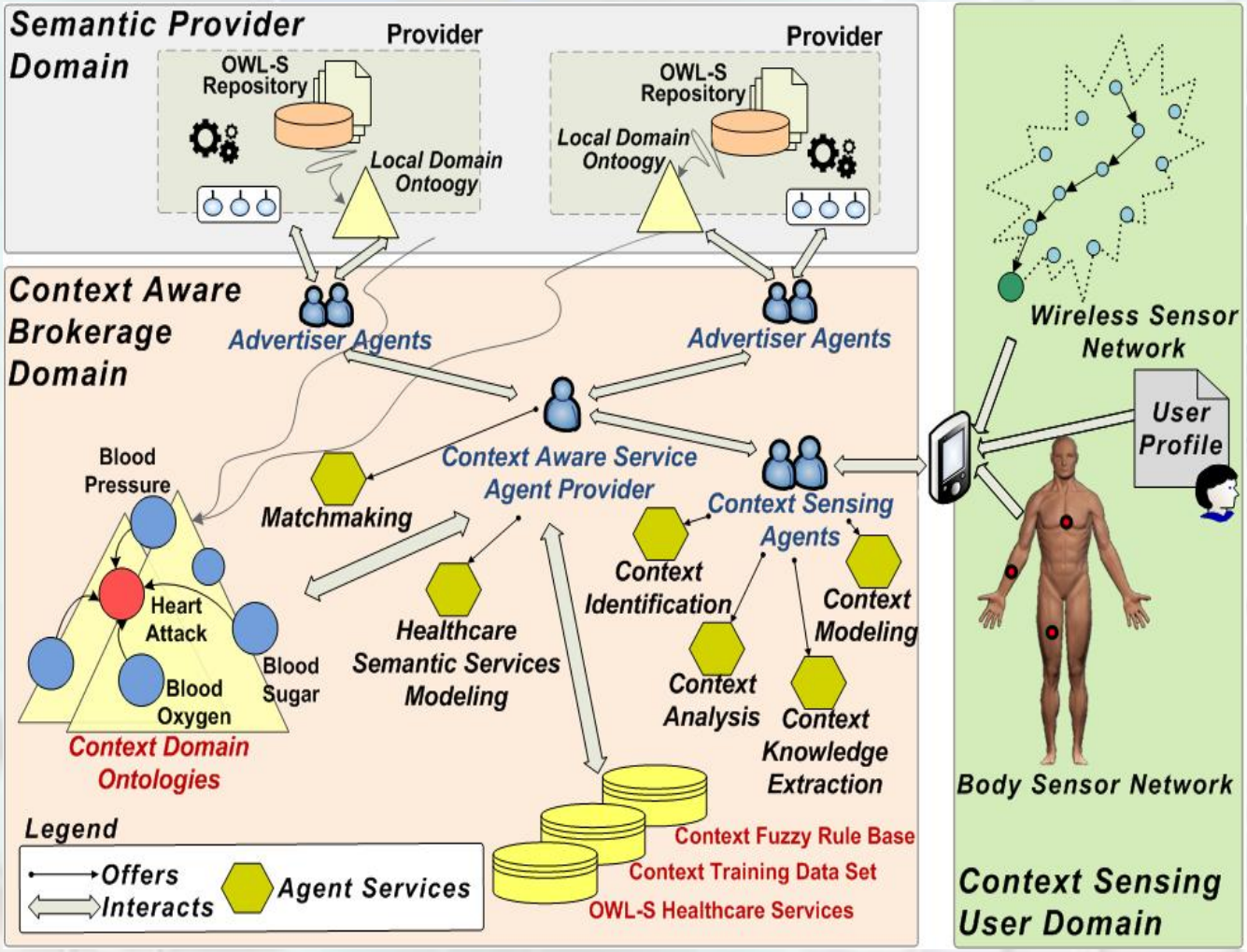
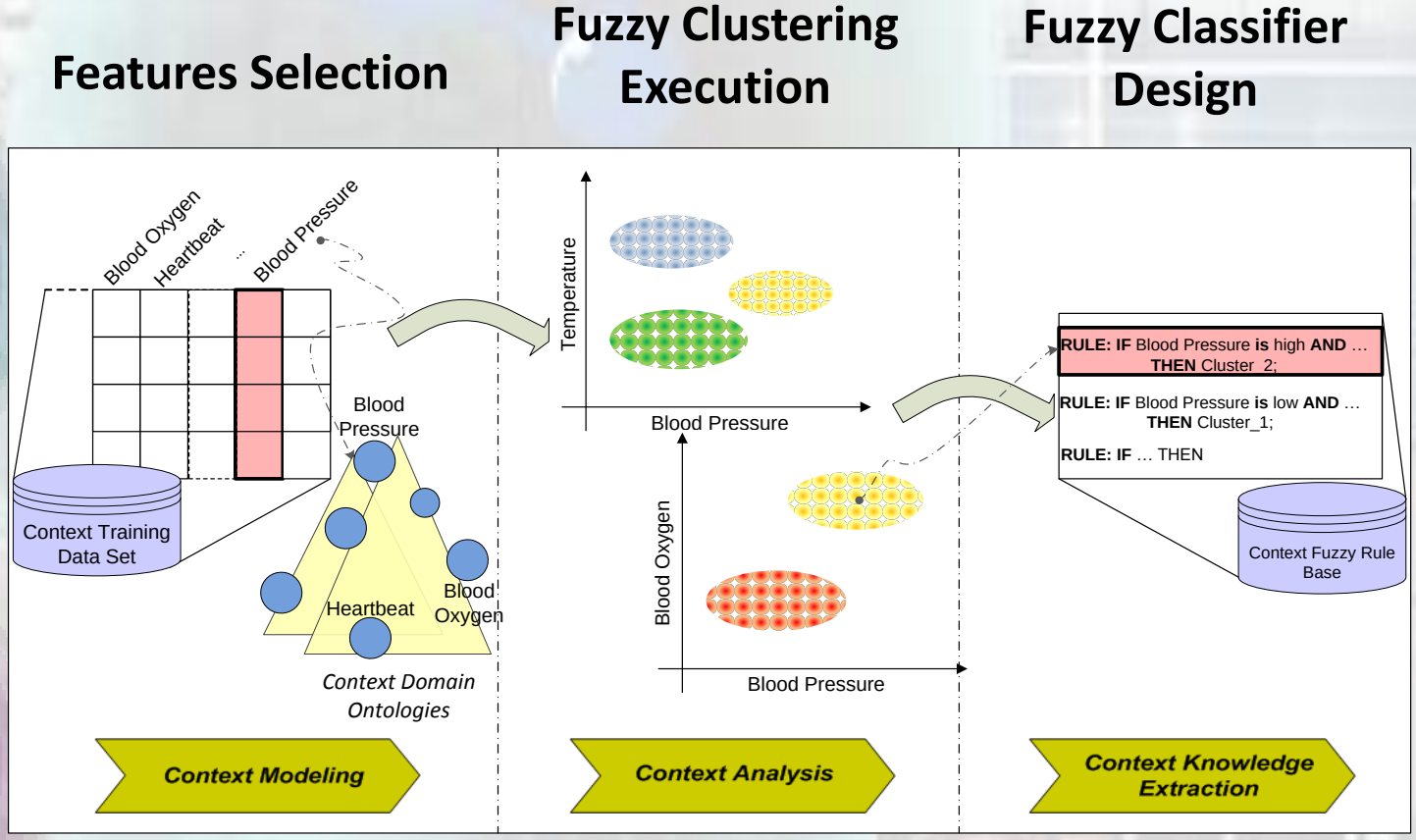
- The rapid worldwide deployment of Internet and sensor technologies is the enabler of a new generation of healthcare applications;
- One of the main problems in this domain is the healthcare personalization;
- To achieve healthcare personalization, factors such as individual's lifestyle, surrounding situations, device capabilities, event of happenings, etc., should be taken into account.

