Chapter XIV
Leveraging Semantic Technologies towards Social Ambient Intelligence

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ABSTRACT

These times, when the amount of information exponentially grows on the Internet, when most people can be connected at all times with powerful personal devices, we need to enhance, adapt, and simplify access to information and communication with other people. The vision of ambient intelligence which is a relevant response to this need brings many challenges in different areas such as context-awareness, adaptive human-system interaction, privacy enforcement, and social communications. The authors believe that ontologies and other semantic technologies can help meeting most of these challenges in a unified manner, as they are a bridge between meaningful (but fuzzy by nature) human knowledge and digital information systems. In this chapter, the authors will depict our vision of "Social Ambient Intelligence" based on the review of several uses of semantic technologies for context management, adaptive human-system interaction, privacy enforcement and social communications. Based on identified benefits and lacks, and on our experience, they will propose several research leads towards the realization of this vision.

INTRODUCTION

These times, when the amount of information exponentially grows on the Internet, when most people can be connected at all times with powerful personal devices, users suffer from the growing complexity of the information society. Our use of technology is moving towards the vision of "Ambient Intelligence", derived from the vision of "Ubiquitous computing" in which "the most profound technologies are those that disappear" (Weiser, 1991) . Thus, access to information is no longer limited to personal computers and the web browsing paradigm. This vision brings many technological and psychological challenges (Streitz & Nixon, 2005) that are considered in several research domains, including:

- Context-awareness: how to take one's context into account to improve his communication ?
- Multimodality: how to span user interfaces from a terminal into separate modal interfaces ? (e.g. various screens, input controllers, microphones, phones)
- Social networking: how to enhance and leverage social communication ?
- Privacy & Trust: how to ease one's life without delegating human control to machines ?

There is one transversal question yet to answer: is there a unified approach that could answer these challenges in a global way and that makes sense? Actually, a common approach exists that is considered in all these research domains, and in most corresponding works and has been shown as very promising. This approach is the use of semantic technologies.

In this chapter, we propose a review of research works relying on semantic technologies towards what we call "Social Ambient Intelligence", a social extension of ambient intelligence. The intention here is to identify the key technologies, approaches and issues that may be blended in order to build an optimal platform for a widescaled ubiquitous system that can support social applications. After defining the foundational terms of this chapter in the Background section, we will review several research works to identify their key technologies, approaches and issues in the State-of-the-Art section, then we will propose several research leads towards our vision of "Social Ambient Intelligence" in the Future Trends section, to finally conclude this chapter.

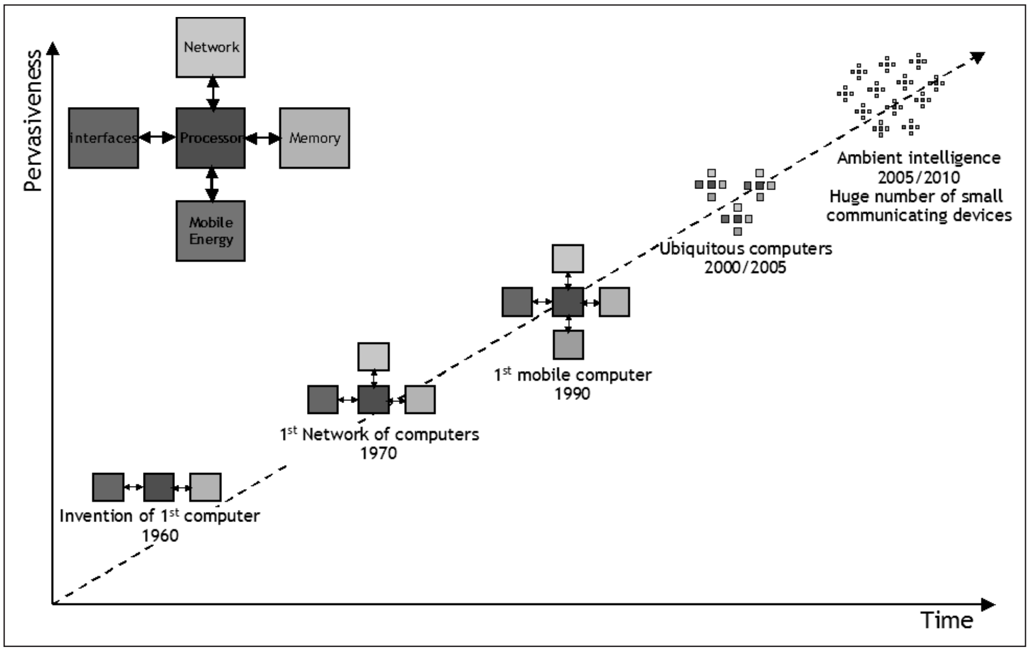
In this section, we propose and discuss the underlying definitions needed to set the foundations of this chapter: ubiquitous computing, context-awareness and semantic technologies.

Ubiquitous Computing, Ambient Intelligence and Context-Awareness

The phrase "ubiquitous computing" was proposed by Mark Weiser while working for the Xerox Palo Alto Research Center (PARC), to qualify a possible evolution of computers. "The Computer for the 21st century" (Weiser, 1991) has become a foundational paper for following works in this area. Indeed, it introduced a vision, in which "ubiquitous computers" are simple communicative devices and appliances that are suited for a particular task and are aware of their surrounding environment while fading into the background. For example, paper sheets could be replaced with flexible screens, bringing any information of the web as an independent element of a real desktop, an element that one could stack into piles, stick on a wall, lend to a colleague or take for lunch.

As depicted on Figure 1, the generation of ubiquitous computers has already arrived, as powerful and communicative computers are spread in many devices like watches, mobile phones, portable media players, game consoles, PDAs (Personal Digital Assistants), ticket machines, bike renting beacons and kids toys. Even though Mark Weiser's vision of interoperable and shared ubiquitous computers has not been reached yet,

Figure 1. The evolution of computing, adapted from "Nano computing & Ambient intelligence" (Waldner, 2007), © 2007 Hermes Science Publishing. Used with permission.

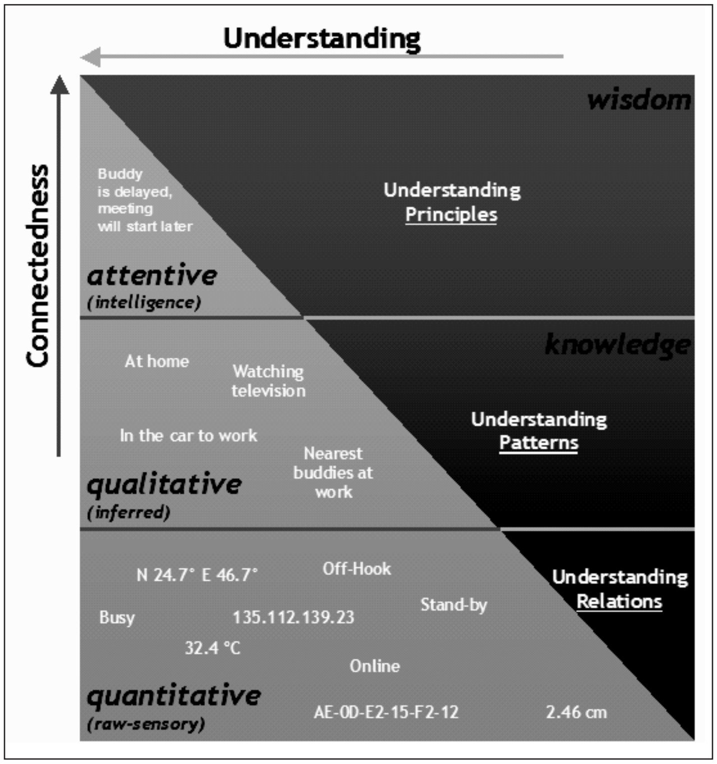


a significant research effort is done towards the vision of "Ambient intelligence" . As such, "Ambient Intelligence" is considered as an evolution of "ubiquitous computing" in which networked devices can also be integrated in the environment (and thus not expecting any user intervention), can sense the environmental, personal and social situation to adapt the experience, and can anticipate forthcoming situations or actions in order to ease and enhance people lives.

Firstly defined by (Schilit, Adams, & Want, 1994), context-awareness is a key research domain towards the vision of Ambient Intelligence. It consists in acquiring low-level context data (e.g. from sensors), inferring high-level knowledge from this data, and predicting context changes in order to clearly improve the user experience. As depicted on Figure 2, the low level of context contains current raw sensor data like GPS coordinates, IP address, surrounding Bluetooth MAC addresses or temperature. By combining and inferring on this knowledge, a meaningful position or activity like "in a meeting" or "watching TV" can be deduced to form a higher level of context. Then, after having learnt the habits of the user, predictions can be made about the actions that are probably going to happen next or about the exceptional cases that have occurred (e.g. the user is going to arrive late at work because he has not left home yet) in order to undertake relevant actions pro-actively (e.g. inform the colleagues that the meeting is delayed).

