wimmics

Web-Instrumented Man-Machine Interactions, Communities, and Semantics.

Summary: Wimmics[1] is a proposal for a joint research team between INRIA Sophia Antipolis - Méditerranée and I3S (CNRS and University of Nice – Sophia Antipolis). The research fields of this team are graph-based knowledge representation, reasoning and operationalization to model and support actors, actions and interactions in web-supported epistemic communities.

Main research area: interaction, knowledge, communities, graphs, semantics, web

Main application area: supporting and fostering interactions in online communities

1 The research team

Head (and INRIA contact): Fabien Gandon

Vice Head (and I3S contact): Nhan Le Thanh

Researchers:

Michel Buffa, MdC (UNS)
Olivier Corby, CR1 (INRIA)
Catherine Faron-Zucker, MdC (UNS)
Fabien Gandon, CR1, HDR (INRIA)
Alain Giboin, CR1 (INRIA)
Nhan Le Thanh, Pr. (UNS)
Isabelle Mirbel, MdC, HDR (UNS)
Peter Sander, Pr. (UNS)

Assistants: Christine Foggia (INRIA) and Marie-Hélène Prosillico (I3S)

PhD students:

Pavel Arapov, to start in October (EDSTIC-INRIA)
Adrien Basse, 2nd year (UGB-INRIA)
Franck Berthelon, 2nd year (UNS-EDSTIC)
Ahlem Bouchahda, 3rd year (UNS-SupCom Tunis)
Khalil Riad Bouzidi, 2nd year (UNS-CSTB)
Luca Costabello, 1st year (INRIA-CORDI)
Corentin Follenfant, 1st year (SAP)
Maxime Lefrançois, 1st year (EDSTIC-INRIA)
Nicolas Marie, 1st year (Bell-ALU, INRIA)
Hasan Rakebul, to start 4th of July (ANR-Kolflow)
Oumy Seye, 1st year, (Rose Dieng allocation)
Imen Tayari, 3rd year (UNS-Sfax Tunisie)
Viet-Hoang Vu, 4th year (UNS-Factory)

Post-doc: Serena Villata (ANR-Datalift)

Research engineers:

Nicolas Delaforge (INRIA, ANR ISICIL)
Erwan Demairy (ADT)
Guillaume Husson (I3S, ANR ISICIL)
Amel Hannech (I3S)

Apprentice: Amélie Gyrard (INRIA)

Interships: Nemanja Vukosavljevic, Cissé Soda Mareme, Mouhamadou Ba.

[1] wimi is a variety of roses

2 Introduction and *raison d'être*: "as we may link"

Vannevar Bush wrote an article called "As we may think" [45] originally published in the July 1945 issue of The Atlantic Monthly, just before the atomic bombs. In this article Bush already identified that "there is a growing mountain of research. (…) The difficulty seems to be, not so much that we publish unduly in view of the extent and variety of present-day interests, but rather that publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships." Vannevar Bush then proceeds with the proposal of an imaginary machine called the Memex (Memory Extension) a mechanized desk that can store books, records, and communications, so that they may be consulted with speed and flexibility and which will form encyclopedias with a mesh of associative trails running through them; a collective memory extension structured by association links.

Twenty years later, Ted Nelson wrote the article "Complex information processing: a file structure for the complex, the changing and the indeterminate" [46] in ACM 65's Proceedings. Directly referring to the article by Vannevar Bush, Ted Nelson proposes a flexible file structure built by links between elements of documents. He coins the terms hypertext and hypermedia already acknowledging the multimedia explosion in computer science 30 years before it happens.

Twenty years later, Tim Berners-Lee allows hypertext to jump through the networks by designing hyperlinks crossing internet paths and weaving a logical web of documents that overlays a physical network of machines [47].

Twenty years later, the web is crossing a new boundary jumping into our daily life investing many objects and virtually every place. And the challenges Vannevar Bush foresaw are all too real now, revealing how visionary he was when he envisioned a world where we would have cameras with us all the time generating even more multimedia documents to be organized. What we also witnessed since the beginning of this new century is that the initial graph of associative thoughts has been joined by a growing number of other graphs. The graph structure that was weaved by our trails of thoughts is now mixed with sociograms capturing the social network structure, workflows specifying the decision paths to be followed, browsing logs capturing the trails of our navigation, service compositions specifying distributed processing, etc.

System	**Author(s)**	**Kinds of links/graph – Linked items**	**Linking Goal**
MEMEX	V. Bush	Association links Mesh of associative trails	Memory extension with a desk able to remember associations and organize readings.
HYPERTEXT / HYPERMEDIA	T. Nelson	Links between elements of documents	Digital structure to virtually organize tracks between fragments of multimedia resources
WORLD WIDE WEB	T. Berners-Lee	Link documents across the network.	Expand the structure over the internet to share it among many users.
Semantic Web	(several)	Link descriptions of any resources and the schema of the descriptions	Making humans and software agents cooperate through the web
Web of Data	(several)	Linked open data on the web	Use the web as a giant blackboard for data exchanges and integration
Social Web / web 2.0	(several)	Link people capture relations	Foster awareness, exchanges and interactions between users
Web of things & ubiquitous web		Link devices, places through their characteristics and services	Allow contextual interaction and web-augmented reality.

Not only do we need the means to represent and analyze these graphs, we also need the means to combine them to allow multi-criteria analysis, and the means to precisely capture them and in particular the different types of constituent links. Wimmics will attack the question of these changing data structures in a ubiquitous and heterogeneous web: the characterization of typed graphs to model and capture these different pieces of knowledge and of operators to process them.

3 **Research Challenges:** Analyzing, Modeling, Formalizing and Implementing Graph-based Social Semantic Web Applications for Communities

The web is no longer the simple documentary system built on a simple protocol (HTTP), a simple addressing scheme (URI) and a simple document formatting language (HTML). It grew to become a huge network of distributed data, applications and users where many flows of heterogeneous messages travel. *The web is an object of science: it is a very complex system that requires a multidisciplinary scientific approach.* INRIA is more and more solicited to understand how these data and interactions can be processed, supported, controlled, exploited or improved. We believe Wimmics can contribute to this understanding in two manners:

(1) by analyzing and modeling, using a multidisciplinary approach, the many aspects of these intertwined information systems, communities of users and their interactions;
(2) by formalizing and reasoning on these models to propose new analysis tools and indicators, and support new functionalities and better management.

3.1 Analyzing and Modeling Communities Interactions through Social Semantic Web Applications: interacting with dynamic semantic systems of the web.

The web is a worldwide system never sleeping. The dynamics of the system and its ever-changing contexts make it very difficult to interact with it. The richness of semantics-based systems is more and more used to tackle the diversity of web resources and applications through metadata describing web resources but it also augments the complexity of the web and makes it more difficult to interact with. In all its dimensions the complexity of the web is growing.

How do we improve our interactions with such an information system that keeps getting more and more complex? We propose to rely on cognitive studies to build models of the system, the user and the interactions in order to support and improve these interactions.

Semantics in knowledge representation and in computer science in general are fixed (e.g. semantics based on first order logics) while semantics in social context are renegotiated all the time (e.g. semantics based on "natural logics").

How do we reconcile and integrate the formalized stable semantics of computer science and the negotiable social interactions? We propose to rely on social studies to build models of the communities, their vocabularies, activities and protocols in order to identify where and when formal semantics is useful.

When users interact with the web they can use a variety of devices (e.g. mobile phone), of modalities (e.g. vocal interaction), of languages (e.g. Chinese) and be in various contexts (e.g. in the bus).

How do we reconcile local contexts of users and global characteristics of the world-wide virtual machine and information systems that the web has become? We propose to rely on knowledge representation methodologies and theories (e.g. ontologies) to build models of the contexts, devices and mediums ensuring the effectiveness, quality and precision of the information delivered, to provide proofs and explanations of the processes applied and ultimately foster acceptation and trust from the users.

3.2 Formalizing Models and Implementing Social Semantic Web Applications: calculating on heterogeneous joined typed graphs of the web.

The models identified in the previous section need to be formalized in order to automate their analysis and processing when supporting web applications.

What kind of formalism is the best suited for such models? We defend that the network nature of linked data, social communities and service compositions on the web and the large variety of types of links that compose them call for typed graphs as formalized in languages like conceptual graphs or RDF/S. We intend to build on our experience with such formalisms to identify, propose and characterize fragments of typed graph formalisms best suited for each type of model identified before.

Each type of network of the web is not an isolated island. Networks interact with each other: the networks of communities influence the message flows, their subjects and types, the semantic links between terms interact with the links between sites and vice-versa, etc.

How do we analyze these typed graph structures and their interactions? We believe that type-based inference algorithms (e.g. conceptual graph projection, inference rules) and type-parameterized operators (e.g. parameterized betweeness centrality) provide declarative formalisms to flexibly define operations to monitor, filter, query, mine, validate, protect, etc. these imbricated graph structures taking into account constraints spanning several types of network at once.

These graphs are not available in a single central repository but distributed over many different sources. Some sub-graphs are small and local (e.g. a users' profile on a device), some are huge and hosted on clusters (e.g. Wikipedia), some are largely stable (e.g. thesaurus of Latin), some change several times per second (e.g. social network statuses), etc.

How do we support different graph life-cycles, calculations and characteristics in a coherent and understandable way? We believe that moving to graphs languages with open-world logics, temporal aspects, distributed and loosely coupled algorithms and model-driven programming relying on higher abstractions (e.g. formal ontologies) provides an adequate theoretical framework to allow at the same time the specification and operationalization of the models and algorithms and the opening of these black boxes to be able to explain, document, prove and trace results for the users.

4 Wimmics: we mix Edelweiss and Kewi

The research team Edelweiss (INRIA), previously known as Acacia and founded by Rose Dieng-Kuntz, aims at offering models, methods and techniques for supporting knowledge management and collaboration in virtual communities interacting with information resources through the Web and using graph-based and ontology-based formalisms and algorithms. Latest research topics include: multilingual interaction with knowledge bases, mobile access to the web of data, rule-based semantic web formalisms, online presence and resource centric sociality, semantic web in business intelligence, automatic indexing of triple-stores.

The research team Kewi (I3S), is interested knowledge engineering techniques and web-based applications to capture, extract analyze, organize, store and share knowledge. Latest research topics include: semantic web and graph-based knowledge modeling; semantic security and access control; affective computing and emotion detection; requirement engineering and collaborative work.

