Toward a
Semantic Web of Things

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Outline

- The Semantic Web of Things (SWoT) vision
  - Reference Architecture
  - Reasoning in the SWoT
- SWoT Applications
  - Semantic-enhanced EPCglobal RFID
  - Driving Diagnostics and Assistance
  - Semantic-enhanced Navigation
  - Smart Home and Building Automation
  - Semantic Sensor Networks
  - Future works
- Collaboration
  - People
  - Opportunities
Semantic Web of Things
Emerging vision in ICT

Convergence of
- Internet of Things [ITU, Internet Reports, 2005]
  - promote the pervasive computing paradigm on a global scale
- Semantic Web [Berners-Lee et al., Scientific American, 2001]
  - share, reuse and combine information in the World Wide Web
  - formal, explicit semantics with logical underpinnings
- Process semantic annotations coming from a large number of heterogeneous micro-devices
- Embed intelligence into everyday objects and locations
- Take into account pervasive computing constraints
  - unpredictability
  - dependence on context
  - severe resource limitations
- Adapt procedures and tools for query and reasoning to the pervasive computing requirements
Knowledge Representation Systems

- **Terminological Box (TBox, a.k.a. ontology, conceptual knowledge)** describes a domain with respect to a reference vocabulary containing classes and properties.
- **Assertion Box (ABox, a.k.a. factual knowledge)** contains individuals describing the modeled excerpt of the observed reality.
- **Knowledge Base (KB = TBox + ABox)** used to infer further knowledge.
- Classic KBs are intended as **fixed and centralized** components.
Ubiquitous Knowledge Bases (u-KBs), evolution of classic KB paradigm

- assertional knowledge distributed across multiple micro-devices
- individuals characterized by:
  1. unique ID (e.g. EPC code, MAC address)
  2. ID of reference ontology (OUUID)
  3. semantic annotation
  4. data-oriented context-dependent attributes
- discovery protocol to build a local KB subset only when reasoning is needed
SWoT Architecture

[Ruta et al., IEEE-ICSC, 2012]
Reasoning in the SWoT

**Mini-ME: the mini matchmaking engine** [Ruta et al., ORE, 2012]

- A lightweight mobile matchmaker for semantic-based pervasive contexts
- Support to Semantic Web ontology languages and syntaxes through the OWL API
- Implemented in Java for the Android O.S.

**Reasoning Services**

- **Standard:** subsumption, satisfiability, classification
- **Non-standard:** Concept Contraction and Abduction [Ruta et al., WIAS, 2011]
  - on moderately expressive KBs
  - semantic matchmaking for resource/service retrieval and composition
SWoT applications and prototypes
Key technological features:

- Slight tag memory extension to store
  - a semantic annotation
  - a set of data-oriented contextual attributes
- Backward-compatible use of EPCglobal UHF Gen-2 Protocol to read/write tag contents
- Ontology identifier (OUUID) code to mark each ontology (hence, each resource category)
- EPCglobal ONS (Object Naming Service) for ontology support
- Compression algorithm to minimize length of semantic annotations
- Application-level integration with semantic-enhanced Bluetooth Service Discovery Protocol [Ruta et al., IJ SWIS, 2008]
Developed case studies

- Ubiquitous commerce [Ruta et al., IJ SWIS 2007]
- Product lifecycle management [Ruta et al., IJIPT 2007]
- Dynamic RFID-based logistics support [Ruta et al., ICEC 2008]
- Pattern analysis of semantic streams in smart supply chains [Ruta et al., IWRT 2011]
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Smart supply chains and ubiquitous commerce (7/10)

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A pair of ranked lists of discovered resources is returned; both the most similar products and the most suitable for a combination with the user request are provided.
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Decision support in healthcare: Architecture [Ruta et al., ISIE 2010]

- **Machine-understandable Knowledge Representation formalisms**
  - Borrowed from the Semantic Web → interoperability
  - Describing relevant healthcare entities and processes

- **Semantic-enhanced RFID** [Ruta et al., IJ SWIS, 2008]
  - Embed knowledge in the environment
  - Semantic descriptions stored in RFIDs
  - Semantic-based discovery via lightweight wireless protocols, *e.g.*, Bluetooth