Context-awareness aims to make user interfaces automatically adapt to the user's environment and intents. It can enhance user inputs without requiring additional efforts from the user (Leong, Kobayashi, Koshizuka, & Sakamura, 2005) and also adapt outputs (Sadi & Maes, 2005). Although several works have been focusing on the implementation of context-awareness on mobile

Figure 2. Levels of context (© Bell Labs. Used with permission.)



devices (Christopoulou, 2008; Korpipää, Häkkilä, Kela, Ronkainen, & Känsälä, 2004; Häkkilä & Mäntyjärvi, 2005), we will not specifically address mobile-based context-aware platforms in this paper.

Semantic Technologies: Ontologies, Knowledge Representation and Reasoning

In their study, (Strassner, O'Sullivan, & Lewis, 2007) define ontologies as « a formal, explicit specification of a shared, machine-readable vocabulary and meanings, in the form of various entities and relationships between them, to describe knowledge about the contents of one or more related subject domains throughout the life cycle of its existence ». Semantic technologies, including ontologies and semantic description languages, are quite similar to human thinking and memorization: they allow the definition of concepts and instances (of these concepts) that are related with each other using semantically qualified links. They also allow to develop an inferred knowledge from the reasoning on this knowledge (Gruber, 1993). Applying such approach to information technologies enable machines to understand the actual meaning of data which is formulated using a distributed and evolving vocabulary. That way, ontologies fill the gap between ambiguous/fuzzy human thinking (e.g. in natural languages, a word can have different meanings) and formalized digital data (i.e. stored using specific formats and interpreted by specific applications for a specific purpose).

One of the benefits of using semantic languages is to allow progressive/incremental modeling of a system, reflecting the natural progression of conceptual understanding of domains. Ontologies can ease the communication between heterogeneous entities (i.e. using different languages/protocols) by matching similar portions of the semantic graph of the sender's knowledge with the recipient's knowledge.

On the other hand, we would like to prevent the reader to make the naïve assumption that semantic technologies are a magic solution to empower machines with autonomic intelligence. It may seem possible to model our universe as an ontology, allowing computers to understand the human world, but it is actually impossible. Indeed, modeling is always relative to a point of view, and integrating ontologies from experts of several domains would necessarily lead to inconsistencies. There is also a usual confusion about the so-called "Semantic Web" (Berners-Lee, Hendler, & Lassila, 2001). This expression does not mean that internet users will have to deal with semantic languages to communicate on the web, but it refers to a set of languages and tools that would allow web resources (i.e. web pages and services) to be described semantically in order to allow seamless processing of knowledge distributed among heterogeneous sites. Today, with the rise of the "Web 2.0" (O'Reilly, 2005), users are already able to create "mash-ups" relying on several components and data streams hosted on different sites. However, the next step is possibly to automatize (or, at least, to ease) the development of such mash-ups, assuming that web data and components are semantically described.

In the next section, we will investigate the use of semantic technologies in ubiquitous context-aware systems in order to identify the existing blocks that we will rely on to build our vision of "Social Ambient Intelligence".

STATE-OF-THE-ART

Previous studies (Strang & Linnhoff-Popien, 2004; Baldauf, Dustdar, & Rosenberg, 2007; O. Lassila & Khushraj, 2005) have identified ontologies as the most promising enabler for ubiquitous context-aware systems because they are heterogeneous and extensible by nature, and semantic technology enables « future-proof » interoperability. In this section, we will study the use of semantic technologies in four aspects of ambient intelligence: context management, human-system interactions, privacy enforcement, and social communications.

Semantic Context Management

According to (Dey, 2001), "a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task". By context, Dey means "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves".

(Gu, Wang, Pung, & Zhang, 2004) gave an introduction to context-awareness by proposing the following requirements: « An appropriate infrastructure for context-aware systems should provide support for most of the tasks involved in dealing with contexts - acquiring context from various sources such as physical sensors, databases and agents; performing context interpretation; carrying out dissemination of context to interested parties in a distributed and timely fashion; and providing programming models for constructing of context-aware services. »

The use of ontologies to store and manipulate context have an impact on other aspects of the underlying system: context knowledge exchange, learning, user interactions, security and applications. In this section we will review several semantic-based approaches for context management platforms and identify the most successful approaches and current lacks.

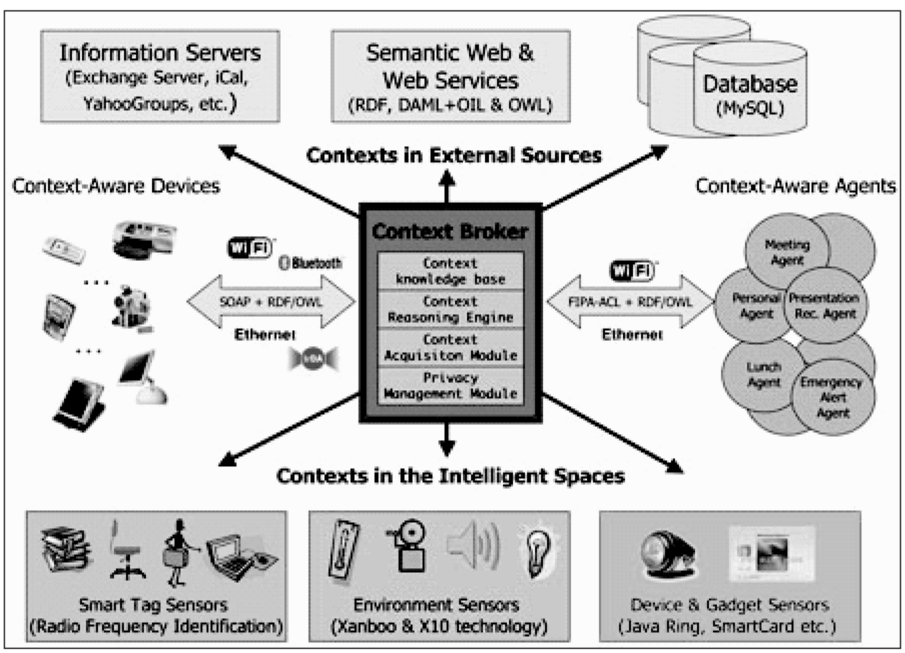
Review of Major Context-Aware Platforms

One of the first semantic context modeling approaches was the **Aspect-Scale-Context (ASC)** model proposed by (Strang, Linnhoff-Popien, & Frank, 2003). Compared to non-semantic models, ASC enabled contextual interoperability during service discovery and execution in a distributed system. Indeed, this model consists of three concepts:

- Aspects are measurable properties of an entity (e.g. the current temperature of a room)
- Scales are metrics used to express the measure of these properties (e.g. Celsius temperature)
- Context qualifies the measure itself by describing the sensor, the timestamp and quality data

Contexts can be converted from a scale to another using Operations, also described semantically, and can be mapped to an implemented service. This model has been implemented as the CoOL Context Ontology Language. The CoOL core ontology can be formulated in OWL-DL (Dean & Schreiber, 2004) and F-Logic (object-oriented). The CoOL integration is an extension

Figure 3. Overview of CoBrA, © 2003-2008 Harry Chen. Used with permission.



of the core to inter-operate with web services. OntoBroker (Decker, Erdmann, Fensel, & Studer, 1999) was chosen for semantic inference and reasoning, supporting F-Logic as knowledge representation and query language.

