A MULTI-AGENT SYSTEM FOR THE FORMULATION OF ARCHITECTURAL TERMS OF REFERENCES

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Abstract. This work aims to use the multi-agent systems, permitting to coordinate the behavior of intelligent artificial agents, in order to help the architect at the first moments of the conception. We proceed by modelling the architectural terms of reference, using the concept of primary architectural system, to manage the initial information. This modelling process proposes a new formulation of this system based on the agent paradigm.

1. Introduction

The architectural conception passes through a preliminary phase witch consists in the formulation of terms of reference[1]. These terms orient the architectural production (Pena, 1977) and therefore they are essential in the process of the architect's information systems.

In the framework of our study, we are interested in the artificial intelligence that actually constitutes a promising solution for the management of complex problems (Halton and al., 1991) Indeed, the contribution of the artificial intelligence in the field of information management, such as the constraints satisfaction (Weigel and Faltings, 1999), or in the field of the forms recognition (Ferrand, 1997) is important. "EsQUIsE" (Leclercq, 2004; Juchmes , Leclercq and Azar , 2005; Leclercq, 1998) for example is a software based on a multi-agent system (Ferber ,1995)for the interpretation of architecture sketches. So, it seems today

[1] We avoid using the term “program” that is strongly connoted. This term is generally reduced to a quantification of surfaces and a qualification of spaces.

possible to reduce the gap between the capacity of the computer tools and the architect's activities.

This paper presents a multi-agent model for the formulation and management of architectural terms of reference. It aims to help the architect, in the preliminary phase of conception. This system must be able to cooperate with the architect in order to produce synthetic information aiming to facilitate the progress of his thoughts and to make him seize the space in total coherence with his creative gait. It is not about automating the architect's tasks but to exploit the complementarity of the human intelligence and the artificial system, to create a helpful tool for the conception. This paper proposes a formulation of the architectural primary system (Arouf and Ben Saci, 2006; Ben Saci, 2000) using the agent paradigm. The architectural primary system is modeled by a multi-agents system which we propose to present its functionality and to debate its contribution for the formulation of the architectural terms of reference in an empiric situation.

2. Primary system of the architecture and multi-agent system

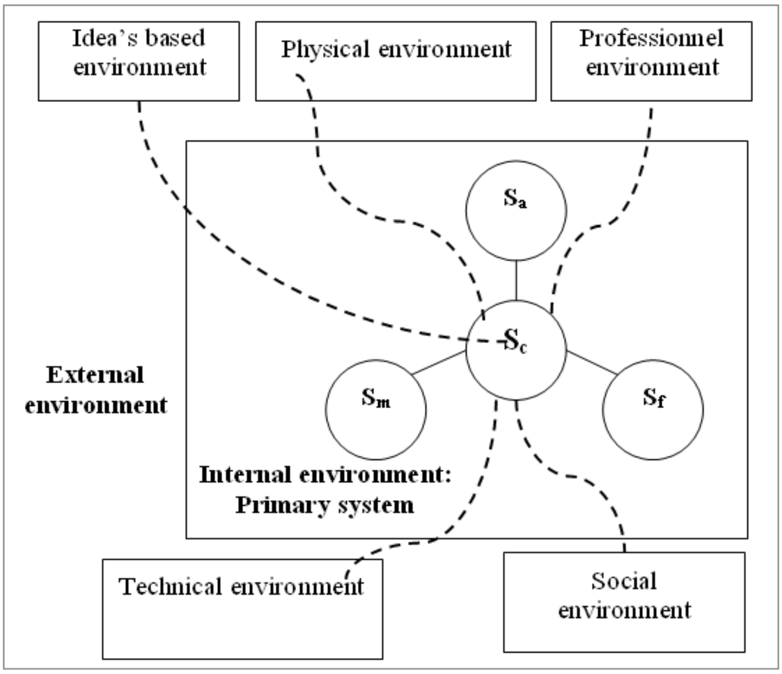

Figure 1. The system of architecture (Ben Saci, 2000)

The system of architecture (Arouf and Ben Saci, 2006; Ben Saci, 2000) (fig.1) is a concept which proposes to modelling the architectural reality. It separates distinctly the external environment (architectural terms of reference for example), from the internal environment (primary system of the architecture). These two environments are connected by an interface named compositional system (S_c). The components of the primary system are the morphic (S_m), functional (S_f) and architectonic (S_a) production systems.