The two teams have been collaborating for now more than seven years and, as shown by their descriptions, exhibit both common interests (web, semantic web, graph-based formalisms, ontologies, etc.) and complementarities (interaction design/ affective computing, triple-stores, rules / access control, etc.). Merging the two teams really is a natural acknowledgement of an ongoing collaboration and numerous co-publications.

Moreover this merge will create a group including full-time researchers, assistant professors and professors that could naturally cover all the activities of a research team.

5 The research project

<table>
<tr><th colspan="2">Web-Instrumented Man-Machine Interactions, Communities, and Semantics</th></tr>
<tr><td>modeling actors, actions and interactions

• Design methodologies
• User-centric design and interaction
• Model collective structures and relations
• Human-web and human-web-human interactions</td><td>graph-based knowledge representation, reasoning and operationalization
• Representing knowledge with graph formalisms
• Querying and reasoning with graph operators
• Composing and integrating sources and operators
• Context-based representation and reasoning</td></tr>
<tr><td colspan="2">synergies and research intersection.
• Web-based Information Systems
• Representing users and interactions with graphs
• Heterogeneous shared web graphs
• Notification, monitoring, watch and surveillance on dynamic networks
• Interacting with the inner machinery</td></tr>
<tr><td colspan="2">Deployment environment: web applications, web standards, web science.</td></tr>
<tr><td colspan="2">Application scenarios: assisting online epistemic communities in one ubiquitous web.</td></tr>
</table>

5.1 Application scenarios

Context application and perspectives: one ubiquitous web.

A number of evolutions have changed the face of information systems in the past decade but the advent of the web is unquestionably a major one and it is here to stay. From an initial wide-spread perception of a public documentary system, the web as an object turned into a social virtual space and, as a technology, grew as an application design paradigm (services, data formats, query languages, scripting, interfaces, reasoning, etc.). The universal deployment and support of its standards led the web to take over nearly all of our information systems. As the web continues to evolve, our information systems are evolving with it.

Today in organizations, not only almost every internal information system is a web application, but these applications also more and more often interact with external web applications. The complexity and coupling of these web-based information systems call for specification methods and engineering tools. From capturing the needs of users to deploying a usable solution, there are many steps involving computer science specialists and non specialists. We defend the idea of relying on semantic web formalisms to capture and reason on the models of these information systems supporting the design, evolution, interoperability and reuse of the models and their data as well as the workflows and the processing. The challenge is to address both the social aspects of that topic (e.g. identify and exchange services and processes available in an organization) and the automation opportunities (e.g. suggest compositions of resources to provide new ones, orchestrate and monitor workflows).

With billions of triples[2] online (see Linked Open Data initiative[3]), the semantic web is providing and linking open data at a growing pace and publishing and interlinking the semantics of their schemas. Information systems can now tap into and contribute to this web of data, pulling and integrating data on demand. Social web applications also spread virally (e.g. Facebook growing toward 500 million users[4]) first giving the web back its status of a social read-write media and then leading it to its full potential of a virtual place where to act, react and interact. Many organizations are now considering deploying social web applications internally to foster community building, expert cartography, business intelligence, technological watch and knowledge sharing in general. As networks are becoming ubiquitous not only do we multiply the access means to the web but also more and more objects of our daily life are entering what is now called the "internet of objects". As they do so they also become visible for the application layers of the Internet and in particular the web.

These evolutions raise a whole new challenge of enabling and leveraging the encounter of two worlds: the real world (where we interact between us and with objects) and the virtual place the web became (where we *also* interact

---

[2] A triple is the smallest piece of knowledge on the semantic web it can be seen as a binary predicate or as an arc of a graph.
[3] http://linkeddata.org/
[4] http://www.facebook.com/press/info.php?statistics

between us and with services and data). This long term vision of a web of objects and people stirs up many questions when one starts to consider what could be done if the objects and people around us were somehow reachable through URLs giving us access to their data, metadata and services in a web-augmented reality.
Enabling a web linking documents, people and objects with their data and services raises a number of research questions: What would be the new models and frameworks of this whole new web reaching far out of its current IT landscape, deep into our daily environment? What are these new hyperlinks we are envisioning and the graphs they would spin? What formalisms do we need to capture, represent and reason on the knowledge about all the resources that could appear and disappear rapidly on this ubiquitous web? What are the new interactions we should design together with their interfaces to synchronize the changes, actions and reactions of real world and those of its representation on the web? How would we browse, search and edit this new web and what are the new functionalities it could offer? Can we use semantics consistently both to foster and to control access to data and services? Can we conciliate stable formal knowledge representations and ever changing negotiated semantics of social interactions?

Family of scenarios: assisting web-supported epistemic communities
Behind these questions is a constantly used and reused data structure: typed graphs. In this web context, typed graphs capture: social networks with the kinds of relationships and the descriptions of the persons; compositions of web services with types of inputs and outputs; links between documents with their genre and topics; hierarchies of classes, thesauri, ontologies and folksonomies; recorded traces and suggested navigation courses; submitted queries and detected frequent patterns; timelines and workflows; etc.
Wimmics will focus on graph-based knowledge representation, reasoning and operationalization to model and support resources, actors, actions and interactions of communities on the web. Our results will assist epistemic communities in their daily activities such as biologists exchanging results, business intelligence and technological watch networks informing companies, engineers interacting on a project, conference attendees, students following the same course, tourists visiting a region, mobile experts on the field, etc.
Reasoning on the linked data and the semantics of the schemas used to represent social structures and web resources, we intend to provide applications supporting communities of practice and interest and fostering their interactions.
Related previous contributions: [14][22][24][26][27][28][29][30]

5.2 Unifying thread: "in touch with the web"

There is one unifying thread to all the research challenges proposed for Wimmics: the study of relations on the web. Relations between people, resources or services on the web provide a very rich source of knowledge from both the graph structure they weave and the trends of their evolutions. Relations on the web are at the heart of many powerful algorithms (e.g. PageRank), models (e.g. RDF graphs) and protocols (e.g. Open Graph Protocol). For this reason we believe that modeling, capturing and analyzing relations is a fertile research area. Providing frameworks to formalize, store, index, query and infer from those relations is real opportunity to participate in the next generation of web-based informatics. This prospect directly meets the growing demand for tools helping us understand users online and provide metrics to manage communities and their resources.

5.3 Modeling actors, actions and interactions

Summary: in this first research field we intend to address human aspects in the design of social web applications taking into account their individual and collective dimensions, their characteristics and dynamics.

Topic: Engineering methods and tools for improving "interoperability" between designers and users of Web applications
Interested members: Alain, Isabelle.
Developing user-adapted web applications needs mutual understanding between designers and users, and between designers themselves, e.g., between designers as representatives of users (or human factors specialists) and designers as "representatives of the applications" (or developers). Users and designers are often faced with

problems of mutual understanding. These problems are due in particular to the heterogeneity of the languages and representations manipulated by users and designers, and to the diversity of the manipulation processes. Speaking schematically, some mainly implement formal representations and processes (programming languages, abstract schemas, etc.) while others mainly develop non formal representations and processes (natural language, images, etc.). Users and designers are unable to match their representations and processes fluently. They fail to reach "conceptual interoperability" [44].

One objective of Wimmics is to propose methods and tools for helping users and designers overcome mutual understanding and interoperability problems, i.e., methods and tools helping users and designers bridge or articulate their representations and processes (e.g., correspondence tables, translators, representation converters…) without losing information essential to them. The representations and processes that we consider in particular are concerned with relationships between persons (direct relationships or relationships through objects, see the next sections). The design of these methods and tools will be informed by empirical studies of designers' and users' bridging or articulation practices.

The interoperability issue will be addressed in part by the study of knowledge-oriented requirement analysis. Requirements for a design are a special kind of knowledge for which we can specialize knowledge engineering approaches: knowledge-based requirement evaluation, requirement evolution, requirement knowledge reuse and personalized requirement engineering are examples.

Related previous contributions: [25]

Topic: Analyzing and Modeling individual users as "relational agents"

Interested members: Alain, Nhan, Peter.

As we seek to develop Web applications supporting the identification, maintenance, diagnosis of (direct or through objects) relationships between persons, if we want to ensure that these Web applications are tailored to users, it is necessary to elaborate user models reporting such relationships. We therefore propose to study the modeling of users seen as "relational agents", i.e., as persons having or seeking for relationships with other persons (and sometimes avoiding such relationships). This will mean: (1) defining users' characteristics determining the relationships that the persons have or could maintain; (2) defining indicators of these characteristics (textual, visual, physiological, etc., indicators); (3) defining the mechanisms to link indicators to characteristics (cf. tag-based user modeling). Interpersonal relationships involving an emotional dimension, we will address the emotional characteristics of persons which significantly determine the establishment, maintenance or the cessation of a relationship. We will rely on work dealing with "relational agency" ("as a capacity to recognize others as resources, to elicit their interpretations and to negotiate aligned actions" [42]), and on "relational agents" (as "computational artifacts designed to build long-term social-emotional relationships with users", [40]). The elaboration of the characteristics to be included in a "relational-user" model will be informed by empirical studies of relationship characterization, and of personality definition by users on the Web (cf. users giving themselves "masked identities").

We aim to adapt the "Personas" user modeling technique [41] to include relational and emotional aspects appropriate to Web applications. Personas are "user models that are represented as specific, individual humans". Personas are derived from significant behavior patterns (i.e., sets of behavioral variables) elicited from interviews with and observations of users (and sometimes customers) of the future product. We will rely on current descriptions of relational and emotional aspects in existing variants of the personas technique (e.g., [43]).

