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Assisting Architectural Designers with a Collaborative Semantic Web

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Abstract: This paper presents a research on the collective activity of architectural design that has led to develop a new semantic web tool for enhancing it. This research has been commissioned by a specific architectural design team to better understand their own work patterns in order to improve them. Consequently, the work has consisted in analyzing the collective architectural design of the team on one hand and to search the better means to aid it on the other hand. So, in a first phase, we have realized an architecturological analysis of the collective work implemented in architectural design and in a second phase, we have developed a prototype of an original new semantic collaborative web tool to assist the agency to better work together. From the first phase, three kinds of result have been built: results about the representations built and uses to collaborate in architectural conception, results about the means of the collective work of architectural conception and results about the needs of computer tools for collaborative design. The second phase of the research has led to build a prototype of a new semantic web tool adapted to the collective work of the agency, based on Web 2.0 technologies, and enhanced with semantic web techniques and a Multi-Agent Systems.

Keywords: Collective work, Architectural design, Semantic collaborative web tool, Architecturology

1 Introduction

Architectural design is a collective activity within which different actors need to share documents [1]. The actors involved in architectural design can be diverse according to the stage of the design process or to the nature of the project conceived [2]. They usually are architects, urbanists, landscapers, engineers, CAD drawers, builders, developers and projects owners. They nowadays can also be philosophers, sociologists, anthropologists, or other researchers supposed to help the designing of the project. It was for example the case of the ten design teams of the Grand Paris [3].

Such diversity of actors implied in architectural design introduces the need of a "common benchmark"[4] to understand the produced documents as well as a common framework to collaborate and to share the information of each [5]. It also requires new tools to share the information and the produced documents because of the difficulty it creates to gather all the actors at the same time in the same place [6].

So, architectural design seems to be a complex collective activity depending on the project situation and that deserves to be questioned in order to describe its mechanisms and its means.

This paper presents a research that deals with this object from the study of a specific architectural design team. This study has been commissioned by the specific architectural design team itself, in order to better understand their collective work and to imagine a new computer tool for enhancing it.

The situation of the collective activity of architectural design analyzed here is characterized by its actors and the general work context of the agency they belong to. These actors are architects, urban planners, landscapers, CAD drawers and engineers distributed in remote antennas of the same agency. They work together on common projects by using different communication means that they deem not enough effective to communicate and to work collaboratively in architectural design.

The agency these actors belong to, has always worked internally or externally in collaboration for architectural designing. It has progressively developed its own methods and systems to facilitate the communication between its members. The extension of the agency to remote sites (Paris, Lyon, Nantes, etc.) and the use of CAD and Web computer tools by its members, have affected its traditional collaborative methods and systems. Consequently, its leader asked us to analyze the current collective work of architectural design in order to describe its mechanisms and to develop new adapted computer methods and systems to enhance it.

Consequently, this research has been conducted over a year in order to describe the ways the actors work together on a project, to understand their needs in term of collaborative computer tools and to develop a prototype of a new one adapted to these needs. The following parts of this paper present the materials and methods of the realized studies (part 2), the needs we have discover concerning the computer tools (part 3) and the prototype of the computer tool we have imagine for enhancing the collective work of the architectural design of the agency (part 4).

2 Materials and methods of the realized studies

This part presents the materials and methods of the research realized on the collective work of architectural design of the agency observed. As written above, the aim of this research is to describe the ways the actors of an architectural project conceive together. To succeed, we have chosen the viewpoint of a scientific French field of the architectural research called Architecturology.

2.1 Architecturology

Architecturology is a scientific field initiated by Boudon in the seventies that has been constituted in order to explain the cognitive activity of architectural design called architectural conception [7]. Its paradigm is situated in between the cognitive sciences and the design sciences.

The “scientific object” (in the sense of Canguilhem (1975) [8]) of Architecturology is the question how conceivers give shapes and measurements to their future objects or spaces?

From this question, the researchers of Architecturology has built a scientific language within which each concept helps to explain how conceivers implement cognitive operations of conception to participate to architectural design [9][10].

Architecturology is nowadays developed within our laboratory MAP-Maacc and its scientific language has been actualized according to the different researches we have done about the collective work of architectural conception, the computer aided architectural conception, the eco-conception, the architectural perception and the architectural representation [11]. An actualized model of the structure of the part of the scientific language concerning architectural conception is represented in the **Fig.1** below.