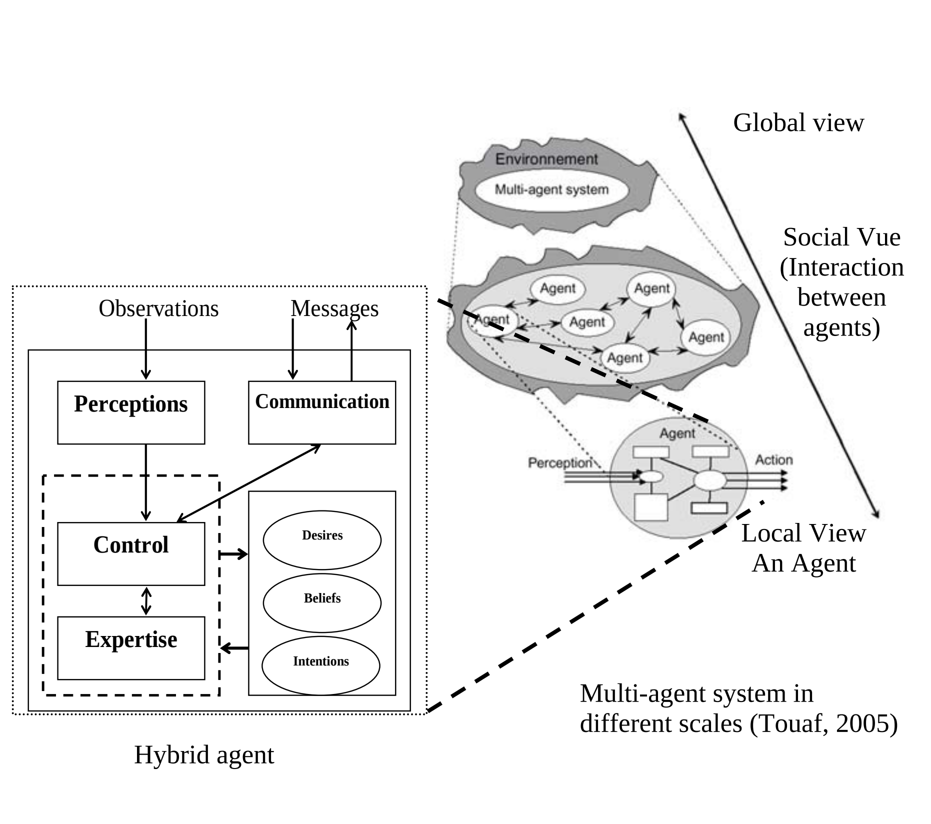

Figure 2. The multi-agent system

The analysis of Alexander (Alexander,1964; Alexander and al.,1977; Salingaros N-A.,2000), Pena (1977) and Prost (1992) works allowed us to affirm the idea of complexity of the architectural terms of reference and oriented us toward the distributed artificial intelligence which is more suitable for the complex systems than the classic artificial intelligence (Ferber,1995). It enriches the process of treatment of the information by sharing it between several agents. The interaction of several incomplete or low-reliable expertises can lead to more complete expertise. The multi-agent systems (Faucher, 2001; Touaf, 2005) (fig.2) permit to coordinate the behavior of intelligent agents, that interacts and communicate between them, in a society, to solve complex problems.

So the complexity of the architectural terms of reference can be treated by the capacity of the multi-agent systems to manage informations. They are well adapted to the case of the formulation of the architectural terms of reference, seeking various expertises and various types of reasoning. The cooperation between several agents having different point of views allows the treatment of complex problem more efficiently than with only one agent.