Related previous contributions: [16][34]

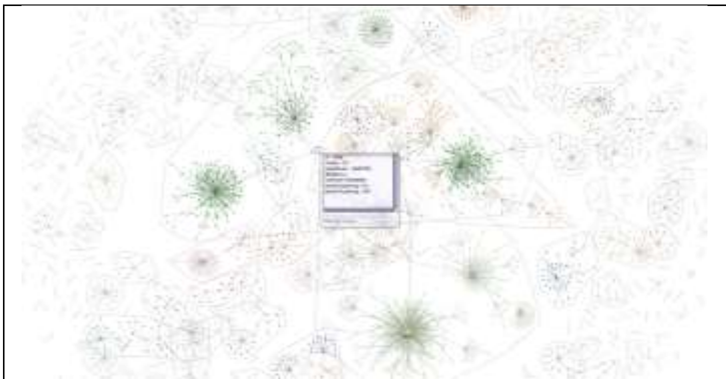
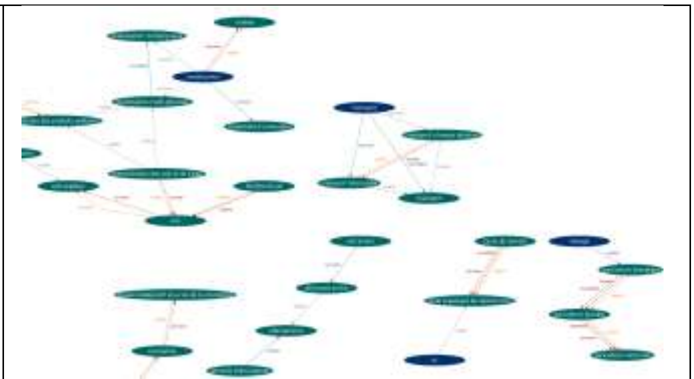
Topic: Model collective structures and relations

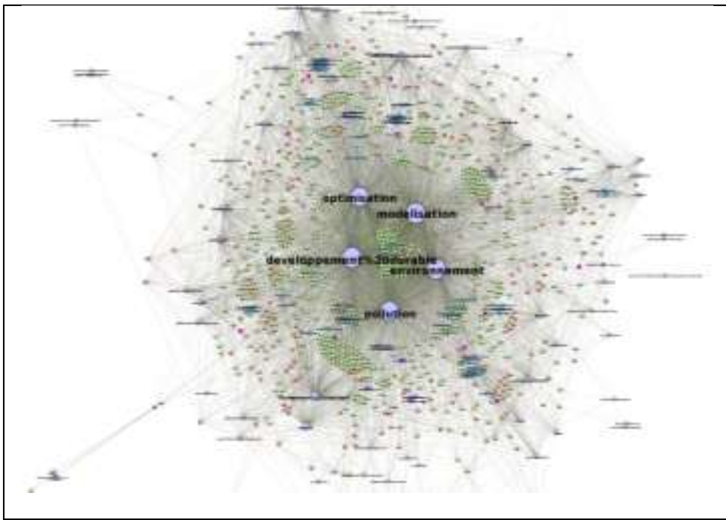
Interested members: Alain, Catherine, Fabien, Michel, Nhan, Peter.

The design of relation-oriented Web applications cannot be limited to modeling individuals. The applications being also directed to the collectives to whom the individuals belong, it is also necessary to model the collectives if we want the applications to be adapted to these collectives. Models of collectives (groups, communities, networks) and of the relations between members of the collectives are required to monitor and manage the communities. There is also a need for models of the articulation between individuals and the collectives they belong to: public profiles and their facets, roles, privacy and security rules, different types of relationships, different groups and memberships, different

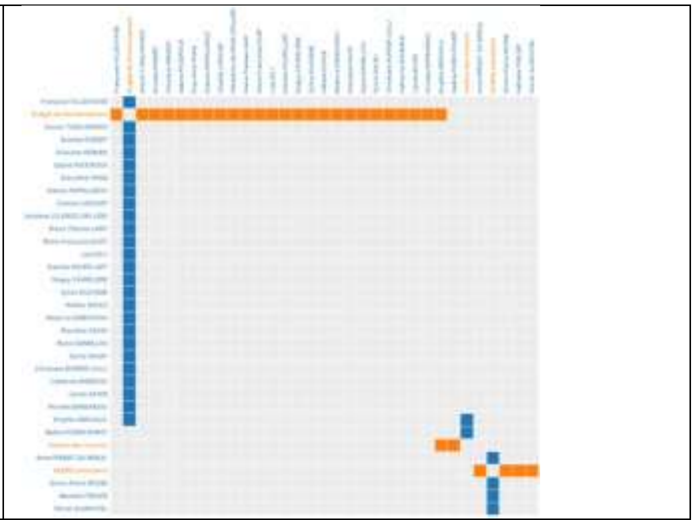
ties. Dynamic aspects for instance models of the behavior of a person in a network or community will also be required to analyze the evolutions and trends of the communities.
Models of the collectives will have to cover many aspects: their structures, their activities, their life cycle, their rules, their resources and their communications. We are interested in modeling the processes of building and maintaining shared representation within a collective, supporting the articulation of representations, and of the tasks involving the representations. Examples of tasks include: indexing-annotating, retrieval-search, annotation-indexing, query-answer. The communication of these representations will also be an important point in designing articulation functionalities and interfaces. We want to design web-based environments which assist the formation of groups and stimulate exchanges and interactions providing an awareness of the social constructs and their activities.
We will need to analyze the interactions of users with persons and objects for instance analyzing communications and interactions (e.g. email, instant messaging) to type relationships and their evolution.
In the long term we would like to include emotions and affective states at the collective level. The idea is to add a layer to the social network models that would represent the affective dimension of the relationship, and help define the profile of the persons over time. Detect for instance the case a person having very little interactions and who suddenly uses the words “alone”, “loneliness”, etc. in the messages she sends. For instance mass written communication (email, tweet, blog, etc.) has emotional content and its analysis can allow gauging popular opinion on some subject in the news.
Related previous contributions: [3][12][17][18]

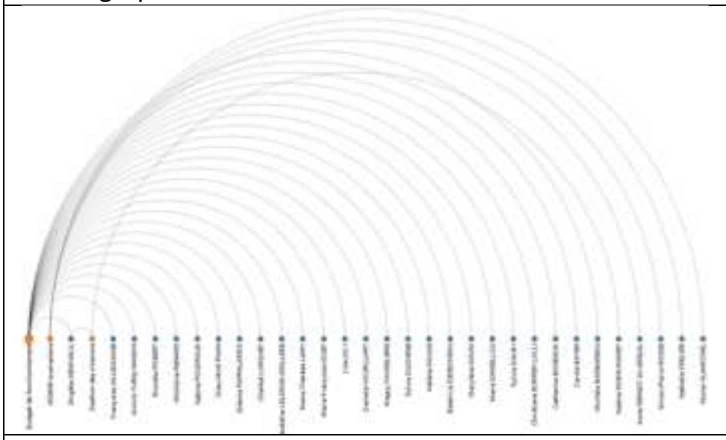
Topic: Human-web and human-web-human interactions
Interested members: Alain, Catherine, Fabien, Isabelle, Michel, Nhan.
Wimmics will focus on the study of web based interactions and web resources as shared representations supporting interaction with a special interest in modeling and designing interoperability and human-machine cooperation on the semantic web. Collaborative situations include for instance engineers organizing a collection of technical reports, photographers tagging a gallery or librarians collaboratively editing a thesaurus. We intend here to observe, analyze, and model the processes of building and maintaining interoperability between humans and SSW applications, and between humans through SSW applications to make human and applications cooperate better. The envisioned tools are called “articulation functionalities and interfaces”. We also think that web is now perceived as a virtual space and that there is a need to study and model specific notions of this space such as the notion of presence *i.e.* what does it mean for a person to be present on the web and how do we represent and use this notion.
In the long term we also believe that human computing and web-sourcing will take a growing importance in web applications and their workflows as some tasks are best delegated to the users. Designing web applications intelligently tapping into the user crowd to carry out some processing, orchestrating human and machine cooperation to achieve some workflow, these are long terms objectives.
Finally, our applications mix graph-based reasoning and user interactions and thus there is a special need for us to produce interfaces and in particular visualizations of these graph-based representations when they come in contact with users as query solutions, reasoning conclusions, explanations, analysis results, etc. Social web applications provide a large number of such cases as shown in some of our previous works:

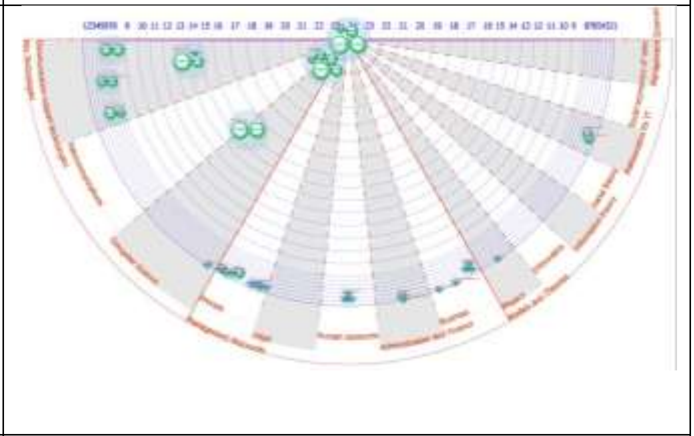
	
Ipernity social network structure	Folksonomy restructuring



Mixed graph of actors and interest


Interest matrix


Interest graph


Clusters in KmP

Related previous contributions: [5][19][23]

5.4 Graph-based knowledge representation, reasoning and operationalization

Summary: in this second research field we intend to address the problem of representing knowledge and reasoning with abstract graph formalisms and operators integrating different formalisms, sources, services and contextual aspects in application workflows.

Topic: Representing knowledge with graph formalisms

Interested members: Catherine, Fabien, Olivier.

We built a strong experience in using graph formalisms to capture knowledge structure. Typed graphs are very flexible and powerful data structures supporting many different types of reasoning and naturally extensible. We believe there is an interesting and valuable work to be done in designing an abstract graph model able to capture different formalisms (e.g. RDF, conceptual graphs, topic maps, etc.) and in studying efficient storage structures, indexes and other implementation characteristics.

An example of such abstract structure is the ERGraph [1] defined relatively to a set of labels L as a 4-tuple $G=(E_G, R_G, n_G, l_G)$ where

- E_G and R_G are two disjoint finite sets respectively, of nodes called entities and of hyperarcs called relations.
- $n_G : R_G \rightarrow E_G^*$ associates to each relation a finite tuple of entities called the arguments of the relation.
- $l_G : E_G \cup R_G \rightarrow L$ is a labelling function of entities and relations.

