CONCURRENT BDI ARCHITECTURE FOR HIBRYD AGENTS

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***Abstract*— This paper presents a concurrent BDI architecture aimed to implement hybrid agents hardware/software. The proposed model includes an innovative model of the agent architecture inspired in human practical thinking in which some mental processes are performed in a parallel and concurrent fashion. The BDI model is composed of several independent modules, internal subagents that can be mapped to different domains of implementation (SW/HW). The paper emphasizes the process that manages agent's goals taking into account different motivations for agent action (needs, opportunities, emotions and obligations). The proposed concurrency schema includes three main components: the beliefs cycle, the desire goal management process and the mean ends intention-based action controller. The model has been validated in a software case study in the field of social simulation.**

Keywords-component; Inteligent agents; BDI Architecture; Concurrency; Goal Management.

I. INTRODUCTION

Modern systems and their applications in different areas can be characterized as complex solutions [1]. Examples of these systems can be found in areas that include and integrate different disciplines such as engineering, sociology, among others. A complex system is defined as those with multiple components and layers of subsystems difficult to predict, manage and recognize. These systems impose critical demands of development related with functionality, cost, quality, and sustainability [2]. Complex systems are characterized by being made up of non-separable elements, which are self-organized and evolve. The design of complex systems from the requirements can be addressed from autonomous entities and establishing mechanisms of communication between them. These structure form multi-agent systems (SMA). The SMA have outstanding advantages over other solutions to complex problems, we can highlight their dynamic nature, goal orientation, rationality, learning ability, scalability and flexibility.

Each agent in a SMA is designed with an architecture that reflects elements of rationality; in general, these architectures are reactive or deliberative. The BDI architecture based on human practical reasoning can be highlighted as a goal-oriented model and presents both the deliberative and reactive structures. Once raised the overall structure of the SMA, we proceed to implement each agent that will make up the system.

For the particular case of BDI agents, the implementation can develop under the classic algorithmic perspective, such is the case of D'MARS (Distributed multi-agent Reasoning System) and PRS (Procedural Reasoning System). The former are frameworks for BDI agents in dynamic environments and in real time, but with limitations for modeling concurrent reasoning processes of the BDI architecture.

For example, one of the most important features in the implementation of BDI agents is the concurrency, which becomes an essential criterion and his analysis should be explicitly developed from implementation domains of Software and Hardware. The Software implementation generates flexible BDI agents, and Hardware agents enhance concurrency and performance requirements. The projection of a hybrid combination, hardware-software is promising, since it would enhance from each domain requirements and characteristics of concurrency. In particular, in programmable logic devices FPGA, we could implement Hardware agents through a solution of a custom circuit and Software agents from the ability of these devices to embed processed systems. The general problem in this paper focuses on performance, interoperability and adaptation requirements addressed from the perspective of the domain of implementation of complex systems, enhancing the solution to these requirements, through the combination of reconfigurable hardware, and software. The hybrid model is articulated with an architecture addressed by multiagent paradigm, generating hybrid BDI agents. We propose that the requirements of adaptability can be achieved through the integration of the concept of migration of domain in the proposed architecture. The migration is originated from configurability of programmable hardware and the flexibility of the software.

The development of hybrid BDI agents with migration of domain implies to think in a different fashion the agency model, addressing its characteristics formally from a BDI traditional approach but also analyzing the agent as a complex concurrent system. The fundamental objective of this point og view is to consider agencies with an effective architecture that can be implemented in hardware, software or in a hybrid form and that may migrate between these three implementation alternatives. In addition, this proposal would be framed in SMA methodologies that include in its cycle, the static domain segmentation, adopting co_design techniques, as well as the dynamic segmentation for the case of the migration process. A

case study of a social simulator in the context of decision-making in a community impacted by PROSOFI, the social project of Pontificia Universidad Javeriana [4] is used as a software validation and also a case study of soccer robot is used to validate the hybrid case.