TABLE 1. Comparison of the centralized multi-agent system and the architectural primary system

	Multi-agent system with centralized control	Architectural Primary System
Components –	Agents	Morphic production system (S_m); Functional production system (S_f); Architectonic production system (S_a)
	Blackboard+ supervisor playing the role of interface between the different agents.	Compositional System (S_c) plays the role of interface inter and intra systems.
Caresteristics	The agents are situated in an environment.	S_m, S_a and S_f are situated in an internal environment named architectural primary system.
	The agents are independents.	S_m, S_a and S_f are independents systems possessing each its own internal and external environment.
	The agents are sociable: they are able to interact between them.	S_m, S_a and S_f communicate between each other, mutual adaptation.
	The agents are also characterized by their intentionality, their rationality, their engagement and their adaptability.	Composition intra and inter components of the architectural primary system.

The multi-agent system permits to provide synthetic information. It avoids all redundancy and discordance between the different information.

We use the multi-agent system (MAS) with centralized control (based on blackboard) to formalize the architectural primary system. In fact, MAS counts among the systems having been validated in many fields of application (Halton and al.,1991; Ishida, Gasser and Nakashima, 2004) and presents a homologous structure to the architectural primary system (Belkaïd, 2006). Through comparing the structure of the architectural primary system to the multi-agents system with centralized control (Table 1), we note the components counterparts and the common features permitting the modelling of the primary system of the architecture in a multi-agent system.

3. Formulation of architectural terms of reference by the agent paradigm

The multi-agents system for the formulation of architectural terms of reference (fig.3) is based on the collaboration between heterogeneous agents corresponding to the components of the architectural primary system. The user collects all information from the external environment to constitute a specific external environment. These information correspond to initial data for a particular architectural production.

We associate to every component of the architectural primary system a suitable agent able to make use of its expertises by collaborating with the other agents in order to accomplish a given task. The components of morphic, functional and architectonic productions becomes then agents. These components manipulate quantitative and qualitative information. In this regard, we choose to define them as being hybrid agents that means cognitive and reactive agents. We refer to the "Belief-Desire-Intention" approach (Touaf, 2005).

The multi-agent system for the formulation of architectural terms of reference is characterized by the communication, cooperation and the coordination of the different agents to manage the information of a specification. Every agent has a capacity to take in charge a task. It is characterized by its autonomy in making decision, its knowledge of itself and of the others, its capacity to act, its intentionality, its rationality, its engagement, its adaptability and its intelligence.

The principle of the multi-agents system for the formulation of architectural terms of reference is to share and to distribute between several agents (of the architectural primary system and the external environment) the set of knowledges in order to manage the initial information.