The construct can be used and reused across graph representations such as RDF, Topic Maps, Social network, etc. In addition, new knowledge structures are regularly identified (e.g. folksonomies, named graphs) and old ones relaunched (e.g. thesauri and SKOS). An abstract graph model should accommodate these evolutions and allow us to integrate different models or translate from one to another when expedient.

Related previous contributions: [1][10][15]

Topic: Querying and reasoning with graph operators
Interested members: Catherine, Fabien, Nhan, Olivier.
Graph operators (joint, homomorphism, propagation, distances, etc.) allow us to perform a broad range of queries and reasoning operations. Not only can we perform search (e.g. homomorphism), logical derivation (e.g. homomorphism and merge) but also approximation (e.g. distances), clustering (e.g. propagation), analysis (e.g. centrality), etc. We target the design of an abstract graph machine generalizing operations needed by and sometime shared across different languages (e.g. SPARQL, RIF, POWDER, RDF/S and OWL inferences) and operations. An example of abstract graph operation is an ERMapping [1]: Let G and H be two ERGraphs, an ERMapping$_{\langle x \rangle}$ from H to G for X a binary relation over $L \times L$. is a partial function M from E_H to E_G such that:

Let H' be the sub-ERGraph of H induced by $M^{-1}(E_G)$

- $\forall e \in M^{-1}(E_G), (l_G(M(e)), l_H(e)) \in X$
- $\forall r' \in R_{H'}\ \exists r \in R_G$ such that
  - $card(n_{H'}(r')) = card(n_G(r))$
  - $\forall 1 \leq i \leq card(n_G(r)), M(n_{H'}^{\,i}(r')) = n_G^{\,i}(r)$
- $\forall r' \in R_{H'}\ \exists r \in M(r')$ such that $(l_G(r), l_H(r')) \in X$

This mapping operator can then be used and reused for many operations (searching, deriving, grouping, etc.) across many graph formalisms. In particular when X is a preorder over L, it captures a hierarchy such as the taxonomical skeleton of an ontology.
We also believe it is interesting to study alternatives to OWL stack and the associated DL-reasoning; for instance looking at rule-based semantic web and an alternative stack (RDF/S + SPARQL + RIF) provides certain advantages: rules are often more natural for humans, they support event-based programming and web service integration, they are usable both for domain independent and domain dependent inferences, etc.
Related previous contributions: [6][7][15]

Topic: Composing and integrating sources and operators
Interested members: Catherine, Fabien, Isabelle, Nhan, Olivier.
Applications and their functionalities usually require more than one source or one service to be called. We identify a generic problem of building pipelines and workflows of operations unrolling follow-up queries, merging results, applying a business process, etc. In particular there is a need for formalisms supporting templates and libraries of generic annotation patterns and recurrent queries that can be instantiated in different workflows and parameterized in different contexts. In addition more and more often workflows need to allow and combine different types of storage and services (database, triple store, DL reasoner, graph engines) addressing the problem of distributed indexes, distributed query solving, distributed reasoning and the orchestration of the workflows composing these distributed resources.
Related previous contributions: [2][6][9][21]

Topic: Context-based representation and reasoning
Interested members: Alain, Catherine, Fabien, Michel, Nhan, Olivier.
There is a clear need to integrate time and evolutions in our knowledge representations as well as other elements of informational context such as location, provenance, author, access rights, copyrights, creation date, use-by date, accuracy, authentication, certification, validity, assumption, modality, dependencies, etc. Each piece of context supports specific reasoning enabling functionalities needed by complete systems e.g. trend analysis, location-based notification, privacy and confidentiality enforcement, traceability and quality enforcing, etc. Therefore we intend to develop both aspects of context-based knowledge representation: models and reasoning.
Related previous contributions: [8][10][11][13]

5.5 Synergies and research intersection

Summary: the two research fields of Wimmics have a very rich intersection where typed graphs and their operators are used to model web-based social applications and raise problems of designing rich interactions.

Topic: Representing users and interactions with graphs

Interested members: Alain, Fabien, Michel, Nhan, Olivier.

A special research topic in Wimmics will be the use of typed graph formalisms to represent individual profiles, interactions, community structures and social networks. The idea is to go beyond structural representation and analysis of sociograms toward richly typed graphs (annotated actors, typed relations) and type-parameterized operators in web-based social applications. For instance the indicator of closeness centrality (C^c) for an actor (k) in a network is the inverse sum of the length of the shortest paths (geodesic g) to each other actor of the network ($x \in E_G$). It represents the capacity of a resource to access or to be reached in a network and we may want to consider only certain types of relations (*<rel>*) in this calculation (e.g. professional relations between people like colleagues, manager, contractors, etc.):

$$C^c_{<rel>}(k) = \left[\sum_{x \in E_G} length\left(g_{<rel>}(k,x)\right) \right]^{-1}$$

We will consider algorithms to compute this kind of parameterized indicators and possible alternatives for calculation (incremental algorithms, approximation algorithms, sampling, calibration problems, etc.).

We will also look at mixed graphs and their multi-dimensional analysis for instance to analyze social network graphs merged with information resource graphs (web links) and folksonomies (tripartite graph tags-resource-taggers) to identify and label communities of interest.

Finally we will study how to augment and enrich the graphs by re-injecting results from our analysis, for instance by applying rules to detect and assert implicit social network structures *i.e.* indirect relations like to share interests, to visit the same places, etc.

Related previous contributions: [6][10][18]

Topic: Heterogeneous shared web graphs

Interested members: Catherine, Fabien, Olivier.

The graphs involved in the scenarios we address span a large spectrum from small ephemeral graphs (e.g. representation of the presence, activity and status of users), to large rather stable graphs (e.g. Wordnet thesaurus, French administrative zoning), from graphs representing web users' networks to graphs representing web service compositions, from bare trees of organizations' hierarchies, to dense graphs of friendship networks, etc. And the value of these graphs is not only in their specific models and analysis but even more importantly in their combinations, interactions and integrated analysis. Moreover, the large graphs formed by linking all this data are not homogeneous in their structures and evolutions: some branches may be tree like others may be dense graphs, some branches may be stable, others may be changing all the time.

Challenges include:

- Model graph structures (RDF) and their typing (RDF/S, OWL) conciliating formal semantics and social semantics.
- Capture and publish these graphs according to their specificities (ephemeral, large, versioned, distributed, etc.)
- Provide efficient specific algorithms for the operations on these graphs combining automated reasoning and human computing to obtain the best results.
- Combine the different graph models and their specific processing to provide cross-model multi-dimensional analysis and support high-level functionalities in social network systems.

Related previous contributions: [10][11][15]

Topic: Notification, monitoring, watch and surveillance on dynamic networks

Interested members: Fabien, Michel, Nhan.

The graphs involved in the scenarios we address may be generated automatically or by users but an aspect of growing importance is that they change over time and their changes are valuable information (e.g. trend analysis). We will have to consider operators on changes (e.g. subtraction, recurrent queries) to provide functionalities in demand such as customized alerts on a topic, regular digests on the last events in a community and other intelligent notification and monitoring mechanisms.

Another family of functionalities requiring this kind of abilities is dynamic access control. Tracing the behavior of web applications for dynamic access control to the databases allows the detection of suspicious behavior in order to dynamically check access rights to data from the behavior of the current application and thus detect the "hidden intention" of the malicious user access to unauthorized data. This requires to model traces of actions and changes and system features to observe the processes, collect the traces, identify relevant sequences and assess their impact.

Related previous contributions: [32][33]

Topic: Interacting with the inner machinery

Interested members: Alain, Catherine, Fabien, Nhan, Olivier.

This topic is at the cross-road of user interaction design and reasoning algorithms. Data and services involved in providing a result or a functionality are more and more distributed and composed in complex IT architectures. When a result is finally delivered or a request rejected, users (be they end-users or developers) may want to know how the system came to that conclusion. To allow traceability and intelligibility of the outputs we need to have models of the processes, explanation and tracing modules and dedicated reporting mechanisms for the different types of users interacting with our systems. From visualizing the propagation of an inference to trapping the most frequent reasons of failure in solving a query, we need the next generation of systems to document, explain and justify their results and behaviors. This is all the more important that more and more often we deal with distributed composed applications for which trust is more and more difficult to obtain.

Users may also benefit from additional ways to control the processes: the maximum time or resources they are willing to spend in order to get a certain result; the precision they want or the fact they just need a sample of the results; etc.

Finally the variety of systems and devices is now offering very different channels of interaction. We would like to consider new interaction means such as controlled natural language for input and output to support new interaction contexts such as mobile accesses through SMS or voice.

Related previous contributions: [6]

5.6 Web standards and Web science

Summary: Besides the research fields mentioned above, Wimmics will systematically position its research in the field of web science and its contributions on top of web standards.

Web applications: Software productions from Wimmics will be web-oriented: we design web applications. A special interest in the team will be to contribute to programming standards making easier the development of semantic web applications. Diffusing semantic web languages supposes the availability of frameworks for developing semantic web applications. Examples of targeted environments include: wiki-like platforms for developing user-based applications, combining the advantages of semantic wikis and application wikis integrating with standard platforms (e.g. Deki Wiki) both for data edition and programming by users; IDE for semantic web programming and debugging e.g. eclipse plug-in. The general goal is to provide a higher-level development framework to hide as much as possible data, schemas, logics, queries and rules from the developers and integrate them in an IDE. A long term objective is to consider MDE approaches to get closer to ontology-oriented programming.

Web standards: In Wimmics, not only do we intend to focus on embodying our results in Web applications, we also intend to continue our participation in W3C, evaluating, applying, extending, and contributing to the web standards. This activity is a double asset for diffusion: building our solutions on top of standards allows for easier adoption and greater deployment; participating to the design of new standards is a great opportunity to diffuse research results. The semantic web activity at W3C will continue to be a choice instance for diffusion in our team and semantic web formalisms will remain a choice framework for our formalizations. In addition sister initiatives emerging from semantic web frameworks (e.g. Linked Data initiatives) will be systematically considered as parts of the ecosystem of the applications we design.