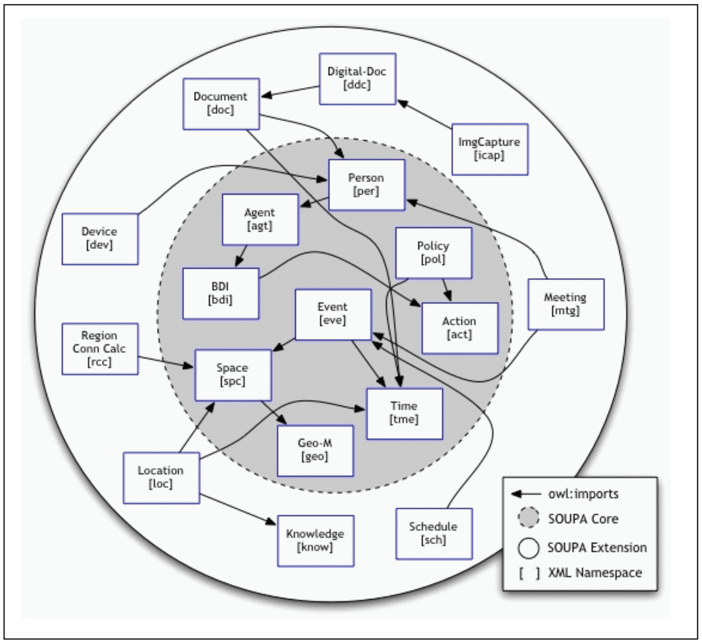
With EasyMeeting, (Chen et al., 2004) proposed a pragmatic application to demonstrate the benefits of their semantic context-aware system called **CoBrA**, for Context Broker Architecture. This application assists a speaker and its audience in a meeting situation by welcoming them in the room, dimming the lights, and displaying the presentation slides, either by vocal commands or automatically. The underlying prototype that they developed is a multi-agent system based on JADE (Java Agent DEvelopment Framework) [http://sharon.cselt.it/projects/jade/] in which a broker maintains a shared context model for all computing entities by acquiring context knowledge from various sensors and by reasoning on this knowledge to make decisions, as depicted on Figure 3. In the EasyMeeting application, this broker can deduce the list of expected participants and their role in the meeting by accessing their schedule, and can sense their actual presence when the bluetooth-enabled mobile phone declared in their profile is detected in the room. That way, the system can notify the speaker about their presence, decide to dim the lights and turn off the music when he arrives. These decisions are made possible by reasoning on the context knowledge using rules defined by the EasyMeeting application. The context knowledge is represented as RDF triples relying on the COBRA-ONT OWL ontology that includes vocabularies from the SOUPA ontology (Chen, Perich, Finin, & A. Joshi, 2004) covering time, space, policy, social networks, actions, location context, documents, and events, as depicted on Figure 4. Inferencing on the OWL ontology is handled by JENA's API [http://jena.sourceforge.net] whereas the JESS rule-based engine [http://herzberg.ca.sandia.gov/] is used for domain-specific reasoning. The execution of rules (when results cannot be inferred from ontology axioms alone) uses the forward-chaining inference procedure of JESS to reason about contextual information. Note that, in this case, essential supporting facts must be extracted from RDF to JESS representation and the eventual results have to be injected in RDF to the knowledge base, which implies additional overhead in the process.

CoBrA's broker enforces privacy policies to define rules of behavior and restrict context communication. The enforcement of user-defined policies relies on the Rei role-based policy-reasoning engine (Kagal & T. A. Joshi, 2003) which does description logic inference over OWL. CoBrA also implements a meta-policy reasoning mechanism so that users can override some aspects of a global policy to define specific constraints at their desired level of granularity. However, they do not provide a tool for the user to express his/her privacy policy.

The **SOUPA** ontology proposed by (Chen et al., 2004) and used in CoBrA was a collaborative effort to build a generic context ontology for ubiquitous systems. Since 2003 it has been maintained by the "Semantic Web in Ubiquitous Comp Special Interest Group". The design of this ontology is driven by use cases and relies on FOAF, DAML-Time, OpenCyc (symbolic) + OpenGIS (geospatial) spatial ontology, COBRA-ONT, MoGATU BDI (human beliefs, desires and intentions) and Rei policy ontology (rights, prohibitions, obligations, dispensations). SOUPA defines its own vocabulary, but most classes and properties are mapped to foreign ontology terms using the standard OWL ontology mapping constructs (equivalentClass and equivalentProperty), which allows interoperability. In the core ontology in which both computational entities and human users can be modeled as agents, the following extensions are added: meeting & schedule, document & digital document, image capture and location (sensed location context of things).

Like CoBrA, **MOGATU** (Perich, Avancha, Chakraborty, A. Joshi, & Yesha, 2005) is a context-aware system based on the SOUPA ontol-

Figure 4. The SOUPA ontology, © 2003-2008 Harry Chen. Used with permission.



ogy. However, this decentralized peer-to-peer multi-agent system implements several use cases covering automatic and adaptive itinerary computation based on real-time traffic knowledge, and commercial recommendation. In this approach, each device is a semi autonomous entity driven by the user's profile and context, relying on a contract-based transaction model. This entity is called InforMa and acts as a personal broker that handles exchanges with other peers. The user profile semantically defines his beliefs, desires and intentions, following the BDI model that is part of the SOUPA ontology. Beliefs are weighted facts depicting user's knowledge and preferences such as his schedule and food preferences, whereas desires express the user's goals. Intentions are defined as a set of intended tasks that can be inferred from desires or explicitly provided. However no clues are given by the authors about how these beliefs and intentions are defined by the user or the system, which let us assume that this is still a manual process yet to be enriched with profiling mechanisms and a graphical user interface to edit the profile. Moreover, this work being apparently focused on trusted peer-to-peer exchange of information according to the BDI user profile, details on the actual reasoning process on context knowledge are not given. InforMa is able to process queries that can possibly involve other peers and advertise information to these peers in vicinity, relying on graph search and caching techniques. However no details were given on how pro-activity is made possible. Another lack identified in the underlying BDI model is that the representation of pre-conditions and effects of intentions are left to the applications, but we have found no clues on how applications fill this issue. Facing an important cost of network transmissions in the exchange process, it seems that this research group is focusing on peer-to-peer networking optimization and trusted exchanges more than on the actual context management. However, they suggested that preparing purpose-driven queries in advance and caching intermediate query results could improve the performance of their system, which is an interesting approach that should be considered in distributed context-aware systems.

The CORBA-based **GAIA** platform proposed by (Ranganathan, Al-Muhtadi, & Campbell, 2004) focuses on hybrid reasoning about uncertain context, relying on probabilistic logic, fuzzy logic and Bayesian networks. In their approach, context knowledge is expressed using predicates which classes and properties are defined in a DAML+OIL ontology (Horrocks, 2002). Predicates can be plugged directly into rules and other reasoning and learning mechanisms for handling uncertainty. This choice reduces the overhead of the CoBrA system relying on RDF triples. Rules are processed by the XSB engine [http://xsb.sourceforge.net/], which is described as a kind of optimized Prolog that also supports HiLog, allowing unification on the predicate symbols themselves as well as on their arguments. HiLog's sound and complete proof procedure in first-order logic is needed to write rules about the probabilities of context.

GAIA's authentication mechanism demonstrates the usefulness of fuzzy/uncertain context reasoning. It allows users to authenticate with various means such as passwords, fingerprint sensor or bluetooth phone proximity. Each of these means have different levels of confidence, and some user roles may require that the user authenticates himself on two of them to cumulate their confidence level up to the required level.

Although GAIA proposes a common reasoning framework, application developers have to define the expected context inputs and specify the reasoning mechanism to be used by providing Prolog/HiLog rules (for probabilistic/fuzzy logic) or Bayesian networks. A graphical user interface is provided to help developers construct rules, whereas MSBN (Microsoft's Belief Network) can be used to create Bayesian nets. Although Bayesian networks are a powerful way to perform probabilistic sensor fusion and higher-level context derivation, they need to be trained. Moreover, inference with large networks (more than 50 nodes) becomes very costly in terms of processing and can result in scalability problems.

Based on previous works, (Gu et al., 2004) propose **SOCAM** (Service-Oriented Context-Aware Middleware), another OWL-based context-aware framework with the aim to address more general use cases by adding more qualitative information on acquired context. The classifiedAs property allows the categorization of context facts as Sensed, Defined, Aggregated or Deduced. The dependsOn property allows the justification of a deduced context based on other context facts. Another contribution is the possibility to qualify context information with parameters such as accuracy, resolution, certainty and freshness. The SOCAM framework was proven (Gu, Pung, & Zhang, 2004) to reason successfully on uncertain contexts using Bayesian Networks, but no performance results were given. The same group of authors have also carried out a performance experiment of the **CONON** ontology (Wang, Zhang, Gu, & Pung, 2004) depicted on Figure 5, which is the name that was given to SOCAM's context ontology. Their results show that the duration of the reasoning process exponentially increases with the number of RDF triples stored in the context knowledge base, which reveals that this approach is not scalable for a widespread context-aware system. Therefore two leads were proposed to increase performance:

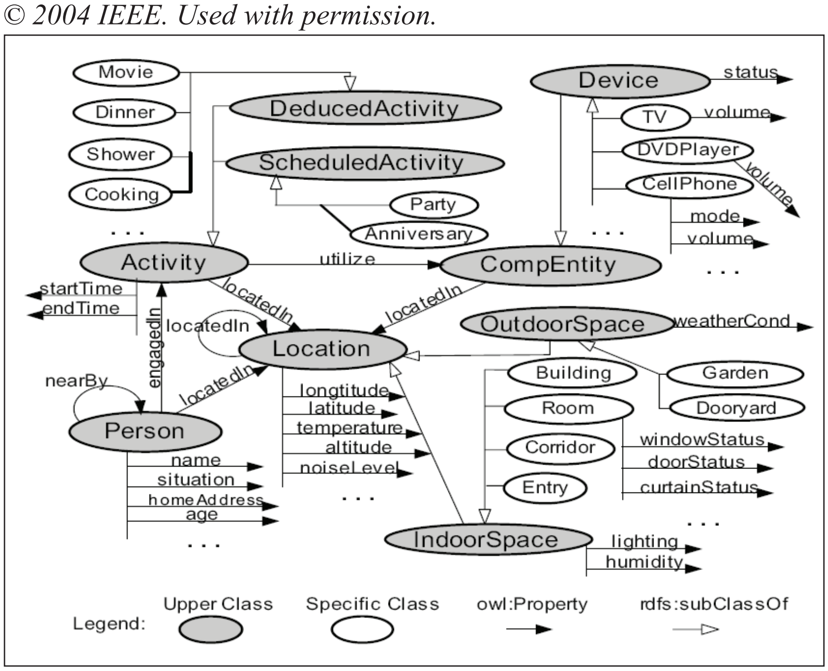
- To perform static, complex reasoning tasks (e.g., description logic reasoning for checking inconsistencies) in an off-line manner.
- To separate context processing from context usage, so that context reasoning can be performed by resource-rich devices (such as a server) while the terminals can acquire high-level context from a centralized service, instead of performing excessive computation themselves.

Later works of that team were focused on the peer-to-peer architecture for context information systems.

Basing on the CONON ontology, (Truong, Y. Lee, & S. Y. Lee, 2005) proposed the PROWL language ("Probabilistic annotated OWL") to generalize fuzzy/probabilistic reasoning from applications to domains by mapping Bayesian Networks to ontology classes and properties. This approach must be experimented with various context-aware applications to prove its feasibility.

The FP6 IST project **SPICE** (Service Platform for Innovative Communication Environment) brought a fresh approach to ubiquitous system, considering them in a wider scope centered on semantic knowledge management for improved ubiquitous end-user services (SPICE, 2006) (SPICE, 2007). On its Knowledge Management Layer, SPICE proposes two different implementations of the context provisioning subsystem: the IMS Context Enabler (ICE) (M. Strohbach, Bauer, E. Kovacs, C. Villalonga, & Richter, 2007) and the Knowledge Management Framework (KMF). In ICE, the SIP protocol (Session Initiation Protocol) is leveraged to control the parameters of the exchange sessions (e.g. data sets to communicate, update trigger, update frequency) and to flexibly adjust the communication path based on the changes in network structure and available context information. Both KMF and ICE rely on a shared ontology called the Mobile Ontology which is freely downloadable on the Internet [http://ontology.ist-spice.org/], the most important difference being the interfaces: ICE uses SIP whereas KMF uses OWL over SOAP Web Services for exchanging context information. However, gateways are also provided so that context data can be converted from a format to the other. Therefore we will abstract these implementations and focus on the common knowledge model. Embracing the

Figure 5. Partial definition of the CONON ontology extended with the home domain (Wang, Zhang, Gu, & Pung, 2004), © 2004 IEEE. Used with permission.



recommendations of the W3C, SPICE Mobile Ontology is defined in OWL and the context data is expressed in RDF. Inspired from the Dutch project Freeband Awareness, SPICE's Physical Space ontology has a finer granularity than any previous context ontology: it notably defines properties for connections between rooms and floors. Following the approach of the « Doppelgänger User Modeling System » (Orwant, 1995), SPICE's User Profile ontology supports domain-specific and conditional (situation-specific) submodels. In this approach, the profile contains subsets which are considered on certain conditions expressed with the form: Context Type, Operator, Value. This allows variations of the profile, depending on the user's context and/or the targeted application/service.

The Knowledge Management Layer also contains a Knowledge Storage module, a Profile Manager, a Service and Knowledge Push and Notification module and three kinds of Reasoners: a Predictor, a Learner and a Recommender. The reasoners can request past knowledge directly from context sources or from an external knowledge storage source. Both feedback-based and observation-based learning are supported, generating LearntRule and LearntRuleSet instances in OWL. The results can be leveraged to propose Recommendations to the user. Experimental results on the use of different learning techniques are to be published. Another interesting contribution of SPICE in the context-awareness domain is the use of a KnowledgeParameter class that is used to qualify context information with values defining their probability, confidence, timestamp, temporal validity and accuracy. However we have not found any mechanism that is similar to the "dependsOn" property supported by SOCAM to justify high-level context with lower-level facts from which it was inferred.

Figure 6. Creating a rule-based service using SPICE's End User Studio (SPICE 2007) © 2008 SPICE. Used with permission.

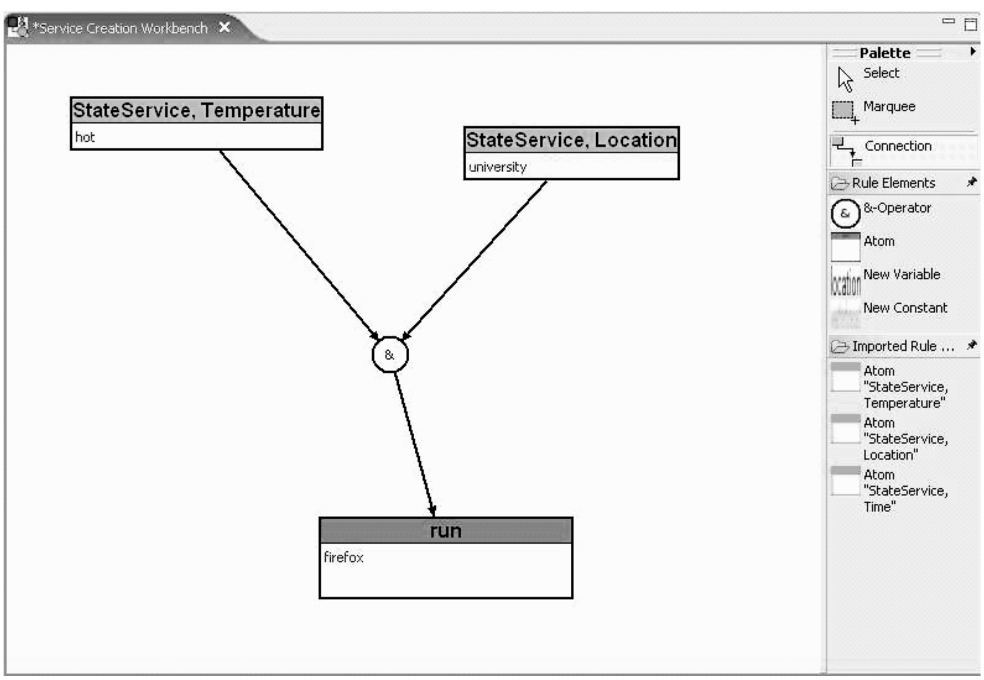
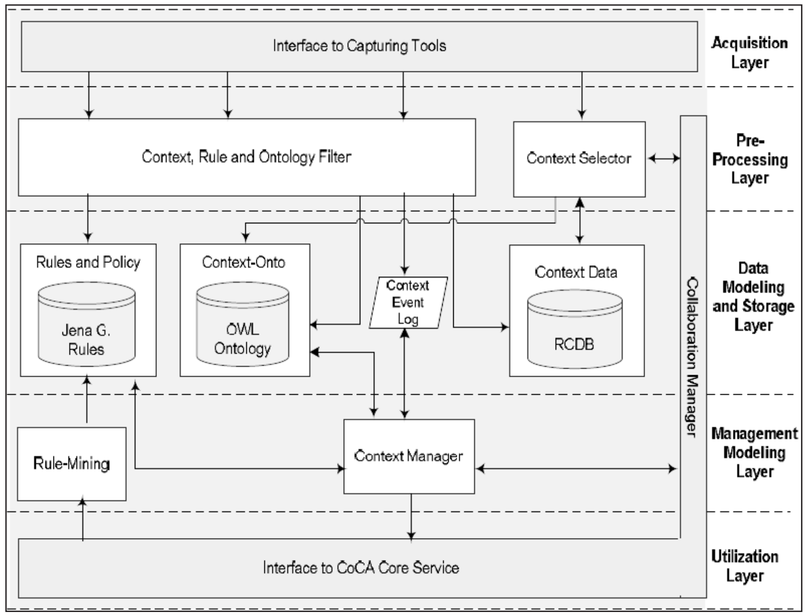


Figure 7. HCoM: Hybrid Context Management and reasoning system (Ejigu et al. 2007), © 2007 IEEE. Used with permission.