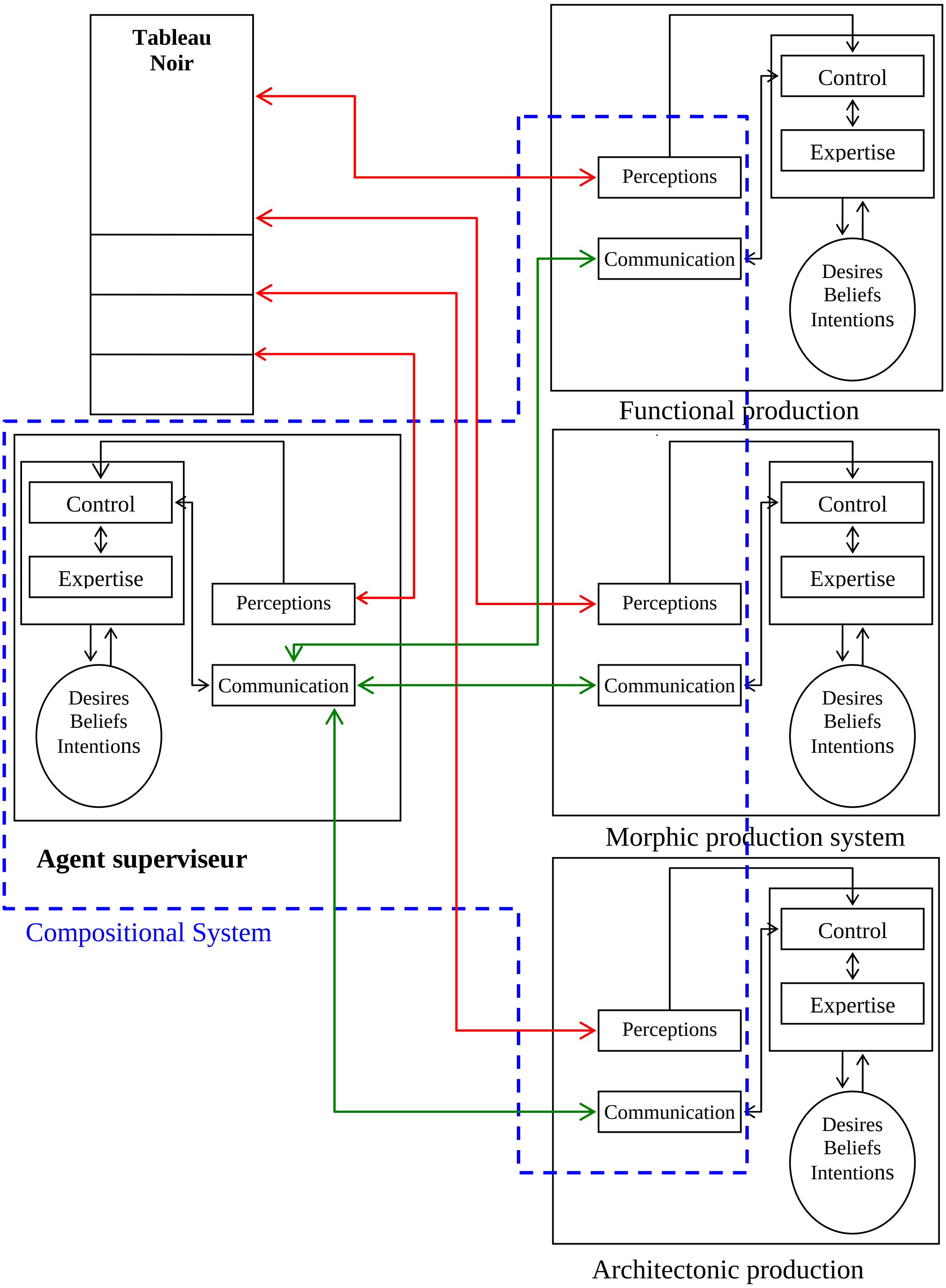

Figure 3. MAS for the formulation of the architectural terms of reference

The different agents communicate between them. When it is about primary information, the agent can consult the blackboard directly. When it is about more complex information, the agent asks the supervisor (S) to find through the other agents the wished information.

A message of communication consists of several elements :

Var: variable

Val: Value

Sender: the emitter of the message

Receiver: the recipient of the message

Request: to ask

Respond: to answer

The messages of communications between agents are the next one :

Request (Var, Sender, Receiver): The emitter asks the recipient a variable.

Respond (Var, Val, Sender, Receiver): The recipient answers the emitter by the value of the variable asked.

Let's present an example. We suppose that one agent responsible for the morphic production (Pm) is going to apply to the supervisor (S) to find specific applicable information to the form. The agent supervisor is going to ask the architectonic agent (Sa) to satisfy the agent's demand (Pm). The communication between the different agents can be written in the following manner :

Pm request (var, Pm, S)

S request (var, Pm, Pa)

Pa respond (var, val, Pa, Pm)

S respond (var, val, S, Pm)

4. System finctioning

4.1. PERCEPTIONS

It is about collecting the initial information to nourish a part of the blackboard which contains facts, hypotheses and basic elements of the situation to be treated. These information interests also the morphic functional and architectonic production agents. The content of the specifications constitutes the data of the blackboard. The same information can interest different agents.