This paper presents a proposal of a concurrent BDI architecture. Initially in section II some fundamentals of the BDI architecture, are collected to provide a basis for the proposal developed in this research work. In section III, IV, and V the concurrent model, the belief system and the scheme of management of objectives are presented. The paper ends with the introduction of the general approach of the concurrency model in section VI and its application in the case studies in section VII and VIII.

II. BDI ARCHITECTURE RATIONALE

Processes of conception and design of agents in a SMA typically take their inspiration from nature. In particular the human being and their mental schemes are considered rational models. The formal definition of a rational agent is supported on concepts of artificial intelligence which derive reactive and deliberative agent architectures [5]. Reactive architecture defines agents capable of detecting changes in the environment and act in accordance with them [6], the reactive agents do not have a symbolic model of the world and the symbolic reasoning is not complex [7]. From the perspective of the reactive architecture the development of agents is local and short range in time. Otherwise, deliberative architecture uses symbolic modeling and includes formal models of behavior and knowledge, including the use of logic in the processes of decision [7]. These features trigger an intensive use of resources and sometimes inability to make decisions in real time. By combining the two types of architectures effective hybrid models are generated to take advantage of both approaches. An example of widely used hybrid architecture is BDI, which is inspired from a theory of human practical reasoning. In this architecture, reasoning and action execution are concurrent processes [8]. The BDI architecture models intentional agents who decide and plan from a set of beliefs, desires and intentions. This section analyses the most relevant features of this architecture.

Intentional theory can be recognized as the source of the BDI architecture. This theory is part of the contribution of the American philosopher Daniel Dennett, who explains that there are three models to classify the information coming from the outside, to explain phenomena and actions, and perceive nature [9]. The first model has a physical approach, in which the individual seeks causal explanations. The second model is an adaptation or design, inspired by the evolutionary process; in this, the individual seeks to respond, why an object was designed and what is its function. Finally, the third model is a mental or intentional scheme that interprets the behavior of an individual, human, animal or object, such as a rational agent that can choose its actions, taking into account their beliefs and desires [8]. Beliefs, desires and intentions are components that make up the mental state of the agent [7].

However, these are not the only elements, also there are other features such as the commitments associated with an objective, responsibilities within the SMA, the needs that emerge in response to the failure, the emotions and motivations, [11], [12]; the nature and maturity of agent [13], the social context, among others. All the elements mentioned above, somehow interact to carry out the complex decision process that will determine when and how to act.

General and persistent elements of mental state can be recognized. In this way an agent has beliefs that correspond to judgments of the world. From the point of view of the agent these statements are truth even if they are false in reality; that is, there is no discrimination of the value of truth [13]. By definition a rational agent will try to maximize the efficiency related to its goal [7]. This approach is an example of the concept of the agent desires, which are actions that the agent wants to perform or situations that he wants to achieve. These desires are not forced, are spontaneous and can be inconsistent between them [14]. The process of transforming those wishes into reality means that agents will have clarity about their intentions from a sequence of viable events, plans and actions aimed towards the goal and in the best of cases focused on the wishes of agent [9]. Beliefs can be generalized as a state of information, desires as a state of motivation and finally the intentions as a deliberative state [15] or a proactive state [16].

III. BDI CONCURRENT ARCHITECTURE

The BDI architecture proposed in this work is supported on an agency model, in which an agent is an autonomous entity that acts to achieve its objectives in a work environment [17]. An autonomous entity can be understood as an individual who makes his own decisions from their perceptions and can complement the information if it is incomplete or partial [7]. An agent located in an environment implies that the interaction with the context is vital to achieve the goal. These interactions are mediated by channels of communication, sensors and actuators. The former constitutes the general agent model and is presented in Figure 1.