Another part of the SPICE project called the Distributed Communication Sphere (Kernchen et al., 2007) allows dynamic discovery of users' surrounding devices, networks and services. This part includes components that leverage context knowledge to enable multimodal interaction, content delivery, data synchronization and dynamic widgets on terminals, requiring a lightweight rule engine to be deployed on every terminal. SPICE also provides the End User Studio, an Eclipse-based GUI (Graphical User Interface) shown on Figure 6 that allows end users to create custom trigger-action rules visually.

One of the biggest identified issues in previously reviewed semantic context-aware systems is the processing time required for reasoning on context knowledge. To answer this issue, (Ejigu, Scuturici, & Brunie, 2007) proposed an hybrid context management and reasoning system (HCoM) which relies on a heuristic-based context selector to filter the context data to be stored in the semantic context base for reasoning, the rest being stored in a relational database, as depicted on Figure 7. They report that this approach is more scalable than pure semantic context-awareness systems when the number of static context instances increases. (Lin, Li, Yang, & Shi, 2005) propose a similar approach but they filter context data according to their relevance to running applications instead of usage heuristics, in order to boost the reasoning performance.

(Tan, Zhang, Wang, & Cheng, 2005) propose to move from on-demand context reasoning to event-driven context interpretation so that reasoning on context data is processed as soon as it is received by the context management framework. However, in their distributed system, the performance is reduced because of increased communication overheads. Moreover, it does not support uncertainty yet.

Trends and Issues

In this section, we have reviewed several approaches addressing modeling, reasoning and distribution of contextual knowledge. Although semantic technologies have been shown as powerful tools to empower context-awareness, they also imply scalability problems, as the required processing time grows exponentially with the amount of knowledge, which is a major issue towards the realization of Ambient Intelligence. However, hybrid context management approaches leverage the assets of both relational and semantic context management, therefore they should be considered in the aim of building a powerful and scalable context-awareness system. Nevertheless, the selection/filtering of context data to be merged in the semantic database is not trivial and may need further research. Another track to consider is closer coupling or integration of rule engines with knowledge bases in order to reduce processing overheads.

Semantics for Adapted Human-System Interactions

After context-awareness, another key aspect of Ambient Intelligence is how the user interacts with the digital world. Today, most internet-based interactions rely on the use of computers (i.e. a screen, a keyboard and a mouse). Whereas most people carry their own powerful mobile phone with them, most of the popular content and services are not adapted to general mobile devices with their constraints (small screen, no keyboard). Of course some of those have been adapted specifically to some popular platforms like the iPhone, but the vision of Ambient Intelligence is not only (i) to bring most of them to virtually any terminal according to its capabilities, but also (ii) to span various modalities of interaction over multiple interfaces (i.e. displays, inputs, speakers and other objects). Therefore, ambient services need to know the capabilities of every platform and interface they are used with, and they need to adapt the interaction to the user according to these capabilities. In this section we will review existing technologies for the discovery of devices and the description of their capabilities in order to enable rich user interactions and multimodality.

Semantic Discovery and Description of Interfaces

CC/PP (Composite Capabilities / Preferences Profile) (Klyne et al., 2004) is a recommendation from the W3C based on the Resource Description Framework (RDF) to create profiles that describe device capabilities and user preferences. It provides a syntax and tools to create terminal profiles and preference vocabularies, and thus can not be used as is. Indeed, the vocabulary of capabilities used for defining profiles is not in the scope of this recommendation and only structural rules and guidelines for interoperability are provided. However, the recommendation includes a pointer to the UAProf vocabulary as a referred example; we will review this vocabulary below. Among the features of the CC/PP syntax, allowed value types are listed, and the definition of default values is explained. The state-of-the-art of (SPICE, 2006) pointed out that conditional constraints are not supported in CC/PP. Moreover, the recommendation clearly informs that a CC/PP profile may include sensitive data, and delegates the enforcement of privacy to the application/system.

UAProf (User Agent Profile) (WAP Forum, 2001) is a CC/PP vocabulary for WAP (Wireless Application Protocol) enabled cell phones developed by the Open Mobile Alliance (OMA). The idea is that compliant cell phones have their capabilities described in a profile stored on a web repository so that adaptive services can gather this information in order to tailor content for embedded web browsers. This vocabulary is focused on software and hardware capabilities, and thus does not cover preferences.

WURFL (Wireless Universal Resource File) [http://wurfl.sourceforge.net/uaprof.php] is a collaborative effort to build an open XML file that describes device profiles based on fixes of their UAProf profiles. This promising initiative addresses several shortcomings of the original UAProf approach in which profiles can be inconsistent across providers, not up to date, or even do not exist.

The Foundation for Intelligent Physical Agents (**FIPA**) also proposed a device description ontology (FIPA, 2002) that can be used to reason and make decisions on the best device and modalities to create a user interface in multi-agent systems. Due to the nature of multi-agent systems, this approach differs from CC/PP in the manner of transmitting the profile. Instead of providing its complete profile on-demand, the terminal returns profile subsets adaptively to requests, allowing to set the granularity and scope of the required profile content in a gradual negotiation between agents. Whereas a CC/PP profile defines the capabilities for the software, hardware and the browser, FIPA Device Description supports the description of agent-related capabilities instead of the browser's. However, it is possible to use this ontology in a CC/PP profile, similarly to UAProf.

Even though this approach is not based on semantic technologies, the **UPnP** (Universal Plug and Play) discovery protocol (UPnP Forum, 2003) defines a XML language that can describe a physical device into a hierarchy of logical devices which map every hardware component of the device and thus its corresponding capability. A deeper study of UPnP is not in the scope of this chapter, but the modularity of this approach is interesting and should be considered in order to improve the re-usability of profiles, according to the fact that common hardware components are part of many devices.

Semantics for Multimodality

When devices and their capabilities are discovered, their use for multimodal interaction requires additional negotiation and synchronization so that user interaction constraints and preferences are respected for a rich user experience. The constraints to validate cover the quality of rendering/sampling, the robustness of the connectivity, the privacy of exchanges (e.g. displaying emails on a public screen should be avoided), and also the environmental context and user preferences.

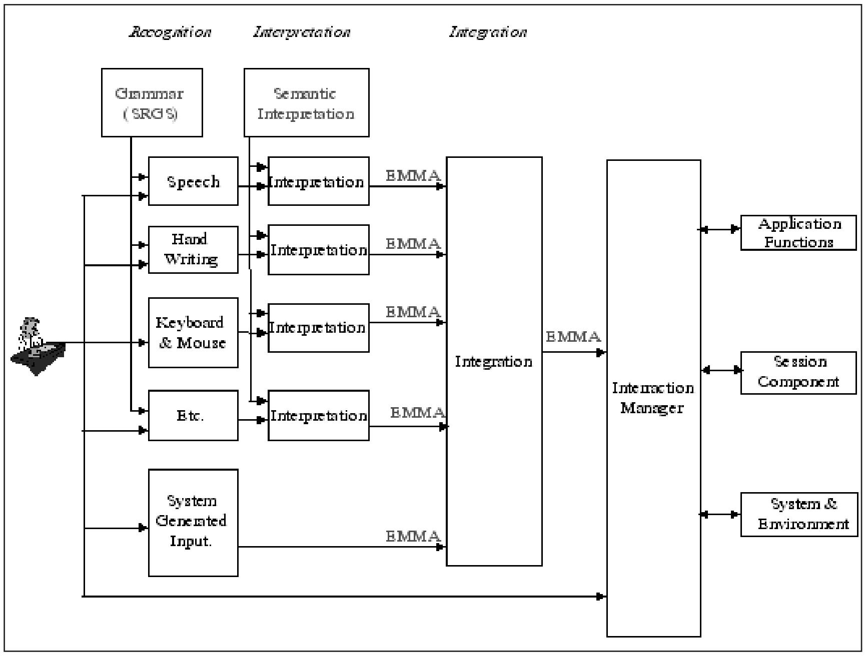
The members of the W3C Multimodal Interaction Working Group propose their specifications of a **Multimodal Interaction Framework** (W3C, 2003) based on a central Interaction Manager that connects user inputs (e.g. audio, speech, handwriting, keyboard…) and outputs (e.g. speech, text, graphics, motion…) to applications and on two other components, as shown on Figure 8:

- The Session Component, which handles the state management for application sessions that may involve multiple steps, multiple modality modes, multiple devices and/or multiple users.
- The System and Environment component, which handles the changes of device capabilities, user preferences and contextual/environmental conditions.