- **Logic-based inference services for decision support**
  - Exploitation of DL-based matchmakers to infer new information
  - Open World Assumption
  - Concept Contraction and Concept Abduction
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Decision support in healthcare

[Ruta et al., ISIE 2010] (1/2)
Adverse indications

The medicine presents counter-indications for the patient:

- Renal
- Circulatory System

Ranking of alternative treatments

1. Name: ABDALIJIHAR
   - Class: Analgesic
   - Dosage: 50 mg
   - Indications: 1% of cases
     - Liver
     - Circulatory System

2. Name: PERINDOLE
   - Class: Corticosteroid
   - Dosage: 5 mg
   - Indications: 5% of cases
     - Liver
     - Circulatory System

3. Name: CORTIDONE
   - Class: Corticosteroid
   - Dosage: 50 mg
   - Indications: 6% of cases
     - Liver
     - Circulatory System

4. Name: IBUPROFEN
   - Class: Anti-inflammatory
   - Dosage: 50 mg
   - Indications: 4% of cases
     - Circulatory System

5. Name: ASPIRIN
   - Class: Anti-inflammatory
   - Dosage: 50 mg
   - Indications: 5% of cases
     - Circulatory System
     - Gastrointestinal System
Semantic POIs Annotation in OpenStreetMap [Ruta et al., IEEE-MS, 2012]

- A method and tool to allow embedding of semantic annotations into OpenStreetMap (OSM) maps
- A navigation system with semantic-based discovery capabilities
- User friendly design to hide complexity of underlying logic-based formalisms
J OSM Plugin for Semantic POI Annotation

- Make any OSM contributor capable of semantically enriching map waypoints and POIs
- Based on simple drag-and-drop operations
- Ontology browser for request composition
- Embedded reasoning engine for matchmaking
- Semantic POI annotation extraction directly from OSM map data
Augmented Reality (AR) navigation tool

Discovery of POIs via a logic-based matchmaking

Result explanation and request refinement

Semantic POI annotation extraction directly from OSM map data

Transparent POI discovery by simply referring to the user profile
Driving Diagnostics and Assistance
[Ruta et al., SEBD, 2012]

Three subsequent stages repeatedly executed

Final outcomes are displayed on the iPhone screen along with acoustic alerts

DATA GATHERING

DATA PROCESSING

SEMANTIC-BASED CHARACTERIZATION AND MATCHMAKING

Three subsequent stages repeatedly executed

Final outcomes are displayed on the iPhone screen along with acoustic alerts

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30 of 46
Exploiting semantic-based matchmaking the system is able to evaluate vehicle health and risk levels.

A set of coloured icons suggests users how to reduce or even eliminate dangers and get better performance and lower environmental impact.

Depending on semantic matchmaking results, each icon changes its color to indicate a low, medium or high value of the related parameter.
Semantic-based enhancement of EIB/KNX protocol standard [Ruta et al., IEEE ICM, 2011]
Agent Framework

[Ruta et al., IEEE TII, 2013 - to appear]

Agent architecture oriented toward a Smart Grid vision

Negotiation protocol [Ragone et al., EC-Web, 2009], originally devised for e-marketplace scenarios, revised for buildings energy systems
Prototypical Testbed

Testbed

Main Panel

Camera

Weather Station

Alarm
Mobile User Profiler

Goals:

- Avoid explicit user interaction
- Automatically detect user needs by exploiting information available on smartphones
- Build a daily user profile
CoAP-based Sensor Networks
[Ruta et al., IEEE iThings, 2013]

IETF candidate standard protocol for WSNs and IoT scenarios [Bormann et al., IEEE IC, 2012]
Semantic-based resource discovery

1. **CoAP GET Request**
   
   **Semantic enhancement**
   
   Annotated request
   - Reference ontology (ro)
   - Semantic description (sd)
   - Annotation-type (at)

   Geographical location
   - Logitude (lg)
   - Latitude (lt)
   - Maximum distance (md)

   Reasoning task
   - Semantic task (st)
   - CCoP attribute
   - Similarity threshold attribute (sr)

2. **Solve CCoP**

3. **CCoP response**

4. **Query/observe the set with best score**

5. **Sensor Data**

6. **Mining & Semantic Event annotation**

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37 of 46
Case Study: Environmental Monitoring

- SSN-XG ontology for Semantic Sensor Networks (SSNs) [Compton et al., JWS, 2012] extended to describe events and sensor nodes for environmental monitoring.