4.2. CONTROL

The Multi-agent system for the formulation of the architectural terms of reference executes a set of actions, thanks to the configuration of the initial data or of the elements of the previously generated situation. By applying knowledge bounded to the field of the architecture, it generates new elements or modifies some of the old. At every stage of the reasoning, several actions can be possible and so to be in conflicts. The module of control of The Multi-agent system for the formulation of the architectural terms of reference, can be formulated therefore like follows: at every instant of information treatment process, which action the system should execute? Thus, the module of control classifies the information following their nature (quantifiable or digital and following the centre of interest of the morphic, architectonic and functional agents).

The module of control chooses in an implicit manner the knowledge to apply, the region of the data to treat and the methods and strategies to use. To do so, it must be able to evaluate the quality of the current proposition, to identify various possible propositions, to know how to recognize a situation of information treatment and to interrupt the process to consider another. Facing complex situations, the agent adopts several levels of reasoning, to separate the local strategies from the global strategies, to adopt and to combine the heuristic and to plan a sequence of actions in order to reach precise goals.

The multi-agent system for the formulation of the architectural terms of reference integrates strategies of communication allowing every agent to know when to communicate, what types of information to exchange (data, goals, plane of actions, expertise…) and with whom to interact. The module of control maintains the consistency of global treatment of information, knowing that every agent has only a partial view of it, and to coordinate the activities of the different agents.

4.3. EXPERTISE

The module of expertise of the SMA is characterized by its capacity of learning using previous experiences. Indeed this module uses, according to the type of information, a precise reasoning (fuzzy, production rules based, to case based or to model based) (Faltings,1994; Faucher, 2001). It analyzes the structure of the new information received according to the structure of the older information. It adds it to its knowledge data base if this structure presents a new shape otherwise it is going to exploit the already stored structures. The module of expertise also occupies a determining place in an agent's architecture. This module is based on several types of fuzzy reasoning, model based or case based to manage the initial information.

5. Illustration of the model : survery of example

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5.1. CASE OF SURVEY

This proposed example concerns the management of the initial information of small architectural terms of reference defining the features, the needs and the performances of a house. These terms of reference can be translated in few lines as follows: "Mr and Mrs. X wants to construct a house (Coefficient of soil occupation: 0.5; coefficient of fundamental use: 0.8; maximal height: 10 m). They express to the architect Y their will to achieve a house of 200 m² of surface for a couple and two children. This house must be convenient and luxurious and does not exceed one hundred thousand dollars. They ask for an entry, two children rooms, a parents room, a lounge, two bathrooms and a kitchen." We propose to limit the illustration to the management of the relative information in the "utility" component. It is about testing the functioning of the model using this category of information to determine reliable data. The test is oriented toward the functional entity "kitchen" which is decomposable in several attributes such as types of materials.

We note that every initial information can interest one or several agents, which mean that several agents can share the same information. We also notice that 40% of the information interests the functional production agent. This rate is the most important. It indicates that theses terms of reference are mainly centred on the functionality. The balancing of the relative information to the interest of the different agents is going to give an indication on every agent's immediate environment. We note that the classic specifications present a predominance of the information concerning the functional production agent (46%). This predominance doesn't mean that the functional agent will be the major in the architectural production. With this consideration, we underline the interest of the multi-agent system for the formulation of the architectural terms of reference that is going to control the information dominance thanks to the communication between the different agents. We keep that 50% of the information are imprecise. They require fuzzy, case based or model based reasoning (Belkaïd, 2006; Faltings, 1994).

5.2. FUNCTIONNING

First, every agent defines its beliefs in relation to the information in the specifications, regardless of the resulted well stocked by the other agents.

Then, it communicates and cooperates with the other agents to generate more precise beliefs. We intend to illustrate the functioning of the multi-agent system for the formulation of the architectural terms of reference through the description of the different communications between agents to generate applicable information. We admit that the time T_i, with $i \in \{0... n\}$ will be affected to the global system composed of subsystems corresponding to functional (P_f), morphic (P_m), architectonic (P_a) production agents and supervisor (S). The time t_i with $i \in \{0... n\}$ will be affected to each of these subsystems (P_f), (P_m), (P_a) and (S).