The Interaction Manager coordinates data and manages the execution flow from various input and output modality components. It combines various user inputs for submitting meaningful actions to applications (multimodal fusion) and dispatches responses to the user through various output interfaces (multimodal fission).

Also proposed by the W3C Multimodal Interaction Working Group, the EMMA (Exten-

Figure 8. The input process of the Multimodal Interaction Framework (W3C 2003), © 2003 World Wide Web Consortium



sible MultiModal Annotation) markup language (W3C, 2007) is a XML markup language for describing the interpretation of user inputs. An example of input interpretation is the transcription of a raw signal into words, for instance derived from speech, pen or keystroke input, or a set of attribute/value pairs describing a gesture. The interpretations of user's input are expected to be generated by signal interpretation processors, such as speech and ink recognition, semantic interpreters, and other types of processors for use by components that act on the user's inputs such as interaction managers. As shown on Figure 8, user inputs are processed in two layers to generate EMMA data which is integrated for submission to the Interaction Manager. The two layers of input processing consist of:

- Recognition components, which capture natural input from the user and translate them into a form useful for later processing. (e.g. speech to text, handwritten symbols and messages to text, mouse movements to x-y coordinates on a two-dimensional surface…)
- Interpretation components, which further process the results of recognition components by identifying the meaning/semantics intended by the user. (e.g. pointing somewhere on a map would result in knowing the name of the corresponding country, nodding or saying "I agree" would both mean acceptation from the user…)

Recommended by the W3C, EMMA is probably going to become a standard for annotation of multimodal inputs. It has shown its usefulness especially for speech-based dialog in extensible multimodal applications (Reithinger & Sonntag, 2005; Manchón, del Solar, de Amores, & Pérez, 2006; Oberle et al., 2006).

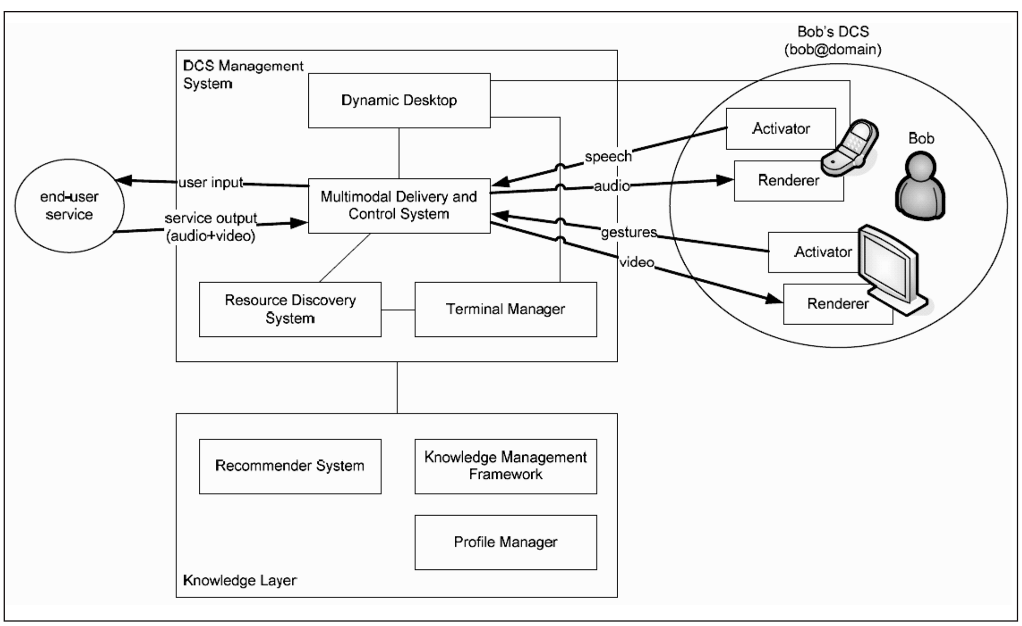
The IST project **Mobilife** proposed a solution (Kernchen, Boussard, Moessner, & Mrohs, 2006) to describe devices and modality services to form context-aware multimodal user interfaces. Their identified requirements include the deployment of a fission component implementing a rule-based algorithm on the device in order to adapt the user's mobile multimodal interface best to the current situation. In the SPICE project (Kernchen et al., 2007), the « Multimedia Delivery and Control System » depicted on Figure 9 has been developed as a part of the « Distributed Communication Sphere », is a multimodal platform relying on the W3C-recommended Synchronized Multimedia Integration Language (SMIL) (Ayars et al., 2000), that supports multimodal fusion and fission. First, the « resource discovery system » of the **MDCS** finds appropriate interfaces, then modalities are selected according to user preferences, context (e.g. Walking, driving), available resources in user's DCS and provision constraints. Modality, device and network recommendations are proposed by the knowledge management framework. This implementation is available as an open source project [https://sourceforge.net/projects/mdcs].

Trends and Issues

In this section, we have identified that semantic technologies have shown their usefulness to improve the discovery, description and exploitation of multimodal interfaces. Several collaborative efforts have been carried out to describe device capabilities. Besides, multimodal platforms are emerging with standardization support from the W3C. This progress leads to the interface-agnostic aspect of ubiquitous computing, but the state of the art of multimodality has still not been transferred from researchers to end-users.

The vision of ubiquitous computing, in which any screen can be used to display personal information, requires privacy enforcement mecha-

Figure 9. SPICE Multimedia Delivery and Control System (Kernchen et al. 2007), © 2007 Ralf Kernchen. Used with permission.



nisms, especially if public screens are expected to be shared as well for this matter. In the next part, we will study how semantic technologies can help enforcing privacy in such systems.

Semantics for Privacy

The vision of ubiquitous computing in which personal information flows in a highly networked ecosystem requires privacy enforcement mechanisms, especially if public screens are expected to be shared for displaying such information as well as personal terminals. Although privacy is a very rich and specific research domain, in this part, we will study how semantic technologies can help to enforce privacy in ubiquitous systems by reviewing a few approaches that must be considered to enforce privacy in Social Ambient Intelligence systems.

According to (Damianou, Dulay, Lupu, & Sloman, 2001), the use of policies is an emerging technique for controlling and adjusting the low-level system behaviors by specifying high-level rules. Policies enforced using semantic rule engines are implemented in most secure semantic context-aware platforms studied earlier in this chapter. In their review of semantic web languages for policy representation and reasoning, (Tonti et al., 2003) explain that "the use of policies allows administrators to modify system behavior without changing source code or requiring the consent or cooperation of the components being governed". **KAoS and Rei** are both semantic policy languages: KAoS is an OWL-based language and uses Java Theorem Prover to support reasoning whereas Rei uses Prolog and RDF-S. They also propose different enforcement mechanisms: KAoS requires the enforcers to be implemented and integrated in the system entities to control, whereas the Rei's actions are to be executed outside the Rei's engine.

(Shankar & Campbell, 2005) propose an extension to the ECA (Event-Condition-Action) rule framework, called Event-Condition-PreCondition-Action-PostCondition (**ECPAP**). In this framework, actions are annotated with axiomatic specifications that enable powerful reasoning to detect conflicts and cycles in policies.

(Brar & Kay, 2004) propose "secure persona exchange" (SPE), a framework based on W3C's Platform for Privacy Preferences (P3P) for secure anonymous/pseudonymous personal data exchange. This framework allows users to negotiate agreements with services that declare their privacy practices and request personal data. The P3P defines such a semantic service description format whereas privacy preferences are described using the APPEL language (A P3P Preference Exchange Language). SPE addresses the following identified end-user requirements: purpose specification, openness, simple and appropriate controls, limited data retention, pseudonymous interaction and decentralized control.

Trends and Issues

We have identified three semantic models that can be used to enforce privacy in ubiquitous systems: rule-based policies, ECA-based policies and secure exchange negotiation according to privacy preferences. Although the last one is the only one to address the issue of secure exchange of personal information, these approaches are complementary and promising to enforce privacy in Social Ambient Intelligence systems.

Semantics for the Social Communications and Activities

In the era of social networking and the participative web, of always-connected chat messengers and virtual worlds, people communicate and exchange more and more over the Internet. If computers are expected to disappear, the communication and exchange paradigms must be adapted to take the context of the users into account and to leverage the social knowledge held in web platforms in order to improve the awareness (and thus, intelligence) of Social Ambient Intelligence systems. One of the key points of such communications is user presence, because being online does not mean paying attention to any discussion at anytime. The second point that we will discuss covers user profiling techniques and the expression of the social graph. Finally, promising technologies for augmenting social activities with the Internet in an interoperable way will be discussed.