- **Specific Goal:**
  - ✓ support the personalized providing of healthcare services by exploiting user's context information.
    - An Enahnced Context-Aware System for the personalized providing of Healthcare Services;
    - **CAPSD**.

Architectural Overview



Context Sensing Agents Workflow

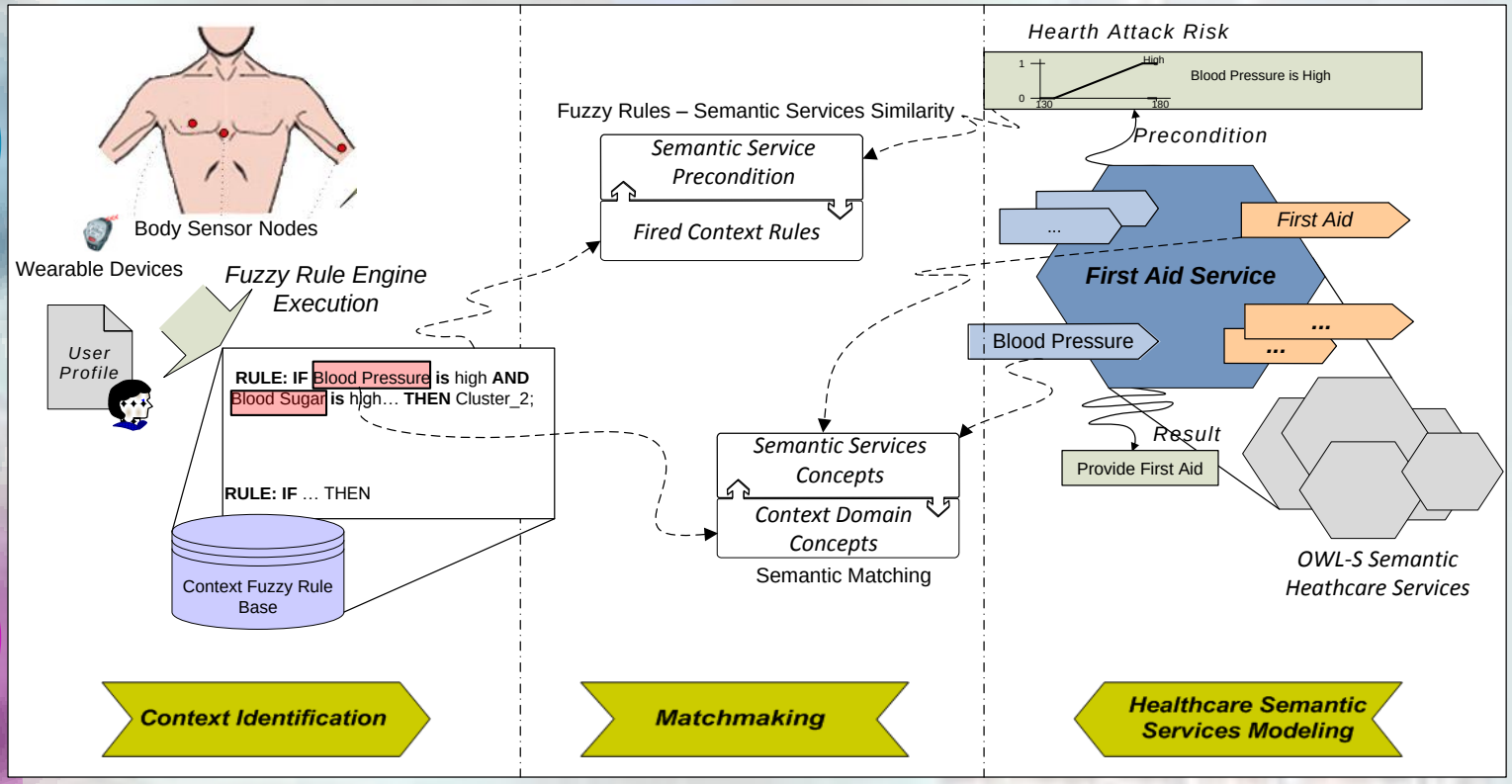


Context Training Phase

Context/Service Matchmaking Workflow

Degree of Fulfilment

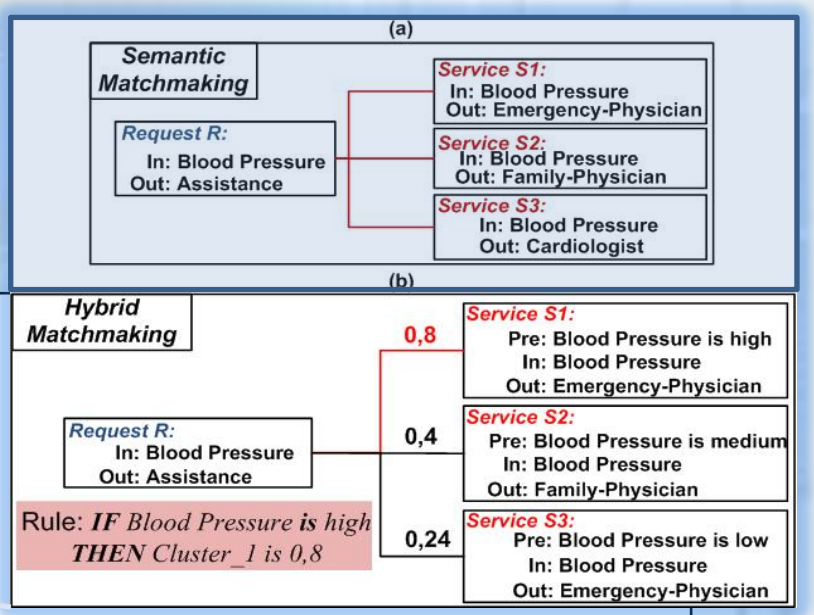
Input/Output Precondition Result



Context-Aware Service Discovery Phase

Context/Service Matchmaking

- The pseudo-code of matchmaking algorithm is the following:



Input:
- *Fuzzy Rules (FR);*
- *Semantic Web Services (SWS);*

Output:
- *Ranked list of services;*

for each rule r_i in FR
  for each antecedent a_h in r_i
    for each sws_j in SWS
      evaluate $deg_{MATCH}(sws_f)$
for each sws_j in SWS
  evaluate avarege degree of $deg_{MATCH}(sws_i)$

return Ranked list of services according to the average of deg_{MATCH} evaluated on each rule of FR.

$$deg_{MATCH}(SWS_f) = \max_i \left\{ \frac{\sum_{j=1}^{n} S(A_j, B_j)}{n} \cdot \mu_i(x) \right\}$$