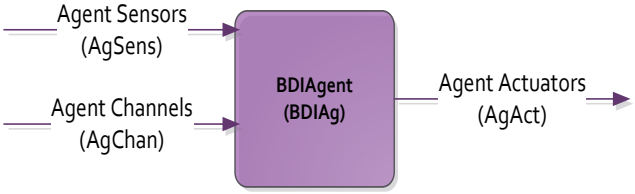


Figure 1. General BDI Model

On the other hand the agents have a set of capabilities and resources which allow them to meet their objectives [17]. In a traditional approach, the BDI architecture manages desires, intentions and beliefs in isolation; its implementation is based on a sequential algorithm that moves away from the real concurrent behavior of human reasoning that inspired it.

In a more efficient and applicable approach to real complex context, desires, beliefs and intentions, rather than being simple elements that make up the system, mark the beginning and end of a process that generates effects in the environment through the execution of actions, and where an evolution in real time of desires to intentions can be recognized. This evolution involves

an instantiation of objectives, the commitment of the agent with the goals and the feasibility of actions related to its resources and capabilities. On the other hand, the implementation of these actions is influenced directly by beliefs, perceptions, pre-established plans and once more resources and capabilities of the agent.

A. Basic Concepts

The flow control for the BDI model is based on a model of concurrent processes therefore is important to define the elements that are integrated in the scheme. Beliefs are mental state elements that compose the lifecycle of an agent; they are modified by the perception of the world and the communication with other agents. In the process of decision of the action, beliefs are one of the essential elements to define the intentions of the agent. In the proposed model, the beliefs include the agent capabilities, emotions, motivations and cause- effect model of actions. In addition, beliefs provide the model of the world indicating what or who interact with the agent, the internal state of the agent, and the means and resources that are available.

Desires are alternatives of action, which still have not materialized, i.e. desires are objectives that have been imposed on the agent by context and the goals that must be met. The agent has different opportunities for action, and the choice of the best chance is affected by the overall objective of the system and the maximization of the efficiency of this goal. The agent detects opportunities in the form of specific objectives, which are analyzed according to their coherence with the overall objective and the cost-benefit relationship.

Intentions are the projection of desires in the future; they are centered in the action to comply with a general objective. In the proposal of the agency model, these intentions become in reality through the implementation of actions. These actions may be reactive or deliberative acts that become essential elements to consider a plan. A plan is a set of intentions of lower order. In fact, intentions are instances of actual goals for the agent, agent is also proactive, because their actions are intended to achieve the objectives, and this causal relationship is a function that transforms the objectives in a reality.

B. BDI Cycle

To describe the concurrent BDI cycle, we will use in parallel the case study of implementation software that implements a human agent in the framework of a social simulator and the hybrid case with a football player robot. In the first case the system simulates decision-making in a community in the area of impact of PROSOFI (social project of Pontificia Universidad Javeriana) [19]. In this sense BDI agents, are individuals in a community who must decide whether to register or not computer training courses. In the second case, the agent is a player who belongs to a team and its decisions are focused on the type of movement that should be developed.

In the proposed BDI model, rational agents are those who act to achieve its objectives and the structure of beliefs, desires and intentions provides a dynamic way to handle such set of goals. As mentioned earlier we identified two types of objectives: general goals or tasks that will guide the process of decision and specific goals imposed by the context and may be seen as opportunities for action towards the overall goals.

In the case of the social simulator a general goal is that a person aims to achieve his well-being through having a better job and doing entertainment activities. It can be thought of as specific goals associated with the general objective, have a minimum of daily money or take care of his health. In the case of the soccer robot player, the general goal is winning the game; specific goals are to defend his area, and to attack in order to score a goal.

From the concepts mentioned above, agents always are related in two ways with the tasks. In the first relationship beliefs are generated from the awareness of the task. This process creates needs, resources, facilities and plans when agent determines if the goal is being fulfilled or not. In this way an individual aware of its goal of welfare, created needs such as money, food, or a strategy to achieve them. On the other hand, player's emerging needs related to speed or the structure of defense or attack. The second relationship generates a level of commitment to the tasks and then the agent is tagged with a role that will guide their actions. An agent committed to the pursuit of well-being through employment, seek a job opportunity, or staying employed, assuming a role of "worker". In a football match are clear roles generated from commitment, emerging the defenses, forwards or archers.