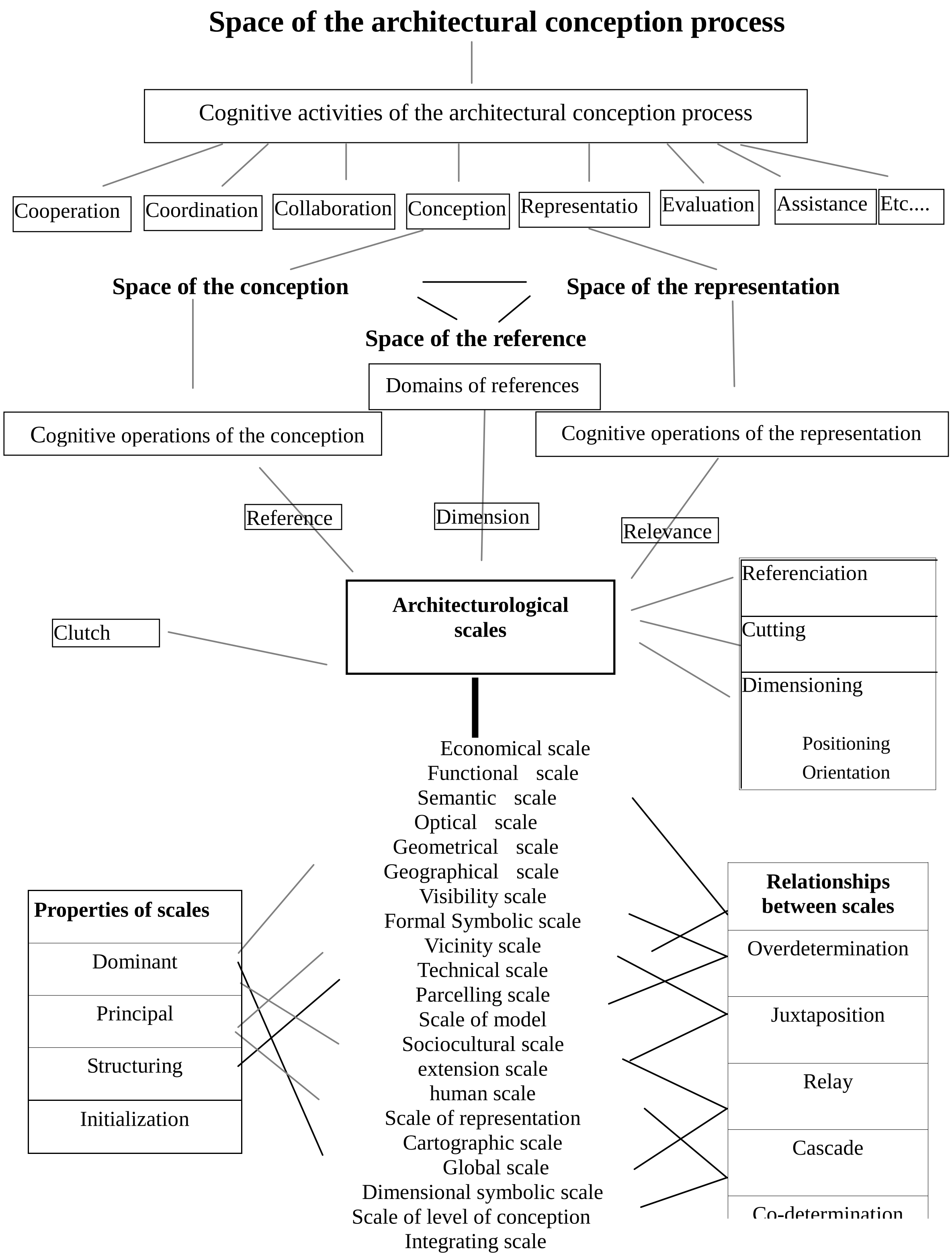

Fig 1 : Structure of the part of the architecturological language concerning architectural conception

In this model, we distinguish different cognitive activities of the architectural design process in which coordination, cooperation and collaboration constitute what we call the collective work [12]. The architecturological language initially focuses on the two activities of conception and representation.

Conception is for us the mental activity developed to think of a new architectural space or object in order to make it feasible. It consists in giving to this future space or object, shapes and measurements by different means, in order to create a representation for its manufacturing. The concept “space of the conception” designates all the cognitive operations of conception likely to be implemented to choose and to precise these shapes and measurements. These cognitive operations of conception can be to choose a reference (referenciation) to give a shape or a measure to an element of the project, to cut the project in elements to shape (cutting) or to link an element to shape with a reference to decide its shape or measure (dimensioning, positioning and orienting). All these cognitive operations of conception are implemented in relation with what we call a “domain of references”, i.e. classes of representation of the reality and data specific to each person as the economy, the geography, the human size, the view, the geometry, etc. (see the list of architecturological scales, fig. 1).

Representation is for us the mental and graphical activities developed to give a virtual or material reality of the conceived project. It implies also cognitive operations of conception (the same evoked above) to build this virtual or material reality. The concept “Space of the representation” designates all the cognitive operations likely to be implemented for building representations.

As we can see, all the scientific concepts have been originally built to describe precisely the cognitive operations of conception at work in architectural conception and representation.

Nowadays, this language is questioned in order to see how it helps to describe the activities of the collective work (cooperation, collaboration, coordination) [13] and to explore their relationships with conception and representation in architectural design [14]. The aim of this current questioning is to complete the originally language with new scientific concepts describing cognitive operations of the conception by which these activities of the collective work is conceived.

This research has already allowed discovering what we call pragmatic operations of the collective work that are: interpretation, evaluation, normalization, task sharing, empowerment, building a common benchmark, taking decision, appropriation [13]. All these pragmatic operations are implemented in the collective work of architectural conception relatively to the production of the sketches, graphical or verbal models of the projects.

This actualized architecturological knowledge is the fundament of the analysis of the collaborative practices of the agency observed here.

2.2 The Architecturological analysis: method and results

The architecturological language is then for us scientific tool that can be used as a lecture grid of real situations of architectural design [15]. This use consists in searching through collected data of observed situations of architectural design, subscripts of cognitive operations of conception or of representation and to identify how cooperation, collaboration, coordination, evaluation, assistance are built to support them.

In our case, we have observed the process of the collective work of the architectural conception of three different current projects chosen for their diverse stages of elaboration: one in the competition stage, one in the business stage and one in the manufacturing stage. To collect data about them, we have done, for each, passive observations of in the presence or remotely working meetings (project workshops), and interviews of the actors implied in each project.

The analysis allows giving up two categories of results. The first ones concern the tools of representation used or built by the actors of the design process to collaborate in architectural conception. The second ones concern the mechanisms of the collective work implies in architectural conception.

2.2.1 Results concerning the tools of representation used to collaborate in architectural conception

Concerning the activity of representation, we have discovered that the agency has created diverse methods and systems to facilitate the collective work. These methods and systems are:

– Green notes that are concrete written notes of information originally realized on green papers to be identify as then. Nowadays, these green notes are realized on computer by each actor and emailed with internet to the actors concerned by the information. The information can be in the body of the email or in an independent folder archived by their authors. They can proceed from working meetings or be the result of the work of one actor that wants to inform the staff about some decisions.

– Black journals that are books gathering all the information of a project. Each project archived has its black journal with graphical and written documents. These black journals can be used as references for other projects. These concrete black journals should become a digital tool but the dematerialization of the data makes their realization not easy. It needs a specific organization to select the last documents and to not multiply the information.