Web science: Finally and more fundamental, the web is both a set of standards (a technical object) and the largest information system in history (a world-wide social object). This emerging social object touches on every aspects of modern life: more and more jobs depend on it, spanning all activities from journalism to commerce, from education to healthcare, from transportation to arts, from activism to government. The complexity of this information system (more than 20 billion indexed pages) justifies multidisciplinary scientific approaches to the many problems it raises and the idea of a web science gathering these contributions was officially launched in 2006. What is at stake is the need we have to understand and influence this system in order to ensure some desirable properties (e.g. openness) and prevent some undesirable ones (e.g. link farms). This understanding calls upon multidisciplinary contributions: to understand the web we need to go beyond its structure and look at the variety of links, resources, actors and interactions it embeds and supports. We need to call upon psychology to model the users, mathematics to model the structures, sociology to model the dynamics, linguistic to model the texts, etc. Wimmics positions its activity right in the context of this cross-fertilization.

Related previous contributions: [15]

References: [39]

6 Diffusion and Collaborations

6.1 Past and current research contracts

- Kolflow[5] (starting in February 2011): Kolflow is a research project funded by the French national research agency. Its goal is to reduce the overhead of communities in the process of continuously building knowledge by extending collective intelligence with smart agents relying on automated reasoning. It intends to do so by building a social semantic space based on distributed semantic wikis where humans collaborate with smart agents in order to produce knowledge understandable by humans and machines.
- Datalift[6] (started in September 2010): Datalift is a research project funded by the French national research agency. Its goal is to develop a platform to publish and interlink datasets on the Web of data. Datalift will both publish datasets coming from a network of partners and data providers and propose a set of tools for easing the datasets publication process.
- ISICIL[7] (until March 2012): ISICIL is a research project funded by the French national research agency. It proposes to study and to experiment with the usage of new tools for assisting corporate intelligence tasks. These tools rely on web 2.0 advanced interfaces (blog, wiki, social bookmarking) for interactions and on semantic web technologies for interoperability and information processing.
- PUSLearn (Project with the University of Annaba, Algeria) we are involved in a 3 years cooperation project funded by CNRS and DPGRF (Algeria) starting in 2010, on the personalization and socialization of ubiquitous e-learning systems based on semantic web models and techniques.
- RBP and ImmunoSearch (until 2011): The objective of ImmunoSearch is to design biomarkers for controlling the harmlessness of the molecules used in perfumes, aromatics and cosmetics. The purpose of this research is to conduct comparative studies of in vivo and in vitro test models on the skin (irritation, allergy) and to propose alternative methods defining the new norms applicable in this field. In this context, we aim at proposing methodological and software support for capitalization and valorization of knowledge resulting from experiments and techniques to preserve and reuse data. We rely on the semantic web technologies (semantic annotations, ontologies, RDF, SPARQL, etc).
- DESIR[8] (ended 2009): This COLOR project aimed at supporting the activities of a community of agronomists and geneticists through a semantic collective memory. It highlighted the need for the capitalization, reuse and sharing of queries and more generally search processes.

---

[5] http://kolflow.univ-nantes.fr/
[6] http://datalift.org/en/
[7] http://isicil.inria.fr/
[8] http://www-sop.inria.fr/edelweiss/projects/desir/wakka.php?wiki=ColorDesirHomePage

- E-Wok Hub[9] (ended 2009): a research project funded by the French national research agency that designed a set of communicating data and service portals offering both: (a) web applications accessible to end-users through online interfaces, and (b) web services accessible to applications through programmatic interfaces. As applicative objectives, the project aimed at enabling management of the memory of several projects on CO2 capture and storage, integrating results of technological watch on the domain.
- SeaLife[10] (ended 2009): a European project that designed a semantic grid browser for the Life Sciences Applied to the Study of Infectious Diseases Project Reference. The browser has access to comprehensive background knowledge of life science topics consisting of domain specific ontologies and dictionaries of proteins. It comprises an advanced text-mining module, which is able to automatically extract ontology terms from free text to form Semantic Hyperlinks and a service module, which enables users to link through semantically identified terms to web/grid services to facilitate actions on the data identified.
- SevenPro[11] (ended 2008): a European project that developed tools supporting deep mining of product engineering knowledge from multimedia repositories and enabling semantically enhanced 3D interaction with product knowledge in integrated engineering environments
- Palette[12] (ended 2008): this European project aimed at facilitating and augmenting individual and organizational learning in Communities of Practice (CoPs). Towards this aim, an interoperable and extensible set of innovative services as well as a set of specific scenarios of use were designed, implemented and thoroughly validated in CoPs of diverse contexts: information services, knowledge management services (based on an ontology dedicated to communities of practice) and mediation services for CoPs. Eleven pilot CoPs were involved in the participatory design of Palette services.
- GRIWES (ended 2008) aimed to specify a generic platform for graph-based knowledge representation and reasoning. We considered multiple languages of representation, such as conceptual graphs, RDF/S, and various extensions of these languages.

6.2 Partnerships

Both teams already have a number of different partnerships that will be merged and some partnerships are already common:

Edelweiss:

- Alcatel Bell-Lucent: with the Ph.D. (CIFRE) of Nicolas Marie we collaborate on the capture and modeling of online user presence and object-centric sociality on the web. We intend to develop new graph models to represent presence, detect opportunities of interactions and foster their emergence.
- SAP: with the Ph.D. (CIFRE) of Corentin Follenfant we collaborate on the integration of semantic web inside Business Intelligence reporting processes in particular to facilitate the reuse of knowledge from previous reports.
- Philips Semiconductors France (now called NXP) in the framework of the KmP-Philips (or KM2) project funded by this industrial company. This two-year project aimed at designing and validating a prototype supporting the strategic management of individual and collective competencies within this firm. During this first year, the prototype was implemented using SeWeSe and Corese, and tested. The second year will be devoted to getting and analyzing usage feedback of the prototype within the enterprise.
- IFP, BRGM and EADS, in the framework of the ANR RNTL project e-WOK_Hub. This 3-year project aims at building a set of communicating portals (the e-WOK Hubs), offering both web applications accessible to end-users through online interfaces, and web services accessible to applications through programmatic interfaces. From applicative viewpoint for IFP and BRGM, e-WOK_Hub aims at enabling management of the memory of several projects on CO2 capture and storage, with use of results of technological watch on the domain. It will enable the diffusion of Corese and SeWeSe to these application partners IFP and BRGM, the

[9] http://www-sop.inria.fr/edelweiss/projects/ewok/
[10] http://www.biotec.tu-dresden.de/sealife
[11] http://www.sevenpro.org/
[12] http://palette.ercim.org/

application of our semi-automatic annotation techniques from texts and our web–service architecture on a real-world application, with a collaboration with EADS on these techniques.

- Semantic Systems (Spain), LivingSolids (Germany), Estanda (Spain) and ItalDesign (Italy), in the framework of the 3-year STREPS project Sevenpro. Semantic Systems and LivingSolids are two IT small and medium enterprises specialised in Semantic and Virtual Reality for engineering technologies. Estanda, a SME manufacturer of metal castings and ItalDesign, a big engineering company play the roles of end-users in Sevenpro. We collaborate with Semantic Systems on the use of RDF(S) and on annotation of CAD files. We apply our semi-automatic annotation techniques to the corpora provided by Estanda and ItalDesign. Moreover, we play the role of support to these end-users on ontology development and on RDF(S) use.
- GDF/Suez : a consulting mission was done in 2010 to evaluate the opportunities of semantic web applications in their IT infrastructure.
- Ongoing discussions with IRIT and UTT (Tech-CICO) for strong associations between the research teams.
- Discussions with In Situ and in particular with Emmanuel Pietriga about the use and extension of Fresnel in our projects.
- Yearly exchange with UGB (University of Gaston Berger, Senegal) for lectures, internships and co-supervised Ph.D. students (Adrien Basse, Oumy Seye)
- Discussions with LSIS UMR CNRS (Bernard Espinasse) on the use of Corese for using ontologies and inference rules.
- Exchanges with EURECOM (Raphael Troncy) in particular in the context of the KIC.
- Contacts with several SME: Life2Times, Slice Factory, AmiSW, ImmunoSearch, Addax, Intellinium.
- We take part in W3C working groups and interest groups: In particular we participated to the note release of the Semantic Web Best Practice working groups and we are editors and co-authors of two drafts of the GRDDL (Gleaning Resource Descriptions from Dialects of Languages) working group (a mechanism to extract RDF from XML dialects) as well as SPARQL, RDFa, RIF, and RDF 1.1

Kewi:

- Centre Scientifique et Technique du Bâtiment (CSTB): we are involved in a long-term collaboration on the management of technical and regulatory knowledge based on semantic web models and techniques. CSTB has already funded two Ph.D. on this domain.
- One of the leaders of the project NiceCampus with the University of Danang (Vietnam) to create a campus and a research Lab.
- Collaboration with Pr. Chatel (Emeritus professor, Pasteur Hospital) and Pr. Robert (Institute Claude Pompidou) on natural and emotional interactions when assisting elder people.
- RoboSoft: experimenter of SweetWiki, a semantic wiki developed during the Palette European Project, also partners for a ANR proposal to come about using an emotion system in assistance robots for elder people
- Discussions with Jolita Ralyté (University of Geneva), Rebecca Deneckere and Manuele Kirsh-Pineiro (University of Paris I) on information system engineering.
- Contacts with several SME: StoneTrip; Ipernity, Robosoft.

Common to Edelweiss and Kewi:

- Collaborations with Orange (CIFRE, ANR), PhD thesis of Guillaume Erétéo on "Semantic Social Network Analysis" defended the 11th of April 2011
- Collaborations with Ipernity (CRE)
- Collaboration with the neuropsychologists of the Laboratoire de Psychologie Cognitive et Sociale, Université de Nice – Sophia Antopolis (experiments on emotional interactions).