- Simulation of a WSSN for detection and annotation of fire risk events:
  - Sink prototype implemented using EFIKA mainboard
  - Sensor data dumps used for system tests
Smart gesture recognition

- Ontology-based semantic annotation of data acquired via Kinect
- Semantic matchmaking for posture/gesture/action detection
Future Work: Sentiment Analysis

Developing a complete platform to:

- monitor biological signals of actors involved in social scenarios via wearable electronics
- extract vital parameters (type, quality and level of emotions)
- annotate human emotions using Semantic Web technologies
- identify corrective factors to enable a feedback control
Object (B)logging: self-description of objects in pervasive environments without outside interventions during its everyday life

Descriptions similar to blog’s entries ("posts")

Proposed approach:

Machine Learning algorithms used to:
- extract the context from the environment
- define a semantic-based object annotation

Stream Reasoning in pervasive contexts for advanced data mining

Knowledge-based discovery protocols for resource constrained environments, e.g. Wireless Semantic Sensor and Actor Networks (WSSANs)
Future work: Vehicular Ad-hoc NETworks (VANETs)

- **OBU** (On-Board Unit)
  - Data acquisition, processing and annotation for driver assistance

- **V2V** (Vehicle-to-Vehicle)
  - Semantic-enhanced protocol for information propagation and fusion
  - Increased safety for all vehicles, even those without on-board sensing platforms

- **V2I** (Vehicle-to-Infrastructure)
  - Update of Road-Side Units (RSU) and then to OpenStreetMap servers
  - Real-time traffic and road conditions update on OSM
Future work: opportunistic model checking

- Model checking: automated system verification technique based on
  - automata modeling the system
  - temporal logics to specify the properties to be checked
- Advantages:
  - no proofs required
  - in case of property violation, a counterexample is produced
- Problem: combinatorial state space → explosion of verification complexity
- Traditional solutions:
  - State space encoding
  - Approximated models
- For pervasive resource-constrained devices and environments, we want to define a new approach,
  - borrow concepts from opportunistic networks
  - divide and solve problems according to available computational resources
Full professor:
Eugenio Di Sciascio

Assistant professor:
Michele Ruta

Post-doc researchers:
Floriano Scioscia, Giuseppe Loseto

Ph.D. students:
Maria di Summa, Agnese Pinto

Research assistants:
Filippo Gramegna, Saverio Ieva
Publications and Awards

- Peer-reviewed publications:
  - 12 articles in international journals
  - 6 book chapters
  - > 35 papers in international conferences

- Awards:
  - ICEC 2007 Best Theme Paper Award - "RFID Meets Bluetooth in a Semantic Based U-commerce Environment" by Michele Ruta, Tommaso Di Noia, Eugenio Di Sciascio, Giacomo Piscitelli, Floriano Scioscia.
  - SEMAPRO 2010 Best Paper Award - "Semantic-based Geographical Matchmaking in Ubiquitous Computing" by Michele Ruta, Floriano Scioscia, Eugenio Di Sciascio and Giacomo Piscitelli
  - AI*IA 2011 Best Ph.D. Thesis Award - Floriano Scioscia won the AI*IA (Italian Association for Artificial Intelligence) 'Marco Cadoli' 2011 Award for the best Ph.D. thesis on Artificial Intelligence
  - ESWC 2011 Best Poster Award - “A Semantic-based Pervasive Computing Approach for Smart Building Automation” by Giuseppe Loseto
  - 56th National Engineers Congress Award - A SisInfLab alumnus, Nicola De Leo, won for the best master’s degree thesis in the ICT field with a work titled "Monitoraggio del comportamento di un autoveicolo attraverso l'interfaccia OBD-II modificata per via semantica", Supervisors: Eugenio Di Sciascio, Michele Ruta
  - KNX Award 2012 Nominee – Project “Semantic Web of Things at Home with KNX" by Michele Ruta, Eugenio Di Sciascio, Floriano Scioscia and Giuseppe Loseto
Opportunities

- All the presented topics are possible thesis subjects for bachelor’s or master’s degree

Requirements:
- problem-solving attitude
- dedication to study
- development skills

Contacts
- SisInfLab, Monday 5-7 p.m.
- E-mail