– A web server called SEDI (Server of Electronic Data Interchange). This web server is a kind of electronic plans cabinet. It allows to download and upload documents and to communicate by email to the subscribers. This web server is not used by the members of the agency because of the easy use of another communication system: Outlook. The use of Outlook is systematic to communicate and send project documents. The web server SEDI is only used when the documents to send are to heavy to be transmitted by Outlook. This systematically use of Outlook creates some difficulties about the management of the mailboxes. They are always full and the users have difficulties to prioritize the information received (this problem is the same in the system SEDI). Sharing mailboxes are then created for each project in order to allow the team to have the whole information of the solely project.

– Public storage boxes that have been created to archive some references and documents of the projects. This kind of sharing boxes is difficult to manage because of their weight. Sometimes members of teams are in concurrence on different projects and the access of these public sharing boxes can be delicate for some confidentialities. At last, these public storage boxes are different from an antenna of the agency to another. The servers themselves are differently organized. Consequently, it is difficult for collaborators to retrieve information about a project.

– A web system of Visio-conference that allows communicating with remote actors. The classical visio-conference system (skype) is not easy to use for sharing documents. So it is often used for coordination or sometimes for cooperation but not really to collaborate in architectural conception. Few actors of the agency use then the specific system Arkadyn allowing sharing the computer screen in order to collaborate at distance and synchronously for architectural conception.

– CAD systems that are Autocad, SkethUp, Photoshop and Xpress. These CAD systems are used to build conventional sketches of the projects following the graphic charter of the agency. The graphic charter allows to understand the nature of the sketches (relatively to the stage of the design process) and to organize the produced documents in specific files. This charter facilitates the recognition of a document and its storing among all those of the project. The agency envisages using a new CAD system: Revit that allows organizing a whole BIM (Building information model) that can be shared by different actors of the project (architects, engineers, etc.). This system is also powerful for its organization that allows to quickly finding the last documents realized.

These results concerning the tools of representation used to collaborate in architectural conception show that nowadays internet has an important role for the communication. They also point the importance of the use of CAD system and the need of a graphical charter to organize the collaboration. Each of these six tools helps to implement what we call the pragmatic operations of the collective work. Some of them can support the cognitive operations of conception (CAD system, Arkadyn, public storage boxes) while others (Green notes, black journals, theme's working meetings, the web server SEDI) are no longer effective today.

2.2.2 Results concerning the collective work of architectural conception

Concerning the collective work of the architectural conception of the agency, we have discovered that the agency organizes what it calls theme's working meetings.

These themes' working meetings are workshops realized in the presence or remotely. They always concern the projects but rarely their conception even if the members of the agency consider them as collaborative meetings of architectural conception.

From our viewpoint on the three activities which constitute the collective work of architectural conception, we have distinguished the meetings of coordination, the meetings of cooperation and the meetings of collaboration.

The meetings of coordination involve the organization of the whole work in the agency in order to distribute the project to each team. They concern the projects and the role of each actor of them but not directly the architectural conception. Their purpose can be to provide the work sharing for pursuing the design. They are usually led in the presence, i.e. all the actors are gathered around the same table, at the same time. These meetings of coordination are then specifically concerned by three pragmatic operations of the collective work: normalization, empowerment and task sharing.

The meetings of cooperation are intended to share information from diverse actors of the project. They concern the project and indirectly its conception by gathering (in preference in the presence) the actors of the project in order to collect the ideas and viewpoints of each on the theme defined for their organization. These meetings can be supported by the written or graphical documents produced on the project for its conception but their object is not to modify them within them. The modifications are made afterward in meetings of collaboration or independently by the designers themselves. These meetings of cooperation can sometimes be realized remotely with the system of visio-conference. They involve five pragmatic operations of the collective work: interpretation, evaluation, building a common benchmark, taking decision, appropriation.

The meetings of collaboration are those meetings within which all the actors gathered work together to find a solution to a problem. The purpose of such meetings is to take common decisions. The object of the meetings of collaboration can be the architectural conception. In such meetings the conception is discussed and the project sketches and models are modified. Generally, these meetings are led by the designers (architects, landscapers, urban planners etc.), the CAD drawers and the engineers. The information proceeding from the meetings of cooperation are taken into account within the discussions.

These meetings of collaboration can be realized in the presence or remotely. When they are remote, the collaborators use the system Arkadyn to share their screen and the documents to modify or, they send their documents to each collaborator by Outlook and discuss about them by phone or visio-conference. The available means are not really suitable to modify together the documents. Consequently, such meetings of collaboration are usually continued with asynchronous remote collective work. This collective work for architectural conception, remote and asynchronous, is then preferred than in the presence synchronous meetings of collaboration. It's the reason why the collaborators use so much outlook and the Emails. At last, these meetings of collaboration involve all the cognitive operations of conception as well as six pragmatic operations of the collective work: interpretation, evaluation, normalization, building a common benchmark, appropriation. They end with the task sharing.

Our analysis of the collective work of architectural conception led within the agency observed shows that collaborative conception is more often implemented asynchronously and remotely involving the use of Outlook for sending the documents and information by Emails and the use of the phone.

The information sent by Emails can be diverse. A content analysis of the messages exchanged by Emails in the situation of the collective work of architectural design, allows distinguishing four kinds of Emails: Emails of coordination, Emails of cooperation, Emails of communication and Emails of collaboration.

The Emails of coordination contain information relative to the “normalization” (pragmatic operation of collective work) of the project by stating the tasks of each actor or the organization of future working meetings.

The Emails of cooperation are composed with a free text written by a principal actor to propose his viewpoint to the others in order to orientate their own tasks of architectural conception. They can also be composed with joint files exposing graphically this viewpoint. The messages of such Emails of cooperation can be decrypted using the architecturological language. In other words, the content of such messages is the architectural conception of their authors (designers, CAD Drawers, Engineers).