6.3 Education and diffusion

Currently we run every year:

- Course on Semantic Web at EPU (Ecole Polytechnique UNS, Master 2 IFI) 45 hours plus several student projects.
- Course on Knowledge Engineering, at EPU (Ecole Polytechnique UNS, Master 2 IFI) (32H).
- Course on Agile Web (32H)) , at EPU (Ecole Polytechnique UNS, Master 2 IFI)
- Course on XML languages at EPU (Ecole Polytechnique UNS, Master 2 IMAFA) (24H).
- Course on Knowledge Engineering, at University of Danang (In English, Master 2 IFI) (36H).
- Course on Semantic Web, License Pro., IUT, UNS (24H).
- Introduction to the semantic web course at University of Nice (master MBDS , master Miage, Master “info”).
- Course on Semantic Web at University Gaston Berger, Saint Louis du Sénégal (18H).
- Invited lecture (3H) at Ecole Centrale de Paris "Web Sémantique ou comment les ontologies pourront favoriser l'échange des connaissances sur le web du futur"
- Course on Human-Computer Interaction at EPU (Ecole Polytechnique UNS, Master 2 IFI) 48 h + several students projects
- Course on Ergonomics of digital technologies (Département de Psychologie & Département de Sociologie, UNS, Master 2 Socio-Ergonomics of digital technologies), 6 h
- Distant Course on Human-Computer Interaction (In English, University of Danang).
- Distant Course on Semantic Web, at University of Danang (In English, Master 2 IFI) (36H).
- Distant Course on Agile Web, Master (In English, University of Danang) (36H).
- Edelweiss and Kewi are currently involved in the KIS course of study of master IFI at the University of Nice and in MIAGE. We intend to reinforce and focus this action on developing an ecosystem to train and support professionals of the web and semantic web. We envision an evolution toward a double curriculum:
- An evolution of the course of study KIS toward a “Web Science” course of study possibly as a European KIC master 2.
- A reinforcement of the Web courses in MIAGE toward a “Web Information System” course of study master 2.

This may also require reinforcing web courses and internships for master 1.

6.4 Current Ph.D. Thesis

- Pavel Arapov: Semantic application wikis, UNS
- Adrien Basse: Graph Index for distributed queries, Univ. Gaston Berger, Senegal
- Franck Berthelon: Detecting emotional states in Serious Games, UNS
- Ahlem Bouchahda: A semantic approach to secure data base accesses, with SupCom Tunis
- Khalil Riad Bouzidi: Management of technical and regulatory knowledge, with CSTB
- Luca Costabello: Mobile access to the Web of Data, INRIA
- Corentin Follenfant: Semantic Web and Business Intelligence, with SAP
- Maxime Lefrançois: Collaborative Management of Interlingual Knowledge, UNS
- Nicolas Marie: Modeling online presence on the Web of People, with Alcatel-Bell-Lucent
- Hasan Rakebul, to start 4th of July, on solving problems upstream and downstream of a distributed query on the semantic web (ANR-Kolflow).
- Oumy Seye: Rules for the Web of Data, Lirima, Univ. Gaston Berger, Senegal
- Imen Tayari : Representing, annotating and detecting emotions in multimodal signals , with Sfax Tunisie
- Viet-Hoang Vu: Ontology-based Semantic matchmaking for eTourism : An application case of abductive reasonings in Description Logics, with Factory

7 Positioning and collaborations

The other actors in the domain of Wimmics have been described and positioned in this section starting from the closest teams from a thematic point of view.

7.1 Semantic web and knowledge representation

7.1.1 Graph based approaches

The closest teams to Wimmics combine semantic web formalisms with graph-based knowledge representation and reasoning to address epistemic problems i.e. propose information systems relying on graph-based formalizations and algorithms to assist their users in knowledge intensive tasks.

- GraphIK: This team was created in 2010 to work on Knowledge Representation and Reasoning (KRR) following a logic-oriented approach of the field with a graph-based vision of KRR. GraphIK focuses on some of the main challenges in KRR, such as querying large knowledge bases, dealing with hybrid knowledge bases (i.e., composed of several modules having their own reasoning mechanisms), or reasoning with imperfect knowledge (i.e., vague, uncertain, partially inconsistent, ...). Graphik and Wimmics collaborated in the Griwes project that led both teams to align their graph models and share their results. We also collaborate on a future project (GraphKit) to share our graph platforms. Although GraphIK is the closest INRIA team from Wimmics, it does not focus on semantic web nor on social web.
- The team COD (COnnaissances et Décision) at LINA, Nantes, studies ontology engineering using semantic web formalisms, data mining using graph approaches and preference integration with visual support to decision making. The team LINA worked on social network analysis but the team did not focus on that subject nor did it focused on bridging graph approaches and semantic web formalisms.
- At IRIT, Toulouse, in the team IC^3 works on knowledge models engineering for cooperative systems and cooperative systems engineering. They use semantic web formalisms for ontology engineering and textual corpus analysis methods and lately they developed graph approaches to suggest query patterns and ease the access to triple stores. However the team does not focus on graph operationalization of semantic web formalisms nor on semantic web approaches to social network analysis.
- At LIC, Laboratory of Computational Intelligence of Laval University, the team studies Conceptual Graphs formalism for Knowledge Discovery, Data Mining and in conjunction with multi agent systems applied to the semantic web. Again, here the difference is that the collective aspects come from the multi agent point of view not really social networks and the focus of the LIC team remains on conceptual graphs formalism not semantic web formalisms.

Therefore the approach of relying on graph formalisms unified in an abstract graph model and operators unified in an abstract graph machine to formalize and process semantic web data, web resources and services metadata and social web data is a characteristic very specific of Wimmics.

7.1.2 Approaches with other formalisms

The closest teams w.r.t. Wimmics are the teams working on knowledge management, knowledge engineering and semantic Web. Through the GRACQ network (Groupe de Recherche sur l'Acquisition des Connaissances) and conferences like IC and EGC, we have regular contacts with most of the French teams working on knowledge engineering. Through networks of excellence like knowledge web, consortium like W3C and communities like ISWC we have contacts with the most active international teams.

Generally speaking, we identified the following close teams:

- EXMO: This team produces theoretical and software tools for enabling interoperability in formalized knowledge exchange. EXMO focuses on three topics: semantic properties in knowledge representation language translation, semantic adaptation of multimedia documents and ontology matching for interoperability. In Wimmics ontology alignment is not a main topics as for EXMO but it may be useful in case of interactions involving multiple ontologies. In this case, results of existing alignment algorithms such as those offered by EXMO among others, could be exploited. EXMO and Wimmics have cooperated in the past and currently cooperate in the ANR project Datalift: EXMO focuses on resource alignment while Wimmics focuses on access control and privacy.

- Orpailleur: The main objective of this team is to extract knowledge units from different sources and to design structures for representing the extracted knowledge units. The research of Orpailleur is at the intersection of knowledge extraction, knowledge representation, and semantic Web. Wimmics and Orpailleur rely on different knowledge representation formalisms (cf. Description logics and Galois Lattices for Orpailleur, Knowledge Graphs for Wimmics), but Wimmics future work on knowledge graphs may take into account the Galois lattice representation studied in Orpailleur. Orpailleur and Wimmics cooperate in the ANR project Kolflow where Orpailleur studies knowledge incoherencies and WImmics studies proof and explanations in queries and reasoning.
- GEMO/LEO: The main theme of this team is the integration of information and its approach combines Artificial Intelligence techniques and Database techniques: integration of heterogeneous data; mediation between sources of information; data warehouses on the web; active XML approach to integrate web services; data model theory. This team historically focuses on XML, Description Logics and databases. Clearly the database-oriented aspect of LEO is a difference with Wimmics and they do not work on the social web either.
- The Karlsruhe University produces KAON an environment for ontology development, ontology learning, semi-automatic annotation from texts, semantic web services, ontology mapping, ontology evolution and versioning, and evaluation of ontology-based tools. KAON v1 and v2 are based on frame systems and OWL. The formalisms used in this team and the fact they don't study social structures and representations are clear differences.
- The Vrije University Amsterdam is a co-proposer of OWL and produces the SESAME. They also have a background in description logics, ontology alignment, ontology modularity and ontology versioning. Again, the models used in this team and the fact they don't study social aspects are clear differences.
- Departamento de Inteligencia Artificial, Politecnica Madrid produces the MethOntology method, the WebODE environment for ontology development, and studied interoperability, peer-to-peer architecture, and semantic grid. This team is extremely active on ontology engineering and ontology based knowledge representations using semantic web formalisms. They do not study graphs structures or social representations
- The Musen Lab, Stanford, tudies methods for building intelligent computer systems that support the work of clinicians and basic scientists. The overall goal is to support e-science and clinical decision making using systems that store encoded knowledge. The laboratory investigates the use of components for building knowledge-based systems, controlled terminologies and ontologies, and technology for the Semantic Web. They produced the well-known PROTEGE ontology editor, Anchor-Prompt platform for ontology alignment and have numerous and huge applications in medical domain. Their application domain and the formalisms they use are again differentiators with Wimmics.
- Manchester Univesity is a co-author of OWL, they study OWL extensions for instanstance with rules, semantic web services, ontologies in biomedical domain and applications in bioinformatics. We collaborated with them in the framework of the SeaLife project on biomedical ontologies .
- DERI, Galway is a leading international web science research. They work on many aspects of the semantic web e.g. semantic web services, rule languages for semantic web. The institute has three overall complementary research strands: Social Semantic Information Spaces, Semantic Reality, Application Oriented Research Domain. The first one is the closest from us but does focus on graph models.
- Trento University has a group studying epistemological foundations of ontologies (e.g. DOLCE top-level ontology) ontology engineering and alignment. Their work is very interesting for the theoretical part of our models (e.g. methodologies for formal ontologies) but not directly comparable to the agenda of Wimmics.
- The Knowledge and Media Technologies department of Salzburg studying social media, content management and semantic technologies. We follow their work on KiWi (Knowledge in a Wiki) combining the

wiki philosophy with methods of the Semantic Web and IKS (Interactive Knowledge Stack) providing an open source technology platform for semantically enhanced content management systems.

- Open University has a group called KMI known for platforms like the Watson semantic web search engine. They also study semantic web services for e-Learning, WSMX for semantic web services, MnM for annotation edition and MAGPIE for Web browsing. We collaborated with them in the framework of the Knowledge Web network. Their closest activity is on interaction design for the semantic web and could be a potential subject of collaboration in the future.
- ICS-Forth group is developing the ICS Forth Suite for RDF which is directly based on relational database approaches.
- HP developing Jena for RDF above relational databases. We use parts of the Jena platform in CORESE and KGRAM and interact with them through our W3C activities.

Again the approach of relying on graph models and operators and the importance given to social dimensions ar clearly differentiators of Wimmics with regard to the other teams reviewed here.