At this point the agent is located in the world, is able to perceive through sensors, communicate through channels and act through actuators. We can recognize three elements of the BDI model: goals, beliefs and the role (commitment to overall goals). The question that arises is how do these elements interact to achieve the general objective? Our model proposes a cycle to manage objectives that creates instances of them at different levels of abstraction in an evolution of desires to intentions. This process of evolution is modulated by the beliefs and then projected in a cycle of decision and action. The model consists of three main processes:

1) Beliefs Manager: this unit supports the belief system, controlling the life cycle of its components. Four States in this cycle can be identified: emergency, update, inference and death. The belief set must be consistent and also includes BDI mental information and update possible learning mechanisms.

2) Goal Manager: in this module wishes are represented as goals and the evolution of them to intentions is processed. The instantiation of desire intention is a process of dynamic state in which those goals are identified, evaluated, activated, or deleted. At the end, active objectives are set as intentions.

3) *Means and Ends Manager:* once the intentions are detected, these will guide the action of the agent, this process has as main tasks, the reactivity as a means of action and the key goals-oriented planning i.e., intentions. At this point we can consider plans fixed, dynamic, and interchangeable. Plans or impulses of reaction will guide the decision of the agent and therefore their actions.

This article will describe in detail the Beliefs Manager, the Goal Manager and the approach of concurrent processes because they coincide with the main development of our work.

IV. THE BELIEF SYSTEM

As it was mentioned in the previous paragraphs beliefs are elements of the mental state of an agent. The perception of the environment through sensors and communication with other agents across channels, make beliefs dynamic components of the BDI architecture. The model of the world, objectives, goals, skills, means, resources and the internal state of the agent are classified as beliefs.

Beliefs grow into a life cycle that includes emergency or inferences from them, their evolution, and death. These states of the cycle are linked to the sequence of perception and communication; and the development of the mental processes of the agent. The belief system can be modeled temporarily, i.e., the change in status of a belief depends on history in the system in which directly affect the credibility of the source generating the new belief, the reliability of the source is a belief too. Reliability can be modified according to the development of events. Figure 2 shows the state diagram or life cycle of a belief.

The concept of the life cycle and reliability can be clarified by using the case studies. For the context of the social simulator, the offer of a new course by PROSOFI, can be evaluated by the agent as a new belief, i.e. a new element, in this case an opportunity. The agent evaluates the credibility of the source according to historical events. In this sense evaluates the reliability of the institution and hosts or undone the new information. We can talk about the emergency of a belief. As new events of perception and communication are presented this belief can be modified or updated, for example evidence of the quality of the course or cancellation thereof due to lack of budget of PROSOFI. On the other hand, a soccer player can infer its adversary strategy picking up patterns of behavior of the opposing team, or stop believing in the same because ambiguities or disordered patterns.

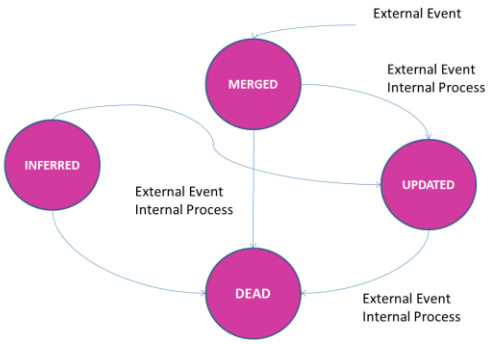


Figure 2. Belief Life Cycle

A. *Word Model*

Model of the world is a construction done over time. Returning to Russell's definition, perceptions sequence of an agent reflects full history of what agent has received. An agent will take a decision depending on the complete sequence of perceptions until that moment (RUSSELL2004).

During lifecycle of an agent, beliefs are complemented and modified by several events related with recurring activation of perception sequence. The Beliefs System uses a perceptual processor which receives the signals from the sensors and messages from other agents through the communication channels. This information is converted into characterization of the context. In order to explain the context concept, in the agency model, an agent is immersed or exists in an environment. The environment can be defined as the environment that the agent can capture through sensors and channels. Elements of the environment are all the physical entities which an agent can find, passive world objects and other agents or active objects. An agent is designed to function in a specific environment, when this changes or the agent migrates to another environment raises a change of reference, i.e. the agent should develop a behavior change that adapts to the new environment.