The architecturological scales can be used as a lecture grid in order to understand how the author expresses his architectural conception. For example, an engineer can intervene to propose a structural system. He will then give information about the materials of the structure (concrete, steel, wood, etc.), the disposition of the support elements (posts, beams, walls ect.), the dimensions of the support elements and details about the construction of the structural system. All these information concern what we call a technical scale, ie taking account technical considerations to give shapes and measurements to the project.

To cooperate with the other actors of the project, the engineer will then give arguments about his choices. He can for example have chosen a post & beam structure in steel for freeing the volume and to allow the installation of sky-domes through which seeing the sky and getting the natural light. These arguments correspond to an extension scale (freeing the volume to facilitate the spatial planning for diverse future functions), a visibility scale (seeing the sky through sky-domes) and a functional scale (getting the natural light).

As we can see, the architecturological language can help to identify the elements that organize the messages and to classify the important information relative to the architectural conception.

The Emails of communication aim at building a common benchmark for the team by exposing the state of the project, the references to use for working and the decisions about the architectural conception. Such Emails of communication do not give arguments to discuss but just inform on decided elements. They can also be composed with joint files expressing these elements. The content of the messages of such Emails of communication can be analyzed through the architecturological language in order to decrypt the domains of references of the architectural conception. Consequently, these Emails can give information about the cognitive operations of conception called referenciation, i.e. choosing domains of references to think the shapes and measurements of the project.

At last, the Emails of collaboration are composed with conversations about the project in which each actor has the same importance and whose goal is to work together to conceive a common complex project. In such Emails, we find questions or answers addressed to one or several actor(s). These Emails of collaboration concern the architectural conception of a project that can be identified through one or several architecturological scales. As the Emails of cooperation, the Emails of collaboration can be architecturologically decrypted in their content to identify the architecturological scales, domains of references and cognitive operations of conception at work in there. The difference of these Emails of collaboration compared with Emails of cooperation is that they look like conversations and discussions on the shapes and measurements of the project while the Emails of cooperation are more informative on possible decisions. Such Emails of collaboration are accompanied with the sending of graphical documents.

3 Needs of the future computer tool

From the results of the architecturological analysis of the collective work of architectural design of the agency observed, we have discovered their collective working habits and problems relative to the use of their computer tools.

As we have seen in part 2, the asynchronous and remote collaborative conception using Emails, sometimes the SEDI system and some of sharing mail boxes or the storage boxes, is current in the agency. We suppose that this habit proceeds from the inadequacy of the tools to facilitate the remote synchronous collective work.

We have also seen that for communicating, Outlook is generally preferred even if a performative system exists within the agency (SEDI: server of electronic data interchange). This systematic use of Outlook implies management problems of the sending documents and the information of the messages. These management problems concern the ways to rank the documents and information, to search them, to access to them, to structure them, to share them and to know their existence and place.

Consequently, the members of the agency asked us to propose a new computer tool by which resolving these management problems. From this requirement, we have questioned the design teams of the projects analyzed in order to know their wishes and their felt needs in term of computer aids.

The first expressed users' need was to be kept abreast of the agency's current and past projects progression but without disrupting how they work. In other words, the future computer tool should be easy to use and should not perturb the design work habits. In fact, the collaborators wanted a new computer tool to facilitate the information transmission and the communication (on the current and past projects) but preserving their usual means of designing.

From the interviews of the actors of the projects observed, we have raised a list of more specific requirements for the future computer tool:

– allowing the control of the documents and messages sending, ie allowing to each collaborator of a project to access to these elements and to eventually add his comments or annotations,

– allowing the rapid recognition of the last documents produced, ie preserving the design historic of the projects and keeping up-to-date the progression if the agency's current projects,

– alerting automatically the collaborators when a new document is created on the project or archiving in one of the storage boxes of the agency,

– allowing the textual exchanges (question, answer) in between two or more collaborators.

– retrieving information from past experiences,

– filtering information about projects according to the user role in the projects and in the agency,

– customizing the display of information according to the user habits.

As we have seen in part 2, the architecturological language and its scientific methods of analysis can help to organize the information of the projects and then can provide the basis of a new computer tool that meets these expectations.

4 The prototype of a computer tool for enhancing the collective work of the agency

This part presents the specifications of a useful collaborative tool for all the staff of the agency as well as the software prototype. This prototype is largely based on Web 2.0 technologies enhanced with semantic web techniques [16] and a Multi-Agent Systems (MAS) [17].

4.1 A web 2.0 based system

The Use of Web 2.0 technologies for sharing and communicating into Architecture Engineering and Construction Industry is a research trend [18][19][20]. Publishing, subscribing, tagging, blogging, chatting etc. are Web 2.0 functionalities that seem to match, at least partially, with the requirements and collaborative needs of the agency staff.

For example, these technologies allow to a project team manager to publish documents on a project in progress (plan, images, 3D model etc…) and to a user to subscribe to this project for accessing them. Subscribers can then comment the production and communicate their ideas to the other subscribers. The user can also tag the documents with words describing its content and thus participate to improve the research performance of the system.

However, applying directly such Web 2.0 technologies seems to not be possible in our case. Publishing, updating and tagging information with such Web 2.0 system is time consuming. The future users of the computer tool don't want to change their working habits and therefore taking time for other tasks. Consequently we have thought that we could proposed a system based on Web 2.0 technologies enhanced with intelligent algorithms that could assist the tasks of publishing, tagging and updating.

These mechanisms of intelligent algorithms can help users in retrieving data about projects in the documents stored in the different remote servers of the agency and in the “semantization” of documents. As we have seen in our analysis, the projects data are heterogeneous and more or less structured in document files (CAD files, Images, freehand sketches, meeting reports, etc.) and we know that a software program can retrieve information included in these files only if semantic data are attached to them. Our issues are therefore very close to semantic web research issues [21].