Simulation Results

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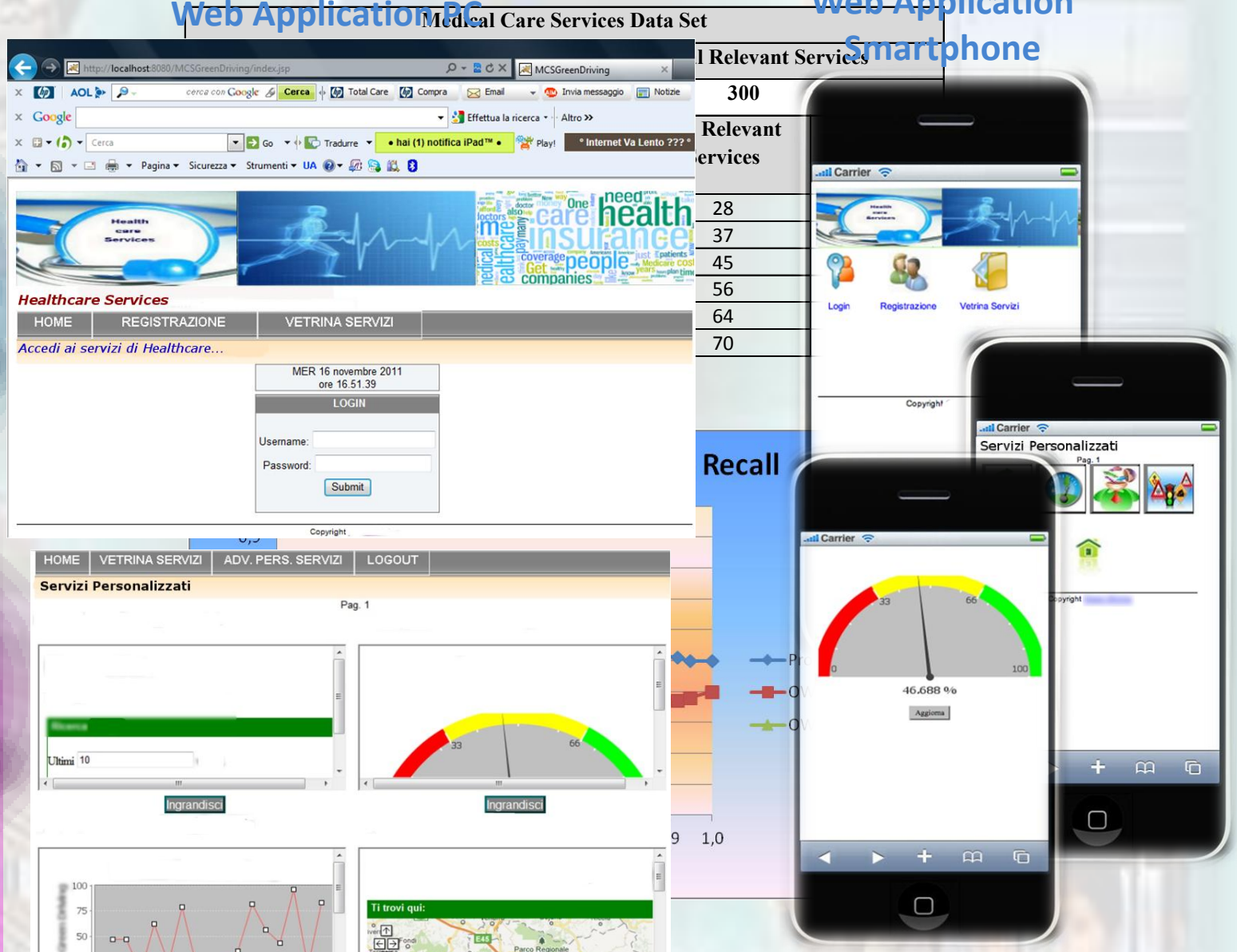
Web Application PC