On the other hand, the model incorporates the concept of current state which is a synonym for context and refers to the instantaneous system conditions that could affect the decisions of an agent. The changes of state or context are also perceived; they are goals-oriented perceptions, and seek to obtain information on the environment to make more effective decisions. The relationship between the context and the environment is that the context is a map of states of the environment at a specific time.

Some beliefs indicate existence of an external resource in a context or inside of the agent: "there is" or "I have". This resources information can be complemented with a belief associated with the "I am able", i.e. capabilities of the agent and his level of competence. Finally, integrating resources and capabilities, the agent must believe in a "How do it". The previous concept is called "skill" in our model. A skill is then the combination of capacities and resources. Skills can be summarized in the following statements:

Know what: the agent knows the existence of a resource (direct object).

Know where: the agent knows the place where the resource is (indirect complement tacit or non-tacit).

Know when: the agent knows when can dispose of the resource.

Know-how: agent knows how to use the resource (capacity).

Know who: agent knows who gave him the resource.

B. *Internal State*

The internal state of the agent refers to all of the features that modulate decision-making of agent. They are considered internal State-related beliefs, emotions, agent motivation, commitment to the overall objective and the variables associated with the time, as maturity and age.

In particular, emotions modulate the decisions through the motivation and commitment to the goals, i.e. an agent will be

more or less motivated and committed according with his state of mind. In the proposed architecture, the emotions are directly related to the success to achieve the same goals. In the contexts of study can be said that a human agent will be happy if he gets greater economic stability or in the case of the soccer player if he makes a goal. In both circumstances that state of happiness will motivate the agent to engage with the mechanisms of training offered or the soccer game.

Two mechanisms of evolution of emotions are recognized, the first is the elicitation, which runs between two extreme emotional states: happiness if the goal has been achieved or sadness if conversely failed in the attempt. In addition, the emotions are affected by a time-dependent evolution. Other time-dependent beliefs are the maturity of the agent and his age or fatigue on the field of play. These variables affect the process of decision, making these temporarily dependent, so a football player will have higher performance at the beginning of the game than at the end when he is tired or a mature individual with responsibilities and duties will take decisions in a different way compared to a teenager, for example.

V. GOAL MANAGER

An agent located shall enter into a cycle of care to build the world and receive stimuli from the outside which will modify their beliefs and will generate a process of decision-action in pursuit of the fulfillment of a general objective. Then we define a classification of objectives to which the agent must face in his mental process.

A. Goal Taxonomy

Our model considers five categories of specific goals: the requirements, needs, opportunities, obligations and survival goals.

The requirements are goals associated with the capabilities related to the raison of being of the agent; they are the context requests to comply with the general goal for which the agent was intended. We define a capacity as the combination of a resource and a skill. Within the framework of the case of social simulator, an agent could have as a requirement finding learning tools online (resource) and manage computers (ability) to achieve the overall objective of well-being associated to work through training. A football player robot generates as requirements accelerate to reach the ball (resource associated with the battery) and kick (ability).

The needs are goals derived from the metacognition and self-critical thinking from a rational agent. Agent assesses whether his overall objective is being fulfilled, otherwise it generates a process of restructuring of its decision mechanism. An agent in the community impacted by PROSOFI, might be realized that regardless of the decision taken will not reach the goal of welfare unless you decide to train. Studying becomes a necessity which must be supply in consistent way with the level of commitment. Also a player will never reach the ball on long passes if his battery is not sufficiently charged to accelerate.