In T_0, the global system has; for objective; to bring supplementary information to the subsystem "kitchen". to assure this desire, the agent supervisor (S) believes that the attributes of the kitchen can concern several levels of perceptions. In other words, the kitchen is a nominal identity that can be perceived as physical space, or as functional space, or as potential place (supposed use). However all these levels of perception suppose numerous and varied information. Therefore to reach its desire, the agent supervisor (S) decomposes the problem into few sub-problems. it confronts itself to the necessity of the goal selection to satisfy at first , and to the action that permit to reach it. For it, the agent supervisor (S) holds account of its beliefs to focus; for the meantime; on the information concerning the kitchen as physical space. it asks the functional agent (Pf) to provide him some indications for the choice of the adequate materials of coating in this kitchen.

In T_1, the functional production agent (P_f) answers the supervisor (S), through the module of communication, its desire to know the cost and the technical features of the materials.

In T_2, thanks to its module of control and through the module of communication, the supervisor (S) consults the architectonic production agent (P_a) to calculate the cost and the technical features of the kitchen.

In T_3, the architectonic production agent perceives the demand of the supervisor. It starts then by calculating the cost of the materials of the kitchen. To do so, it elaborates a plan of actions constituted of intentions, engagements and beliefs on the its environment. It decides to calculate the surface of the kitchen first, then its cost of realization, to finally be able to determine the cost of the materials.

The architectonic production agent (P_a) needs to know the surface of the kitchen. It consults the blackboard, where it is recovered, the global surface of the house as well as the number of permanent inhabitants. It is going to resort to a rule of production, (Expertise1) to determine the surface of the kitchen. The architectonic agent is going to be able to calculate from the global cost of the house, (recovered from the blackboard), and the surface of the kitchen (calculated with the expertise 1) the cost of the kitchen, thanks to a rule of production (Expertise 2). Finally, the architectonic agent is going to be able to determine from the surface and the cost of the kitchen, the cost of the coating materials, thanks to a rule of production (Expertise 3). It communicates this result then to the supervisor agent.

In T_4, the architectonic agent has the desire to know the technical features of the kitchen's coating materials. This agent is going to resort to its beliefs. It believes that a coating of a kitchen must be strong, easy to clean and to maintain. It must be non-skid for soil for security reasons. These beliefs corresponds to the pattern n° 233 of Alexander concerning the coating of soil (Alexander and al., 1977).

Thanks to its beliefs as well as its expertise, the architectonic production agent communicates to the supervisor the following result: "For the coating of the walls and soil, it is advisable to use tiles made of sandstone enamelled ceramic that includes a protective layer to antibacterial effect by photocatalyse under the action of light and to absorbent effect under the action of steam with a mat aspect for soil, satin and brilliant for the walls. It is also possible to use the ceramics enamelled for the walls with a brilliant aspect."

The architectonic agent offers a catalogue of materials for the choice of the available materials and responding to the different constraints.

In T_5 the supervisor communicates to the functional production agent all information collected, concerning the technical features (solidity, aspect, composition…), of the coating materials in a surface of 15m² that does not exceed the cost of 1000 $.

6. Conclusion

We have seen a model of information management used in the earlier phases of the architectural conception. The multi-agents system for the formulation of the architectural terms of reference operates by coordination, cooperation and communication between intelligent artificial agents. It aims to bring a help to the architect since the first moments of the conception. This model permits to manage the initial information of the specifications and to term to structure the numeric architectural production. While verifying the compatibility of the information, it erases some redundancies, present synthetic information and proposes strategies of management of the contradictions. This work lets an important number of open perspectives to reach an operational system. We can consider a work on the knowledge formalisation, the modularity and the evolutivity of this system as well as the development of modules of expertise of the architectonic, functional and morphic production agents.

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