Web Application Smartphone



CAPSD Research Objectives

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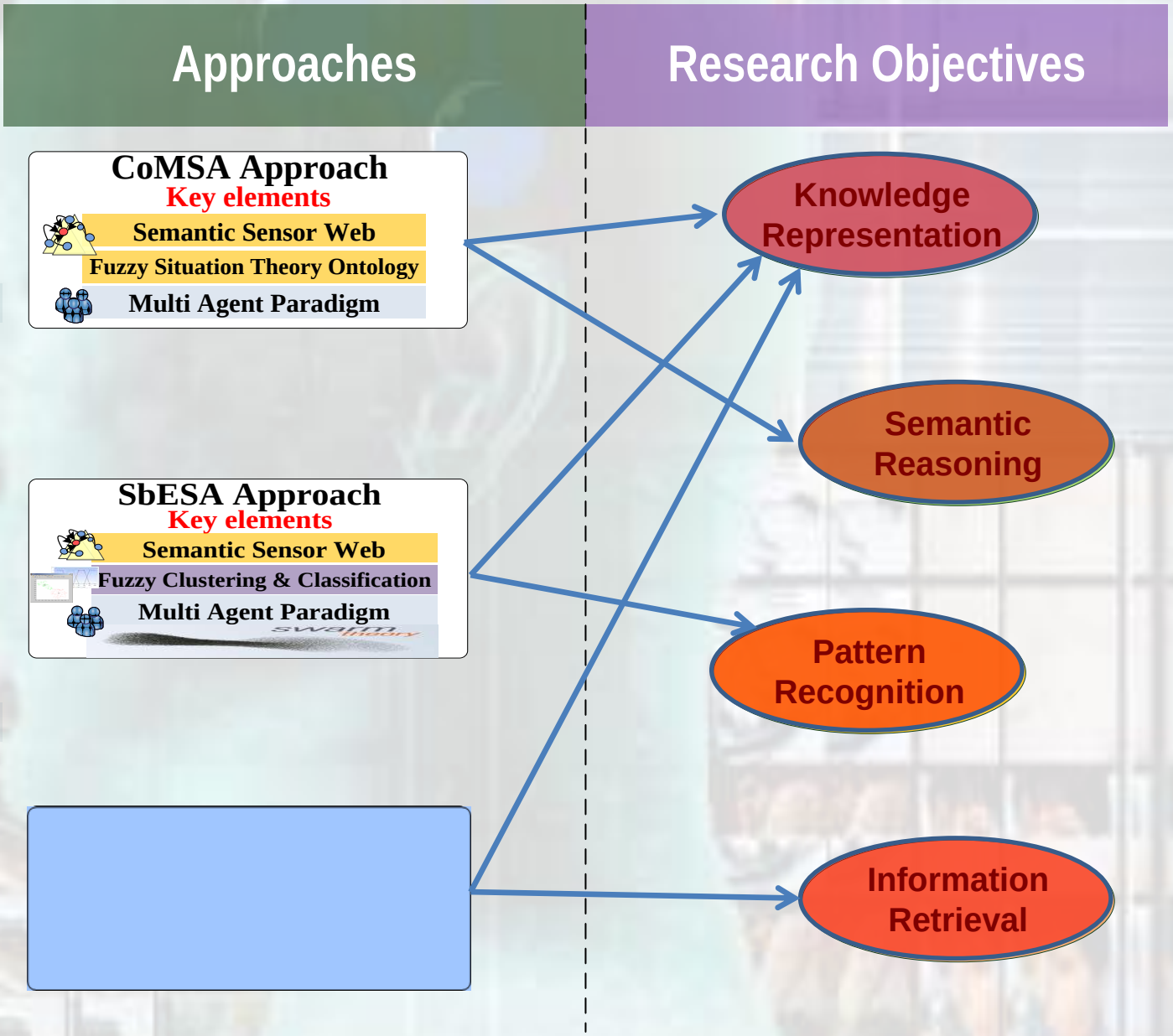

Final Remarks

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- This research work analyzes and addresses the main issues in the fields of **Situation** and **Context Awareness**.
- As result, this work proposes to combine technologies deriving from **Semantic Web** and techniques of **Computational Intelligence** in order to overcome these challenges and meet research objectives:
  - ✓ Knowledge Representation;
  - ✓ Semantic Reasoning;
  - ✓ Pattern Recognition;
  - ✓ Information Retrieval.
- The **main contributions** of this research work concern with:
  - ✓ the exploitation of sensor ontologies to support the acquisition and aggregation of dynamic environmental information from the field (i.e. sensors, cameras, etc.);
  - ✓ the definition of formal approaches to knowledge representation (i.e. situations, contexts, concepts, relations, etc.);
  - ✓ the definition of formal approaches to knowledge processing (i.e. reasoning, classification, extraction, retrieval, recognition, discovery, etc.);
  - ✓ the definition of multi-agents architectures capable to efficiently support the modeling and processing of a large amount of knowledge.
- **Future works** are going to focus on:
  - ✓ Semantic Modeling of Fuzzy Control;
  - ✓ Temporal Issues;
  - ✓ Automatically Ontology Elicitation;
  - ✓ Semantic Query Editing;
  - ✓ Extension to other Application Domains;
  - ✓ More Experiments.