Other researches aim to develop collaborative design tools based on web semantic technologies [22, 23, 24] with different purposes. They show that the developed tools can reason on exchange data between several enterprises in order to improve interoperability of distributed software applications. Consequently, we have decided to develop a tool with the web-semantic technologies for assisting documents retrieving and a multi-agent system for adding semantic to documents.

4.2 Building an ontology

In a semantic web application the semantic is generally described in an ontology [16, 25]. An ontology describes the concepts and the relations of a knowledge domain [26]. For our purpose, the knowledge domain refers to the architectural design built by the members of the agency.

During the Architecturological analysis, we have established a list of sharing words used to communicate and to work collectively in architectural conception. This list is organized in four groups: sharing words about the actors of the architectural conception (architect, structural engineer, VRD responsible, CVC Responsible, Pilot site, Supervisor, etc.), sharing words about the organization of the project (candidacy stage, competition stage, APS study stage, Pro stage, etc.), sharing words about the communication tools used (in the presence or remote meetings, emails, reception plan by Emails, phone, chantiers.net (the name of the SEDI), etc.), sharing words about produced documents (Visas by post, Autocad drawing plans, implementation plans, summary tables, bibles, graphical charted, library, archive server, etc.).

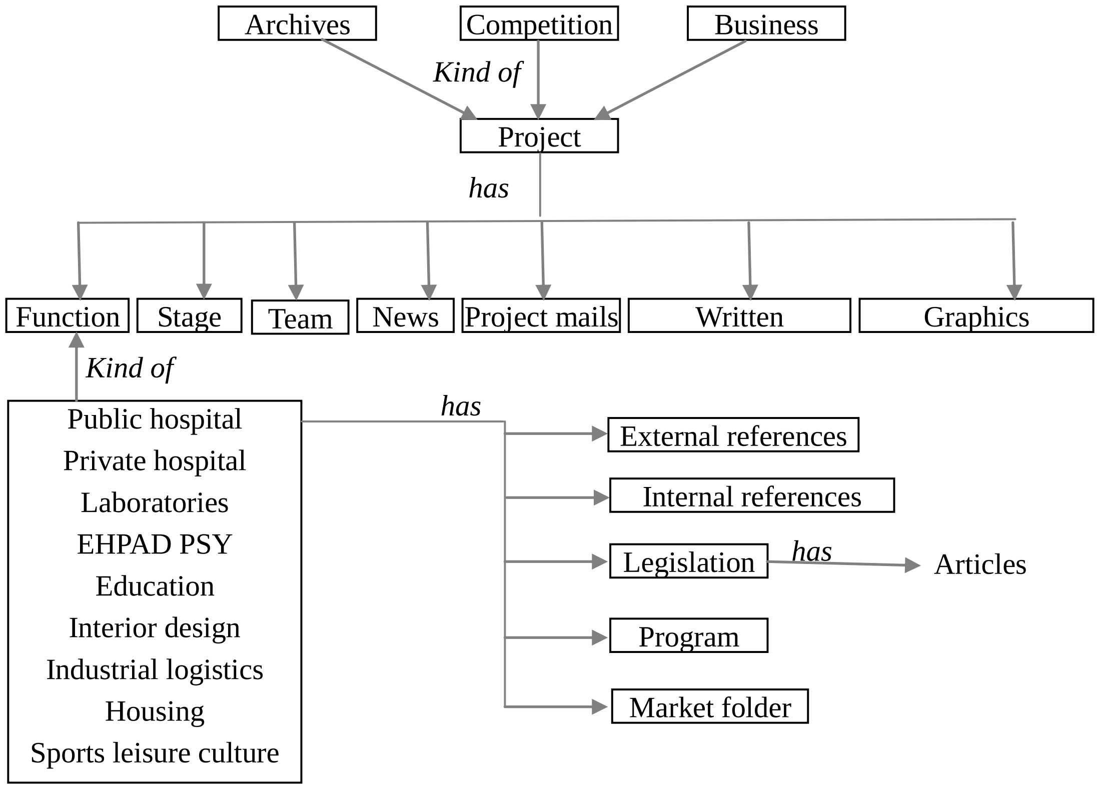

Fig. 2: Some words of the agency's language

These agency’s words can be used for describing the concepts and the relations of the system ontology. The fig.2 is an example of such an ontology built with the agency's words and allowing storing and retrieving projects documents.

The prototype’s ontology has been developed with the Ontology Web Language (OWL) which is recommended by the W3C for developing ontologies [27].

A group of entities that share same properties are described in OWL class. For example, our ontology includes the Document class which describes the properties of all the documents produced by collaborators during design activities. Some of these properties, called non-terminal properties, express relationships of a document with other concept of the ontology: what collaborator is the author of the document, for what stage of what project it is produced etc.. A terminal property expresses that a document has an address URI (Unify Resource Identifier) that gives the access path to the document on the files server.

Because OWL programming is a difficult task, we used the Protégé editor of ontology developed by Stanford University [28]. Protégé offers many tools that help ontologies developers. It includes useful tools for editing classes, relations and properties, tools for validating ontology and detecting errors, tools for graphically visualizing the semantic net, etc. Once the ontology is completed, Protégé can automatically generate the corresponding OWL file.

The next figure presents a partial view of the ontology hierarchy class (Fig. 3).