User Presence and Communication

The major context information in a synchronous communication network is presence, which is information on reachability, availability, and status across all communication channels (e.g., networks, applications, transports over Internet, wireless and wireline).

Two major presence exchange formats are considered here. The first one is **SIMPLE** (Session Initiation Protocol for Instant Messaging and Presence Leveraging Extensions), an extension of the SIP protocol recommended by the Open Mobile Alliance (OMA) that supports new features such as: voice, video, application sharing, and messaging. Leveraging the communication and security of the IMS (IP Multimedia Subsystem) platform, SIMPLE extends the user's presence to take into account the user's willingness, ability and desire to communicate across all different kinds of media types, devices, and places. Even though it is not a semantic language, the Dutch project Freeband Awareness (Bargh et al., 2005) chose the SIP/SIMPLE protocol for realizing a context-aware network infrastructure with the focus on secure and privacy-sensitive context exchange between a core network owner (e.g. a cell carrier) and external entities. In other projects, the use of SIP can be limited to exchanges that imply an interaction with the user: notifications, confirmations… In the SPICE project (M. Strohbach, E. Kovacs, & Goix, 2007), SIP is used to share presence information with the IMS platform and exchange data with the communicating user. On another hand, SPICE's Mobile Ontology includes a presence ontology based on **PIDF** (Presence Information Data Format) which allows definitions of the user's input, mood, contact relationship, place characteristics, current activity, and service. Transformation templates are provided to switch from the internal semantic representation in RDF into PIDF, and the other way round.

SIP has a wide range of possible uses but is not an optimal solution for all kinds of exchange. (Houri, 2007) criticized the weakness of SIP/SIMPLE in domain scaling. Furthermore it appears (Saint-Andre, 2005) that SIP/SIMPLE does not support advanced messaging mechanisms like workflow forms, multiple recipients, reliable delivery and publish-subscribe which are useful for context-aware systems. PIDF has shown to be suitable for the SPICE project.

Profiling and Social Graph

Considering the user's profile and social graph is important to personalize access to information and communication means. At a time when silo web-based social networking sites rapidly spread, many initiatives try to free our social data from these platforms using interoperable formats.

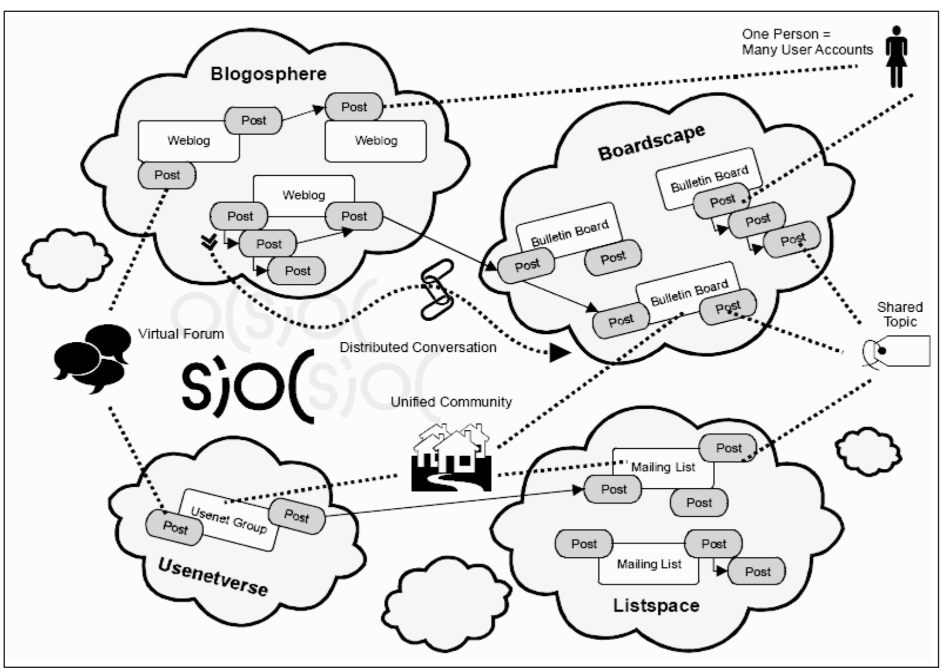
FOAF (Friend-of-a-Friend) (Brickley & Miller, 2007) is a RDF vocabulary based on an OWL ontology to describe people profiles, friends, affiliations, creations and other metadata related to people. FOAF's vision is a decentralized and extensible machine-readable social network based on personal profiles. The profile contains descriptions of personal user data, possibly his/her work history, and links to his/her contacts and affiliated services. Each person has a unique identifier, usually a hash of the email address. The community of FOAF users being principally made of researchers and semantic web enthusiasts, it does not compete with popular social networks like LinkedIn [http://www.linkedin.com], Myspace [http://www.myspace.com] or Facebook [http://www.facebook.com]. Many tools have appeared, including FOA-

Fexplorer [http://xml.mfd-consult.dk/foaf/explorer/] which can be used to visualize FOAF profiles. However, there is a potential privacy issue with this language because selective privacy-aware views of a FOAF file are not addressed. It may be interesting to evaluate a mechanism similar to the conditional profiles proposed in the SPICE project or to enforce selective distribution of content using a policy-based system.

SIOC (Semantically-Interlinked Online Communities, http://sioc-project.org) represented on Figure 10 is an ontology-based framework aimed at interconnecting online community sites and internet-based discussions. The idea is to enable cross-platform interoperability so that conversation spanning over multiple online media (e.g. blogs, forums, mailing lists) can be unified into one open format. The interchange format expresses the information contained both explicitly and implicitly in internet discussion methods, in a machine-readable manner. A similar approach is proposed by the OPSN (Open Portable Social Network, http://www.opsn.net/) initiative which also covers notification and synchronization of contacts across platforms. However there is no existing implementation, and privacy control for personal published information seems not to have been addressed yet. DISO (distributed social networking, http://diso-project.org/), is yet another collaborative work to follow.

These initiatives would be a promising way to leverage consistent social relations, discussions and exchanges from various web platforms in order to build a more precise profile of user's interests, like with the **APML** language (Attention Profiling Mark-up Language, http://www.apml.org/), and qualify the types of relations in order to improve the social communication experience.

Figure 10. Overview of SIOC: Semantically-Interlinked Online Communities [http://sioc-project.org]. © 2006 John Breslin. Used with permission.

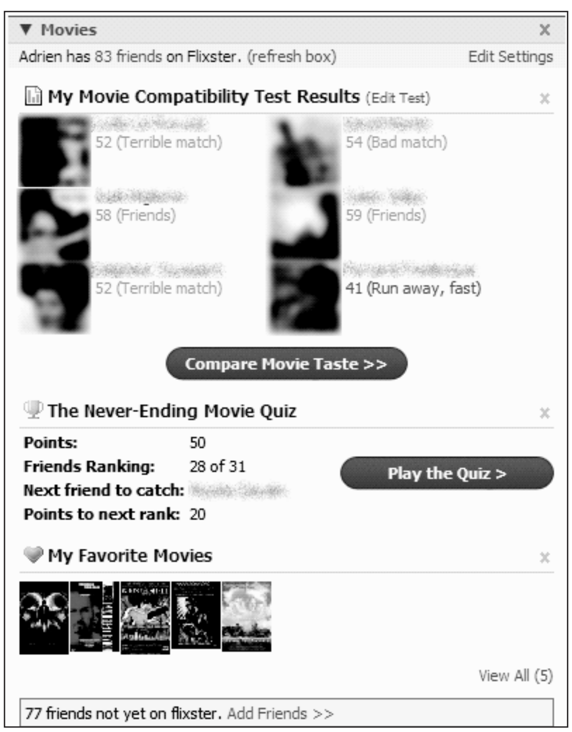


Social Interactivity

Social networking sites (SNSs) have become very popular communication platforms on the Internet, enabling new ways for people to interact with each other. Although the proposed interactions are similar on most SNSs, each of these sites were developed as silos, and thus their social graph (i.e. the list of "friends") and applications are not portable. We believe that consolidating SNS-based interactions is a key towards our vision of Social Ambient Intelligence, and that semantic technologies can help to solve this interoperability issue.

With its open application platform, the social networking site **Facebook** became a huge Internet player in a few months, attracting many service providers and increasing their population of users significantly. Indeed, Facebook made it easy for application developers to leverage the user's profile and social graph of the underlying platform, and thus bring user-friendly services with a social dimension. For example, as shown on Figure 11, the "Movies" application allows the user to rate movies so that his/her favorite movies are shown on his profile page. But the most interesting aspect of this application is the possibility for friends to compare their movie tastes to evaluate their compatibility.