7.2 Data and knowledge based systems

A number of other teams are interacting with us or partially relevant to one of our subjects:

- MODALIS: this team aims at modeling and exploiting large scale distributed computing infrastructures such as grids. Its research works include the design of flexible service architectures taking into account user needs. Several members of both teams regularly have discussions on knowledge modeling.
- LARIA, Amiens, that now studies organizational semantic webs with a strong emphasis on ontology engineering.
- UTC (COSTECH) Compiègne, that studies epistemological foundations of ontologies, multi-agents approach for KM, learning memory combining semantic web and eLearning,
- UTT (Tech-CICO), Troyes, multidisciplinary team that studies cooperative approaches for knowledge management, action communities, socio-semantic web, project memory and memory for professional training.
- LIRIS Lyon working on knowledge-based systems, case-based reasoning and trace modeling. They use semantic web formalisms to represent their models.
- LIPN, Paris that works on terminology and NLP tools, and has developed TERMINAE, a tool supporting construction of ontologies from texts.
- Sheffield (NLP tools such as GATE or Amilcare, used by their partners of the AKT project in UK). We relied on their NLP platform GATE in our previous work on semi-automatic generation of annotations from text.

7.3 Interaction design and knowledge systems

- IN-SITU: This interdisciplinary project develops new interaction techniques, new tools and new methods for designing interactive systems. The goal is to develop situated interfaces, i.e. interfaces that are adapted (or adaptable) to their contexts of use, taking advantage of the complementary aspects of humans and computers. Two IN-SITU research themes are close to Wimmics' themes: 1) Participatory design; 2) Engineering of interactive systems - A new research action could be particularly worth considering by Edelweiss, namely: End User Interaction with Semantic Web Data. Precisely, IN-SITU is exploring the problem of displaying RDF data in a user-friendly manner through the development of visualization applications based on state-of-the-art interaction techniques, as well as through the specification of new languages for describing Semantic Web data presentation knowledge.
- GRAVITE: this team aims at designing interactive visualization methods and tools to analyze and mine large datasets. Their emphasis is on the visualization of graph structures to help users gain insights from large datasets and large-scale simulations, to understand the data and/or the underlying model, and ultimately, to identify intrinsic properties or emergent phenomenon. With the ADT of Erwan Demairy we are currently evaluating how graph visualization tools like the ones designed by GRAVITE could be adapted to take advantage of typed graphs like the one processed in Wimmics.

- AXIS: This team performs research on: (1) Web Usage Mining and Reuse, (2) Semantics and Web sites, (3) Design management of Web sites. Axis focuses on knowledge mining while Wimmics focuses on knowledge representation and the processing it supports.
- RAINBOW: the research area of this team covers software engineering for ambient computing, from middleware to Human Computer Interaction. Both teams are complementary and collaborate on model and HCI composition and transformation.

7.4 Social Network analysis and knowledge systems

The domain of social network analysis is a whole research domain in itself. Important teams in this domain include: The team of Mark Newman (Michigan University), the team of Ulrik Brandes (Konstanz University), the team of Santo Fortunato (Complex Network Lagrange Lab, Institute for Scientific Interchange, Turin), the team of Albert Barabasi (Boston, Northern University), etc. However we do not intend to contribute on the core theory of social networks like these teams do but rather focus of what can be done with typed graphs in this domain.

7.5 Semantic Requirement Engineering and knowledge systems

Finnaly, Different attempts have been made to "semantify" requirement engineering, especially to improve requirement elicitation. The group of John Mylopoulos (University of Toronto), in collaboration with Ivan Jureta (Louvain School of Management) are currently working on foundations of Requirements Engineering and provide a core ontology about requirement engineering. Duisburg-Essen University and Leipzig University collaborated in the framework of the Softwiki project and proposed the SWORE ontology as a mean to support functional requirements elicitation. Nonfunctional requirements have also been addressed, for instance by the group of Pericles Loucopoulos (Manchester university), which proposed the OWL ontology ElicitO. Seok Won Lee (University of Nebraska Lincoln, USA) currently works on the Onto-ActRE and GenOM framework relying on ontologies to link together different requirement elicitation paradigms.

8 Some selected peer-reviewed publications

From books and book chapters:

- Rose Dieng, Olivier Corby, Fabien Gandon, Alain Giboin, Joanna Golebiowska, Nada Matta, Myriam Ribière, Knowledge management: Méthodes et outils pour la gestion des connaissances, 3ème édition, DUNOD, 2005
- Alain Giboin. Correspondances : cadre dialogique pour analyser et assister la coordination entre production et compréhension de documents, in: Production, compréhension et usages des écrits techniques au travail, Toulouse, France, D. Alamargot, P. Terrier, J. Cellier (editors), Octarès, 2005, p. 225-243.
- Fabien Gandon, Ontologies in Computer Science, Book Chapter in Ontology Theory, Management and Design: Advanced Tools and Models, Ed. Faiez Gargouri, Wassim Jaziri, Pages 1-26, ISBN10: 1615208593.
- Alain Giboin (2004). Construction de référentiels communs dans le travail coopératif. In J. Hoc & F. Darses (Eds.), Psychologie ergonomique : tendances actuelles (pp. 119-140). Paris: Presses Universitaires de France.

From Journals:

- Olivier Corby, Rose Dieng-Kuntz, Catherine Faron-Zucker, Fabien Gandon. Searching the Semantic Web: Approximate Query Processing based on Ontologies, IEEE Intelligent Systems Journal, January/February 2006 (Vol. 21, No. 1).
- Michel Buffa, Fabien Gandon, Guillaume Ereteo, Peter Sander and Catherine Faron, SweetWiki: A semantic wiki, Special Issue of the Journal of Web Semantics on Semantic Web and Web 2.0, Volume 6, Issue 1, February 2008 , Edited by Mark Greaves and Peter Mika, Elsevier, Pages 84-97
- Isabelle Mirbel, Ralyte, J. Situational method engineering: combining assembly-based and roadmap-driven approaches. Requirement Engineering Journal, 11(1), 2006, pp. 58--78.

- A. Yurchyshyna, C. Faron-Zucker, N. Le Thanh, and A. Zarli. Knowledge Capitalisation and Organisation for Conformance Checking Model in Construction. International Journal of Knowledge Engineering and Soft Data Paradigms (IJKESDP), 2(1):15–32, 2010.
- Isabelle Mirbel, Pierre Crescenzo, Improving collaboration in the neuroscientist community. International Journal of Web Portals. To appear 2011.
- Amel Yessad, Catherine Faron-Zucker, Rose Dieng-Kuntz, M. Tayeb (2011), Ontology-based Semantic Relatedness for Detecting the Relevance of Learning Resources, In Interactive Learning Environments Journal 19(1), Special issue "Semantic Technologies for Multimedia-enhanced Learning Environments", pp. 63--80.

From international conferences:

- Fabien Gandon, Olivier Corby, Alain Giboin, Nicolas Gronnier, Cecile Guigard, Graph-based inferences in a Semantic Web Server for the Cartography of Competencies in a Telecom Valley, ISWC, Lecture Notes in Computer Science, Galway, 2005
- Olivier Corby and Catherine Faron-Zucker, The KGRAM Abstract Machine for Knowledge Graph Querying, IEEE/WIC/ACM International Conference, September 2010, Toronto, Canada.
- Olivier Corby, Web, Graphs & Semantics, Proc. of the 16th International Conference on Conceptual Structures (ICCS'2008), Invited talk, July 2008 Toulouse
- Olivier Corby, Rose Dieng-Kuntz, Catherine Faron-Zucker.Querying the Semantic Web with the Corese search engine. Proc. of the 16th European Conference on Artificial Intelligence (ECAI PAIS'2004), Valencia, 22-27 August 2004, IOS Press, p. 705-709.
- Guillaume Ereteo, Fabien Gandon, and Michel Buffa, SemTagP: Semantic Community Detection in Folksonomies, IEEE/WIC/ACM International Conference on Web Intelligence, WI 2011
- Guillaume Erétéo, Michel Buffa, Fabien Gandon, and Olivier Corby. Analysis of a Real Online Social Network using Semantic Web Frameworks. In Proc. International Semantic Web Conference, ISWC'09, Washington, USA, October 2009.
- Amira Tifous, Adil El Ghali, Alain Giboin, Rose Dieng-Kuntz. O'CoP, an Ontology for Communities of Practice, in "Networked Knowledge - Networked Media. Integrating Knowledge Management, New Media Technology and Semantic Systems", T. Pellegrini, S. Auer, K. Tochtermann, S. Schaffert (editors), Studies in Computational Intelligence, vol. 221, Springer, 2009, p. 155-169.
- Freddy Limpens, Fabien Gandon and Michel Buffa, Helping Online Communities to Semantically Enrich Folksonomies, Web Science Conference, April, 2010, Raleigh, NC, USA.

9 All relevant publications

[1] Jean-François Baget and Olivier Corby and Rose Dieng-Kuntz and Catherine Faron-Zucker and Fabien Gandon and Alain Giboin and Alain Gutierrez and Michel Leclère and Marie-Laure Mugnier and Rallou Thomopoulos. Griwes: Generic Model and Preliminary Specifications for a Graph-Based Knowledge Representation Toolkit. Proc. of the 16th International Conference on Conceptual Structures (ICCS'2008) July 2008 Toulouse

[2] Adrien Basse, Fabien Gandon, Isabelle Mirbel and Moussa Lo, Frequent Graph Pattern to Advertise the Content of RDF Triple Stores on the Web, Proc. Web Science Conference, Raleigh, NC, USA, April 2010.

[3] Michel Buffa, Catherine Faron-Zucker, Anna Kolomoyskaya: Gestion sémantique des droits d'accès au contenu : l'ontologie AMO. EGC 2010: 471-482

[4] Michel Buffa, Fabien Gandon, SweetWiki : Semantic WEb Enabled Technologies in Wiki, WikiSym?, International Symposium on Wikis, August 21-23, 2006, Odense, Denmark

[5] Florie Bugeaud, Alain Giboin and Eddie Soulier, Shared Representations for Innovation: Experience Feedback on Two Innovation-oriented Projects, Workshop The mediation role of shared representations in cooperative activities: new challenges, in conjunction with the 9th International Conference on the Design of Cooperative Systems, COOP, Aix-en-Provence, 2010

[6] Olivier Corby and Catherine Faron-Zucker, The KGRAM Abstract Machine for Knowledge Graph Querying, IEEE/WIC/ACM International Conference, September 2010, Toronto, Canada.