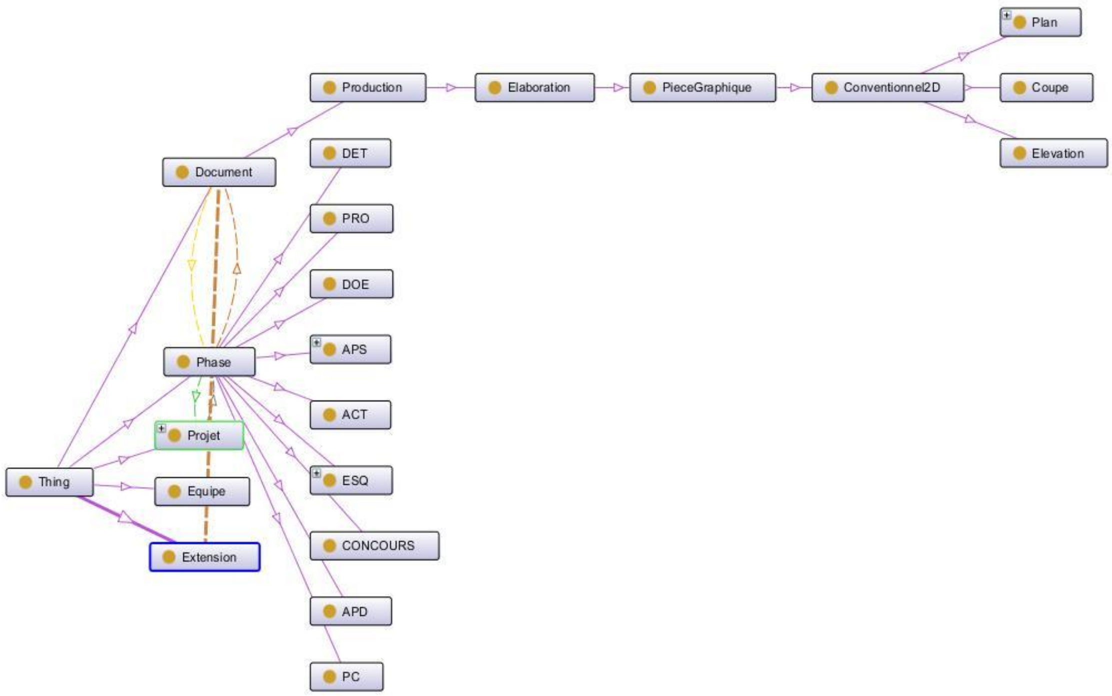

Fig. 3: A partial view of the ontology hierarchy classes (French version)

Instances of these concepts are connected through relations in order to form a semantic network that describes knowledge about projects and their associated documents. As the main requirement expressed by the collaborators was to not perturb the work habits with the future computer tool, the instantiation of this knowledge base is automatically realized by a multi-agent system that reacts to data movements operated by collaborators on the file-servers.

4.3 The Multi Agent System

The MAS includes specialized agents that analyze events to update the knowledge base. The MAS role is to manage automatic "semantization" of document, i.e. instantiation of concepts of the ontology describing a new document, modification of the properties of objects describing an existing document or objects removal if the document is deleted.

In the current state of the prototype development, the agents analyze file paths of the document in order to guess its contents. For example, when a new document is created in a folder (the folders are in inclusion and inheritance relations), the MAS creates a new instance of the folder class in the knowledge base: For example a new plan in the Plan class folder that is in relation with the Stage class folder and the kind of project class folder. Agents use regular expressions [29] in order to find, in the path, words that correspond to concepts of the ontology. Following, the MAS links this instance of Plan to the instance that represents the stage of the project and the name of the project.

It would be possible to develop more sophisticated agents that could open the document and inspect the content in order to create the "semantization" with the words used in the document. Such sophisticated agents need structured data (IFC files, XML files, DXF files etc.) that they can inspect according to their functioning mechanism.

The agents of the MAS are specialized for capturing specific events of data movements: creating document, modifying document, erasing document etc.. If such events occur, the MAS controller sends to all agents a message describing the events. The agents filter these messages and react if they are concerned.

Because the agency's collaborators wish to continue using their tools, a plugin has been developed for capturing the email sent and received in Outlook. This plugin implements a specific agent for the MAS. The collaborators practice consists in declaring a new recipient when a new project starts. The name of the project is given to this new recipient. Therefore, the outlook software agent has to inspect the recipient of the email to know what project is concerned. He creates a new instance of the email class in the knowledge base, links this instance to the project instance and sets an URI to the email resource.

The agents functioning must be partially different for each agency's site in order to take into account specific local work habits.

4.4 Architecture of the system

We developed the prototype with a range of tools used for building Web 2.0 [30] applications and for developing knowledge-based applications with ontology.

Our development strategy consisted in reusing as much as possible existing web 2.0 tools. For example, to build the prototype it was possible to use popular Content Management System (CMS) as Wordpress, SPIP or Dupral1. We decided to use the open-source SPIP [31] because it is easy to use by end-users and because numerous free add-ons are available for this CMS. These add-ons provide us most of the required Web 2.0 functions. However, we have developed new SPIP add-ons for requesting the knowledge based and displaying information on the agency projects progression.

Requesting and reasoning

It is possible to describe request with a description language (DL) for retrieving entities. These requests are considered as new classes which can be automatically placed in the class hierarchy and then it is possible to retrieve all the entities that belong to this new class. For example, the following request describes the conditions that define the plan created during the outline scheme design stage of the design activity (stage D in english RIBA and APS in french) for designing the project of a clinic hospital for the French city of Annemasse (Fig. 4):

```
Plan and hasStage some (APS and isStageOf value Annemasse_Clinic)
```

Fig. 4: An example of DL request

SPARQL is another language used for retrieving entities in an OWL knowledge based. Below (Fig. 5) is the SPARQL translation of the DL request stated above.

```
Select ?plan Where { ?Plan document:hasStage ?APS
                     And ?APS stage:isStageOf Anemasse_Clinic }
```

Fig. 5: SPARQL translation of a DL request

The user of the collaborative web application can use these two languages for retrieving information about the agency's project. The next sections describe briefly the system architecture and the role of the different software components that compose the prototype.

Concerning future developments, it is envisaged to complete the agency's ontology and to link it with IFC-Based Ontology so that it will be possible to retrieve information extracted from Building Information Model (BIM) [32] and thus to provide more details about the projects progression. We also imagine enhancing the developments with the use of the architecturological language that allows specifying the ontology on information relative to architectural conception itself.