Scientific Publications

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- Chapters:
  - Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, Sabrina Senatore, "Ap-proximate processing in medical diagnosis by means of deductive agents". In Handbook on Reasoning-Based Intelligent Systems. Nov 2012 ISBN: 978-981-4329-47-7.
- International Conferences:
  - Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, Mario Veniero, "Agent-based Cognitive approach to Airport Security Situation Awareness", in the proceedings of International Conference on Complex, Intelligent and Software Intensive Systems, 2010, ISBN: 978-0-7695-3967-6, pages 1057-1062.
  - Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, "Enhanced healthcare en-vironment by means of proactive context aware service discovery", in the proceedings of the 25th IEEE International Conference on Advanced Information Networking and Applications (AINA-2011) Biopolis, Singapore, March 22 - 25, 2011, ISBN: 978-0-7695-4337-6, pages 625-632.
  - **Domenico Furno**, Vincenzo Loia, Mario Veniero, Marco Anisetti, Valerio Bellandi, Paolo Ceravolo, Ernesto Damiani,"Towards an Agent-based Archi-tecture for managing Uncertainty in Situation Awareness", in the proceedings of 2011 IEEE Symposium on Intelligent Agents, April 11-15, 2011 - Paris, France, ISBN: 9781612840598, pages 1-6.
  - Giuseppe Fenza, Enrico Fischetti, **Domenico Furno**, Vincenzo Loia, "A hybrid context aware system for tourist guidance based on collaborative filtering", in the proceedings of 2011 IEEE International Conference on Fuzzy Systems, June 27-30, 2011- Taipei, Taiwan, 978-1-4244-7315-1, pages 131-138.
  - Carmen De Maio, Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, "Swarm-based approach to evaluate fuzzy classification of semantic sensor data", submitted to 8th IEEE International Workshop on Sensor Networks and Systems for Pervasive Computing, March 19-23, 2012 - Lugano, Switzerland.
  - Carmen De Maio, Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, "Swarm-based semantic fuzzy reasoning for Situation Awareness Compu-ting". In the proceedings of IEEE World Congress on Computational Intelli-gence, June 10-15, 2012 - Brisbane, Australia.
  - Carmen De Maio, Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, "f-SPARQL extension and application to support context recognition". In the proceedings of IEEE World Congress on Computational Intelligence, June 10-15, 2012 - Brisbane, Australia.
- Journals:
  - **Domenico Furno**, Vincenzo Loia, Mario Veniero, "A fuzzy cognitive situa-tion awareness for airport security". In "Control and Cybernetics" journal, 2010, vol. 39, issn 0324-8569, No. 4, pages 959-982.
  - Carmen De Maio, Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, Sabrina Senatore, "OWL-FC: an upper ontology for semantic modeling of Fuzzy Control". Journal of Soft Computing - A Fusion of Foundations, Methodolo-gies and Applications, Springer, pp. 1-12, Issn: 1432-7643, Doi: 10.1007/s00500-011-0790-4.
  - Giuseppe Fenza, **Domenico Furno**, Vincenzo Loia, Hybrid approach for con-text-aware service discovery in healthcare domain, Journal of Computer and System Sciences, Volume 78, Issue 4, July 2012, Pages 1232-1247, ISSN 0022-0000, 10.1016/j.jcss.2011.10.011.
  - **Domenico Furno**, Vincenzo Loia, Alfredo Vaccaro, "Decentralised Smart Grids Monitoring by Swarm based Semantic Sensor Data Analysis", submit-ted to the International Journal of Systems, Control and Communications (IJSCC) Published/Hosted by Inderscience Publishers. ISSN (printed): 1755-9340. ISSN (electronic): 1755-9359.

Acknowledgements

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- My sincere acknowledgements go to:

SESM A Finmeccanica Company

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Azienda Ospedaliera San Camillo-Forlanini

- that made possible the definition of interesting application scenarios and the execution of meaningful experimentations.

Question Time

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Thank you for your attention