[7] Corby O., Faron-Zucker C. (2007), Implementation of SPARQL Query Language based on Graph Homomorphism, In Proc. of the 15th International Conference on Conceptual Structures, ICCS 2007, LNCS 4604, Springer, Sheffield, UK

[8] Corby O., Faron-Zucker C. (2007), RDF/SPARQL Design Pattern for Contextual Metadata, In Proc. of the IEEE/WIC/ACM International Conference on Web Intelligence, WI 2007, Silicon Valley, CA, USA
[9] Olivier Corby, Catherine Faron-Zucker, and Isabelle Mirbel. Implementation of Intention-Driven Search Processes by SPARQL Queries. Poster at Int. Conference on Enterprise Information Systems, Milan, Italy, May, 2009.
[10] Olivier Corby, Web, Graphs & Semantics, Proc. of the 16th International Conference on Conceptual Structures (ICCS'2008), July 2008 Toulouse
[11] Fabien Gandon and Olivier Corby, Name that Graph, RDF Next Step Workshop, W3C, June 2010, NCBO, Stanford, USA.
[12] Fabien Gandon, Olivier Corby, Alain Giboin, Nicolas Gronnier, Cecile Guigard, Graph-based inferences in a Semantic Web Server for the Cartography of Competencies in a Telecom Valley, ISWC, Lecture Notes in Computer Science, Galway, 2005
[13] Fabien L. Gandon, Norman M. Sadeh, Semantic Web Technologies to Reconcile Privacy and Context Awareness, Web Semantics Journal Vol. 1, No. 3, 2005
[14] Fabien Gandon, Talel Abdessalem, Michel Buffa, Florie Bugeaud, Sébastien Comos, Olivier Corby, Nicolas Delaforge, Guillaume Ereteo, Alain Giboin, Patrick Grohan, Frédéric Herledan, Valérie Le Meur, Mylène Leitzelman, Benoit Leloup, Freddy Limpens, Anne Merle, Eddie Soulier, "ISICIL: Information Semantic Integration through Communities of Intelligence online", 10th IFIP Working Conference on Virtual Enterprises (PRO-VE'09), 07-09 Octobre 2009, Thessalonique.
[15] Fabien Gandon, Graphes RDF et leur Manipulation pour la Gestion de Connaissances, Habilitation à Diriger les Recherches (HDR), soutenue le Mercredi 5 novembre 2008.
[16] Alain Giboin, Motivating the Use of Affective Ontologies in Semantic Web Applications Which Mediate Interactions Between Members of Organizations or Communities, COOP'2008 Workshop on Affective aspects of cooperative interactions, Carry-Le-Rouet, May 2008.
[17] Alain Giboin. From Individual to Collective Persona: Modeling Realistic Groups and Communities of Users (and not Only Realistic Individual Users). Proc. of the Fourth International Conference Advances in Human-Computer Interactions (ACHI 2011), Gosier, Guadeloupe, February 23-28, 2011.
[18] Guillaume Erétéo, Michel Buffa, Fabien Gandon, and Olivier Corby. Analysis of a Real Online Social Network using Semantic Web Frameworks. In Proc. International Semantic Web Conference, ISWC'09, Washington, USA, October 2009.
[19] Freddy Limpens, Fabien Gandon and Michel Buffa, Helping Online Communities to Semantically Enrich Folksonomies, Web Science Conference, April, 2010, Raleigh, NC, USA.
[20] Freddy Limpens, Alexandre Monnin, David Laniado, Fabien Gandon "NiceTag Ontology: tags as named graphs", International Workshop in Social Networks Interoperability, ASWC09, 2009
[21] Moussa Lo, Fabien Gandon, Semantic web services in corporate memories, ICIW 2007, International Conference on Internet and Web Applications and Services, May 13-19, 2007, Mauritius
[22] Mirbel, I. and Crescenzo, P. Des besoins des utilisateurs à la recherche de services web : une approche sémantique guidée par les intentions. Revue Ingénierie des systèmes d'information (Hermes), appear. 2010.
[23] Mirbel Isabelle and Crescenzo Pierre. Improving Collaborations in Neuroscientist Community. In The 2009 Workshop Web2Touch - living experience through web in conjunction with The 2009 IEEE/WIC/ACM International Conference on Web Intelligence, Milan, Italy, September 2009.
[24] Mirbel Isabelle. OFLOSSC, an Ontology for Supporting Open Source Development Communities. Int. Conference on Enterprise Information Systems, Milan, Italy, May, 2009.
[25] Mirbel Isabelle, Contributions à la modélisation, la réutilisation et la flexibilité des systèmes d'information, HDR, University of Nice - Sophia Antipolis, I3S, CNRS
[26] Amira Tifous, Adil El Ghali, Alain Giboin, Rose Dieng-Kuntz, O'CoP, an Ontology Dedicated to Communities of Practice, Proceedings of I-KNOW'07, The 7th International Conference on Knowledge Management, Graz, Austria, September 5-7, 2007.
[27] Yessad, A., Faron-Zucker, C., Sander, P., Laskri, M.T. (2010), OrPAF: an Environment for Adaptive Hypermedia Courses in the Semantic Web Context, in Novel Developments in Web-Based Learning Technologies: Tools for Modern Teaching, Advances in Web-based Learning (AWBL) Book Series
[28] A. Yessad, C. Faron-Zucker, R. Dieng-Kuntz, M. Tayeb Laskri (2008), Ontology-Driven Adaptive Course Generation for Web-based Education, In Proc. of the World Conference on Educational Multimedia, Hypermedia and Telecommunications, ED-MEDIA 2008, Vienna, Austria
[29] A. Yurchyshyna, C. Faron-Zucker, N. Le Than, A. Zarli (2010), Knowledge Capitalisation and Organisation for Conformance Checking Model in Construction, In International Journal of Knowledge Engineering and Soft Data Paradigms, 2(1), pp 15-32
[30] A. Yurchyshyna, C. Faron-Zucker, N. Le Than, A. Zarli (2008), Towards an Ontology Based Approach for Formalising Expert Knowledge in the Conformity Checking Model in Construction, In Proc. of the 7th European Conference on Product and Process Modelling, ECPPM 2008, Sophia Antipolis, France

[31] Viet Hoang VU, Nhan Le Thanh. "Concept Abduction in Description logics with cardinality restrictions" (long paper) in Proceedings of the International Conference on Information and Knowledge Technology 2010 (ICIKT 2010), WASET: World Academy of Science, Engineering and Technology, 12 pages, Venice– Italy, 24-26 november 2010
[32] Ahlem Bouchahda-Ben Tekaya, Nhan Le Thanh, Adel Bouhoula, Faten Labbene-Ayachi. "RBAC+: Dynamic Access Control for RBAC-administered Web-based Databases" in Proceedings of the Fourth International Conference on Emerging Security Information, Systems and Technologies, SECURWARE 2010 (SECURWARE 2010), IEEE Computer Society, Venice, Italy, 18-25 july 2010
[33] Ahlem Bouchahda-Ben Tekaya, Nhan Le Thanh, Adel Bouhoula, Faten Labbene-Ayachi. "An Access Control model for Web Databases" in Proceedings of the 24th Annual IFIP WG 11.3 Working Conference on Data and Applications Security (DBSEC’2010), IFIP, Springer Lecture Notes, Rome, Italy, 21-23
[34] Imen Tayari, Nhan Le Thanh, Chori Ben Amar. "Towards an algebraic modeling of emotional states" in Proceedings of the The Fifth International Conference on Internet and Web Applications and Services (ICIW 2010), IARIA: Int. Academy, Research and Industry Association, pages 513-518, CPS-IEEE CSDL, Barcelona, Spain, 9-15 may 2010
[35] Thi-Anh-Le Pham, Nhan Le Thanh, Peter Sander. "-based Reasoning for Large Knowledge Bases in Description Logics" in Integrated Computer-Aided Engineering (ICAE), 15 (1), pages 53-70, IOS Press, jan 2008
[36] Thi-Dieu-Thu Nguyen, Nhan Le Thanh. "Modeling ORM Schemas in Description Logic" in Complex Systems Concurrent Engineering, pages 533-541, Spinger-Verlag, 2007
[37] Thi-Anh-Le Pham, Nhan Le Thanh, Peter Sander. "approaches of ontology Decomposition in Description Logics" in Complex Systems Concurrent Engineering, pages 523-532, Spinger-Verlag, 2007
[38] Guillaume Ereteo, Fabien Gandon, and Michel Buffa, SemTagP: Semantic Community Detection in Folksonomies, IEEE/WIC/ACM International Conference on Web Intelligence, WI 2011

10 External references

[39] Nigel Shadbolt and Tim Berners-Lee, Web Science Emerges, Scientific American, October 2008.
[40] Bickmore, T.W., Picard, R.W. (2005). ACM Transactions on Computer-Human Interaction., Vol. 12, No. 2. (June 2005), pp. 293-327.
[41] Cooper, A., Reinmann, R. (2003). About Face 2.0: The Essentials of Interaction Design. Indianapolis, IN: Wiley Publishing, Inc.
[42] Edwards, A. (2007) Relational Agency in Professional Practice: a CHAT analysis, Actio. An International Journal of Human Activity. 1. 1-17.
[43] Olsen, G. (2004). Persona Creation and Usage Toolkit, Information Architecture (IA) Summit, 15 pages. http://www.asis.org/~iasummit/2004/finalpapers/Olsen_Handout_or__final__paper.pdf
[44] Simone, C., Mark, G, and. Giubbilei, D. (1999). Interoperability as a means of articulation work. In D. Georgakopoulos, W. Prinz, and A. Wolf (eds.) Proceedings of ACM Conference on Work Activities Coordination and Collaboration (WACC'99), ACM Press, Feb. 22-25, 1999, San Francisco.
[45] Bush, Vannevar. "As We May Think." The Atlantic Monthly. July 1945. Reprinted in Life magazine September 10, 1945
[46] Nelson, T. H., Complex information processing: a file structure for the complex, the changing and the indeterminate, In Proceedings of the 1965 20th national conference, pages 84-100, New York, NY, USA, 1965. ACM Press.
[47] Tim Berners-Lee, Information Management: A Proposal, CERN internal proposal, March 1989, May 1990 http://www.w3.org/History/1989/proposal.html