Distributed architecture of the system

The collaborative web application is duplicated in a specific web server in each agency sites (identified by a letter in the next figure (Fig. 6)). Data of the projects designed in each site are stored in local file-servers.

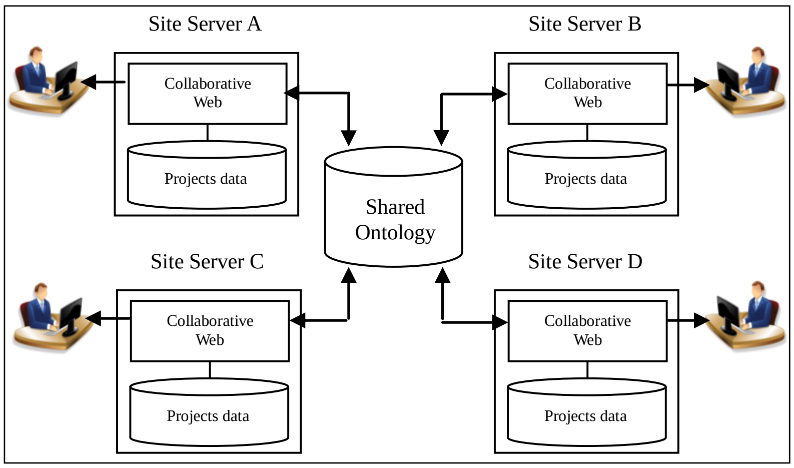

Fig. 6: The distributed architecture of the collaborative web tool on remote sites

The collaborative web application includes two software packages installed on each web server: the Knowledge Base Manager package (KBM) and the User Interface Manager (UIM).

The knowledge base manager

In each agency site there is a file server that collaborators share for storing documents about projects (Storage boxes). The same organization and hierarchy of folders is used for each project of a site but this organization can be different for another site. The next figure presents the project folders organization of one of the agency sites. For each new project the team manager copies the folder tree so that each team member can record his productions in the right folder. It is the current collaborators work habits and, as we have already said, they don't want to change it.

It's why we have developed a Multi-Agents System (MAS) that reacts to data movements on the file servers and adds semantics to documents. The KBM package includes this multi-agents system and a Java Servlet for requesting the knowledge base and retrieving information about projects (Fig. 7).

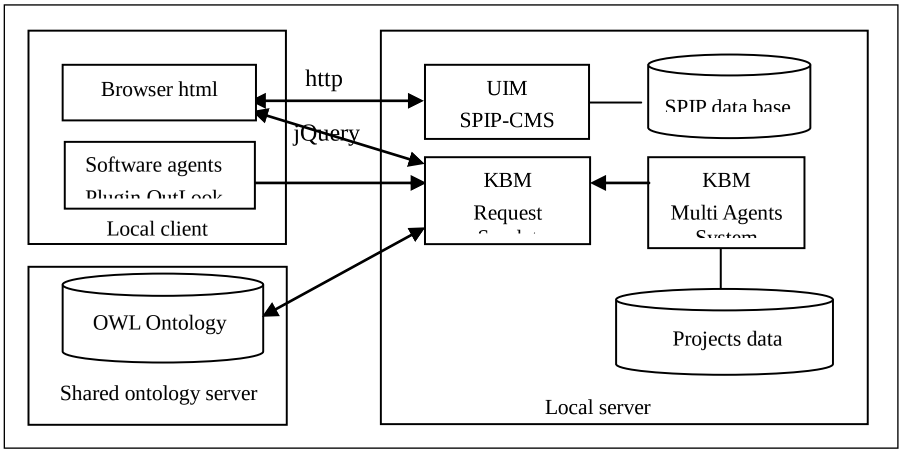

Fig. 7: Architecture of a local web collaborative tool

The knowledge base requesting Java Servlet

A Java Servlet is a software program running on a server and used to respond to requests.

The Java Servlet of our collaborative web application includes requests for retrieving elements of the knowledge base through DL or SPARQL language.

These DL_request and SPARQL_request return to the user an XML description of retrieved knowledge base entities. The Servlet requests are called through jQuery technologies in order to dynamically display information about projects. jQuery is a JavaScript library intended to dynamically display server data on a client html page without having to reload it.

The user interface and information displaying

As mentioned above, we use the CMS SPIP as tool for publishing information about projects. It allows an access to all the web 2.0 tools: publishing, subscribing, comments, chats, forums and so on.

For helping collaborators in publishing contents, we have developed a new plugin that defines a new publication object for SPIP: the project progression wall object (PPW). The project manager has to create a new PPW when a project starts. He has to declare the project team members, to define authorizations for accessing the wall and post comments, and to describe what information the PPW will content.

A PPW is a kind of SPIP section, with possible subsections, whose part of content is the result of requests to the knowledge base. The requests can be express with DL or SPARQL. They can return a list of URL towards documents produced by the project team. The plugin also allows user to specify how documents will be displayed on the wall: URL, icon or image.

When a new PPW is created, the knowledge base is automatically populated with concerned entities: a new project entity, a new project team and other entities concerned. All relationships between these entities are updated so that the system is ready for displaying the progression of the design work on this new project. The figure 9 presents a possible very simple interface that displays URL to documents related to the progression of the Annemasse Clinic project. The content of the three articles are automatically displayed with the results of requests to the KBM Java Servlet. For example the request for displaying the content of the article entitled “Last Plan” is the following (Fig. 8):

```
<kbm|DL_Request= Plan and ofTheStage some (isStageOf value
Annemasse_Clinic) and (lastModification some positiveInteger[<=
7])>
```

Fig. 8: Request for displaying the content of "Last Plan" subsection of the Annemasse_Clinic project progression wall

This request returns the list of documents whose last modification has occurred 7 days ago or less. The number of comments posted by collaborators about the project is indicated. These comments can be displayed by clicking on the word post (Fig. 9).