Opportunities are events or circumstances that arise by the operation context of the agent, therefore the BDI agent should make an effort to take advantage of them. Following the case of the social simulator, the agent in the role of individual seeking welfare, aware of their need to study can seize opportunities as study useful topics on a course, learn from experts, to be self-taught. Despite its late, agent could deviate from their goal and choose to take advantage of an opportunity like attend a cultural event, although it is not consistent with its primary objective. On the other hand, a soccer player will leverage his fellow passes, his position in the field and his proximity to the ball.

Obligations arise from the nature of the agent and its context. An agent in the simulator can be parent and must act in a consistent way with its new role; the individual must balance their decisions even if they are not consistent or does not contribute to the overall goal. In this sense goals generated by obligation will affect directly the decision-making processes. A specific objective related to this category would be to pay the basic public services for his family. In the case of the robot obligations are framed in the rules of the game, the limits of the field, his role in the formation or game strategy raised by the coach.

Survival is a category of goals essential to an agent, since it is focused on its own care and protection. In this way, a social agent has to obtain the minimum of money to survive or take care of their own health; without these elements the agent may not act in pursuit of its overall goal. A football player agent depends necessarily on the battery charge.

From the presented categories and analyzing a possible scenario, an agent may face at the same time multiple specific targets, in this sense, must manage these objectives concurrently to determine which will guide its actions. In the proposed Goal Manager, this variety of goals is modeled in competition through a system of states associated to them. The model can be scaled to multiple goals that guide the action, this article only introduces a scheme with a single dominant goal; the extension for multiple goals is outside the scope of this work. Figure 3 shows the diagram of states of the goals; the events that are collected by sensors and communication channels make goals evolve between these states.

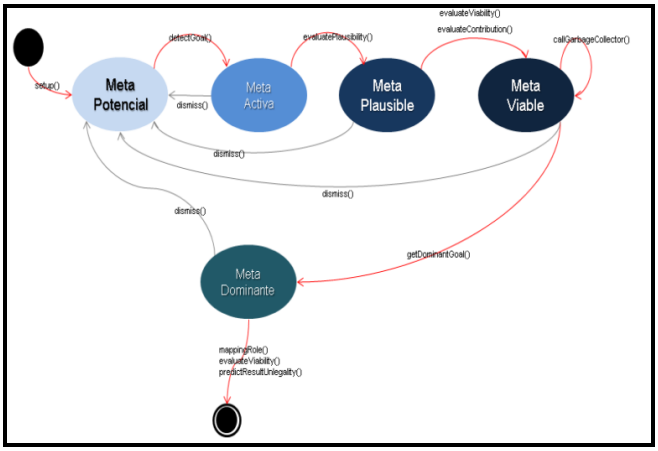


Figure 3. State Diagram for BDI Goal Manager

All goals start as potential goals. Subsequently, to reach the state of active goal, specific objectives are filtered and classified into one of five categories of objectives (requirements, needs, obligations, opportunities and survival goals); if the goal does not reach enough elements to be listed in any of the categories will remain as a potential goal. Subsequently, each active goal is evaluated in parallel through a valuation of plausibility. We define a plausible goal as a goal that is legal in the context of the agent. The transition between active goal and plausible goal is generated by applying a function of legality that has as parameters the threshold of plausibility for the specific application, in our case the social simulator or the soccer game. Once again, the evaluation will return an illegal goal as a potential objective.

The plausible goals will be evaluated again by a filter of feasibility based on the capabilities of the agent. This filter is based on a function that calculates if the agent has the skills and resources to meet each specific goal. In the event that the agent lacks these skills, the goal will not be viable and will resume the status of potential goal. All viable targets will be evaluated recursively plausibility and feasibility, as a cleaning mechanism (garbage collector), which allows adaptation to the changes in context; i.e., generating capacity of adaptation to a change of overall goal. In some cases, the viable goals will have a transition to become potential goals. Viable goals are evaluated by a contribution arbiter. This arbiter has a hierarchy established with respect to the categories of goals, so that some kinds of goals take precedence over others. Figure 4 shows the pyramid of the hierarchy of goals, where survival goals are of high level of priority; and in the other hand, the agent needs are of low level.