Figure 11. The "Movies" application on Facebook,© 2008 Flixster, Facebook. Used with permission.



Because there are many existing social networking sites on the Internet that are adopting the application platform approach à la Facebook, Google initiated the **OpenSocial** project, an interoperable framework to build applications on any compliant social networking site. However this framework implements basic contact management actions only and don't have access to all the information and capabilities of all social networking sites. For example, some of them are capable of exchanging "pokes", "gifts" and comments, but there is no interoperable way of invoking these capabilities from OpenSocial so far. This could be the opportunity to develop an ontology of social interaction which could be enriched by the platforms and gradually supported by applications without preventing them to work in degraded mode (e.g. by sending a comment instead of a gift, if this capability is not supported by the platform).

Trends and Issues

Despite the exponential popularity and value of Social Networking Websites (SNSs) on the Internet, the possible links between ubiquitous context-aware platforms and existing "Web 2.0" platforms (O'Reilly, 2005) have been neglected by academia, while Internet players are working together to build controlled interoperability. Although extraction of consistent knowledge from the Web 2.0 is not trivial (Gruber, 2006), there is a huge value in social networks sites (and user-generated content) that should be leveraged to extend the awareness of Social Ambient Intelligence systems, as we will explain in the next section. We believe that proposing a common SNS interaction ontology in current collaborative efforts such as the OpenSocial project is a good track for researchers towards our vision of Social Ambient Intelligence.

Conclusions of the State-of-the-Art

In this State-of-the-Art part, we have depicted an overview of several past and current approaches for context-aware systems, adapted human-system interactions, privacy enforcement and social communications and activities. We have identified the assets of semantic technologies in all these domains, and several issues.

Whereas semantic technologies are a powerful tool to enable interoperability among heterogeneous entities, and to unify knowledge in a common model, we realise that existing research on Ambient Intelligence does not leverage the value of collective intelligence which has emerged with the Web 2.0 and its Social Networking Sites. In the next part of this chapter, we will respond to this paradox by defining our vision of "Social Ambient Intelligence" and proposing several research leads towards this vision.

REALIZING SOCIAL AMBIENT INTELLIGENCE

In this part, we define our vision of "Social Ambient Intelligence" and propose several research leads towards this vision, based on our previous study.

What is Social Ambient Intelligence?

As explained in the Background part of this chapter, the vision of "Ambient Intelligence" consists in leveraging new technologies and techniques (including context-awareness) to design applications that are user-centric, and thus more adapted to the user, his knowledge and his current environment/situation. As the Web 2.0 gave birth to the concept of Collective Intelligence, which consists in generating knowledge from user contributions and interactions on the Internet, it sounds like leveraging this knowledge would be extremely valuable to increase the awareness of "Ambient Intelligence" systems. Assuming that, for instance, recommendations coming from friends are necessarily given more confidence than recommendations coming from predictive statistics, adding a social dimension to "Ambient Intelligence" would result in more relevant results for users, and thus a better user-centricity, which was the rationale of "Ambient Intelligence".

Based on this analysis, we propose "Social Ambient Intelligence" (SocAmI) as an extension of "Ambient Intelligence" (AmI) that adds a social dimension in order to increase awareness, knowledge and intelligence of such systems. This social dimension would benefit from the "collective intelligence" of Web 2.0 platforms (such as Social Networking Sites), and therefore it will bring more relevance and confidence to users. The addition of this dimension also gives the opportunity to augment the user communication experience with new kinds of social interactions inspired by Social Networking Sites, without having to sit behind a computer.

As semantic technologies have been shown as an excellent framework to model, integrate and exchange formalized knowledge in a unified manner among heterogeneous agents/entities that constitute Ambient Intelligence systems, we believe in their capability to integrate the social knowledge gathered from the Collective Intelligence of the Web users.

In the following paragraphs, we will discuss the issues and challenges implied by the realization of Social Ambient Intelligence.

Converging with the Social Web

It is time for the social web, context awareness, and multimodal interfaces to converge into a Social Ambient Intelligence platform that enforces users' privacy. We believe that semantic technologies are the best enablers for interoperability, extensibility and intelligent exploitation of user, hardware and social web knowledge, in order to improve interactions between users and information. However, leveraging web knowledge in a semantic ubiquitous system may not be a trivial task according to (Strassner et al., 2007) who claimed that: in order for ontologies to be adopted by a system, this system should have a sufficient amount of semantic knowledge and minimal legacy information to carry. Indeed, the Semantic Web still being an unachieved vision (Berners-Lee, Hendler, & O. Lassila, 2001; Cardoso, 2007), most websites don't rely on semantic technologies to maintain their data. We have presented several initiatives that intend to create interoperable standards based on semantic technologies for universal use of user-generated content and communications kept in separate web platforms. Academics should get involved in this process, in order to take into account the requirements of Social Ambient Intelligence platforms that will leverage these standards. In the mean time, web platforms APIs (Application Programming Interface) can be used to build gateways between specific web social platforms and ubiquitous systems. For example, user feeds (e.g. Facebook's mini-feed, twitter, del.icio.us) could be analyzed as an additional source of context knowledge in the aim of identifying user activities and profile. On the other hand, ubiquitous systems could also be used to push content to these platforms, e.g. automatic presence information inferred from the context.

Bringing Ubiquitous Systems to People

Another issue that we want to address here by adding a Social dimension to Ambient Intelligence is the lack of integration and public visibility of research works related to Ambient Intelligence. The growing ubiquity of networks (infrastructures and ad-hoc), screens and mobile devices brings more exciting opportunities for people to communicate and exchange content but we lack interoperability standards, preventing people from experimenting state-of-the-art research results. In the meantime, innovative ubiquitous products appear on the market, such as electronic photo frames, widget displays, toys that can give weather reports and read emails, and powerful domestic management systems but they all work on their own because we lack common standards and platforms. One promising way of making people progressively adopt ubiquitous systems is to advertise them as applications on popular social platforms (e.g. Facebook), inviting users to deploy required software on their terminal to benefit from exciting new services that could possibly leverage users' context and social graph. Some people may be reluctant to use such systems at first, but we believe that there are solutions to make them accept them.

Gain trust from potential users

Potential users of ubiquitous context-aware systems can be reluctant for the following reasons:

1. Privacy

Users will be concerned with the idea of provisioning private contextual knowledge (such as user positioning) to a "black-box" system which they may not trust, because they are afraid of loosing control of this information (Abowd & Mynatt, 2000), of being tracked or even spied (Bohn, Coroama, Langheinrich, Mattern, & Rohs, 2004). Moreover, most Internet users are already concerned with spam, and many already complain about profiling operated by web sites to improve the relevance of advertising; therefore sharing contextual knowledge can be seen as a major threat for privacy and control of personal information. We believe that advertising should be taken into account as the fair counterpart of a service, but it must be moderated by the system. E.g. a music recommendation service that advertises live performances and merchandising of one's favorite artists seems like an fair service that benefits both the user and the service provider, if the user is fond of music. Nevertheless, the user must constantly be in control of his private information, and confidentiality/security of exchanges must be enforced using mechanisms such as pseudonymity or cryptology. The transparency of the ubiquitous system's implementation and knowledge base can be a major source of trust for users, like it has been with open source software.

2. Intrusion

The subscription to many services that have access to extensive knowledge about users (e.g. their interests, their social network) and also privacy policy management can lead to digital pollution. Users could receive hundreds of recommendations, being asked hundreds of questions about their current situations and confirmations for proposed relevant actions to undertake. Research must be carried out to moderate explicit user interaction (i.e. requests and notifications) without compromising intended communications, user awareness and control. A promising approach for semi-autonomous control of user private data is the use of policies. However, as (O. Lassila, 2005) pointed out, we need a rich representation of policies so that users can define and visualize their privacy rules in a clear and easy way, and delegate their enforcement to the system.

In this section, we have sketched our vision of Social Ambient Intelligence. Main issues consist of the convergence of Ambient Intelligence with the Social web, the involvement of end-users with current research works, the definition of common standards, and the trust to be gained from users (regarding privacy and intrusion).

CONCLUSION

In this chapter, we have reviewed several uses of semantic technologies for context management, adaptive human-system interaction, privacy enforcement and social communications in the scope of Ambient Intelligence. Based on identified benefits and lacks, we defined our vision of "Social Ambient Intelligence" and proposed several research leads towards the realization of this vision based on the convergence of Ambient Intelligence, Collective Intelligence of the Social Web and Semantic Technologies. Through our involvement in several ongoing European, national and internal research projects, we will strive to focus our research on these points and to convey our position and trends to our collaborators.

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