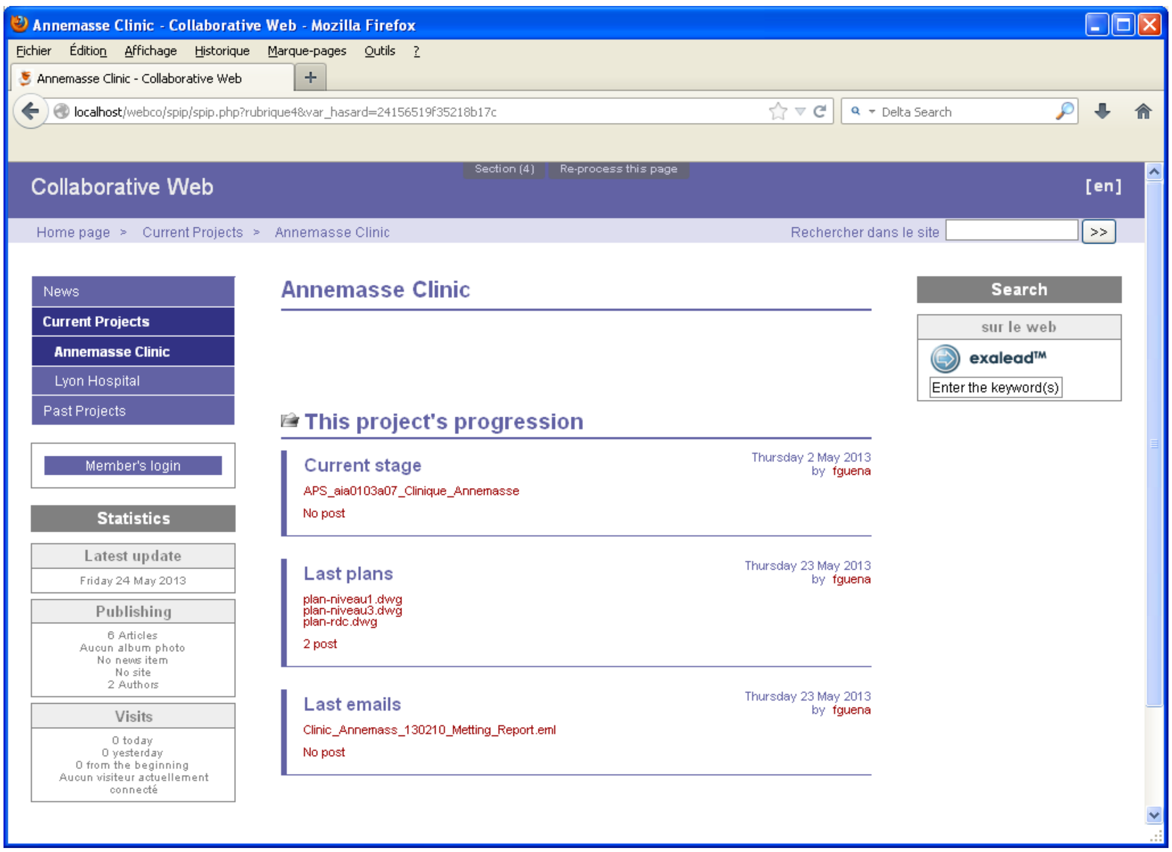

Fig. 9: Example of an SPIP interface that displays a brief project progression

User interface customization

The collaborators authorized to access to a project information can subscribe to the project to be advertised when changes occur in the project progression. Each collaborative web application of the agency sites can use RSS (Really Simple Syndication) feed syndication to locally consult a PPW available on another site. SPIP offers tools for filtering RSS data transfer and we can select information to display.

In addition to PPW, authorized users can add new sections and articles in a local UIM. As for the PPW publication object, these sections and articles can include requests to the knowledge based expressed in DL or SPARQL in order to display any useful information retrieved in the knowledge base.

The PPW plugin and the existing Web 2.0 communication as SPIP tools, offer a great flexibility for displaying information about project and for the collaboration between the agency's members.

5 Conclusion

Architectural design is then a complex collective activity depending on the project situation, its actors and their working habits so as the means and tools used to share and exchange information and documents of the project. In other words, architectural design is specific to each project and enlightening its process needs scientific knowledge on the activities it involves for analyzing cases.

Architecturology, which distinguishes the collective work (coordination, collaboration, cooperation) and the cognitive activities of designing (conception and representation), offers a scientific framework to lead research on architectural design and then to build knowledge on its process.

We have here shown how we have used it to understand the collective work implemented in the architectural design process of an agency installed on different remote sites. The architecturological analysis has been realized on three different current projects of the agency and has allowed understanding how the collective work is involved in architectural conception according to the use of specific tools of representation. It has also allowed to described the mechanisms of the collective work by exploring different kinds of remote or in the presence working meetings (meetings of coordination, meetings of cooperation, meetings of collaboration) and has pointed the important use of Outlook and Emails to collaborate in architectural conception.

From these results, we have, with the projects teams observed in the architecturological analysis, raised a list of needs for a future computer tool enhancing the collective work now known. The collaborators wanted a new computer tool to facilitate the information transmission and the communication (on the current and past projects) but preserving their usual means of designing.

This list of needs and the knowledge we have built on the collective work of the architectural conception of the agency have allowed us to elaborate the specifications of a useful collaborative tool for all the staff of the agency as well as the software prototype. This prototype is largely based on Web 2.0 technologies enhanced with semantic web techniques and a Multi-Agent Systems.

The semantic web techniques used here has involved the development of an ontology built with the words of the agency concerning architectural design discovered in the architecturological analysis. This ontology could be completed with IFC- Based Ontology for retrieving information extracted from Building Information Model and with the architecturological language for specifying the ontology on information relative to architectural conception itself.

The architecture of the system is largely presented here and shows how this computer tool allows keeping collaborators up-to-date with the projects progression and offers tools for posting, publishing and commenting information.

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