As we mentioned above, the agent may face a decision between goals even in the same category of goals, at this point the concept of contribution is relevant. Contribution refers to a function of weighting of each specific objective regarding the overall goal in which the commitment of the agent is a variable that directly affects the process. This value will indicate the order of goals in the same level of the pyramid. Once sorted the goals in the hierarchy structure, the arbiter can select the dominant goal, i.e. the goal that may evolve to be an intention that guides the action of the agent. As mentioned in a model with only one dominant goal structure, only a goal can deal with that state and in that sense the current dominant goal will be evaluated under the same parameters of the elements that make up the pyramid. The process, in which a dominant goal is replaced with a new one and sent to the state of potential goal, is called expropriation. The process to change from feasible goal to dominant goal is called activation. During the entire process management, a context switch can induce a change of overall goal. This situation may result from various causes, among which we can highlight; the current overall goal is already fulfilled. The agent must synchronize with the new overall goal and in the case of not having it enter attention cycle; here his objective will be to find a new overall goal. In this sense the agent will always be committed to a goal. General goal changes generate a process of reconsideration, which refers to the synchronization of parameters, beliefs, desires and intentions.

Figure 4. BDI jerarquical goal structure

In the process of management of objectives we can identify the wishes of agent as transient goals that evolve from potential targets until viable goals. Once the arbiter chooses the potential goal, he identifies an intention to action which is the input of the Means and Ends Manager, in which the decision-making process is identified. In a first stage, over the dominant goal or intention a deeper feasibility assessment is applied, this process is more detailed than the process generated in the Goal Manager. Concurrently, a prediction of plausibility function is applied to generate a more accurate value of legality on the intention. In addition, the decision stage starts with the assignment of a role agent.

VI. CONCURRENCY MODEL

The proposed BDI architecture has multiple elements and relationships difficult to define and predict. It is true that architecture itself is constituted as a complex system. The design of the model was then approached from the same multiagent paradigm making use of an organizational AOPOA methodology for the construction of SMA [17]. The process concluded in three meta-agents that involve the modules of the system referred to in section III: meta-agent of information flow that includes the Belief Manager, meta-agent of conversion from desires to intentions and the meta-agent for execution that integrates the management of means and ends. The criteria of assignment of duties to each meta-agent include the homogeneity of resources and skills required to perform the tasks, the compatibility of activities, the re use of functions and the detection of concurrent mental processes.

Each meta-agent is a thread of process, belief management, goals and the decision-making process are performed in parallel and their synchronization and updating is in charge of the reconsideration process. Figure 5 shows the three threads. Three process threads have specific roles among which stands the synchronization inter threads and communication parameters. Within each process thread generated processes than thought-inspired pragmatists can be considered parallel constituting a new concurrency layer as shown below.

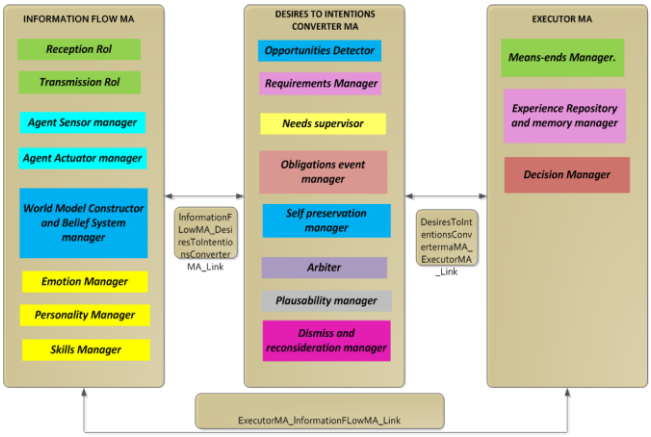


Figure 5. Hilos concurrentes de la arquitectura BDI

The Information Flow thread is responsible for the management of sensors and actuators, mechanisms of transmission and reception of messages, the construction of the model of the world, management system of beliefs, emotions, skills and personality managers. These last are modulating variables of the mental process BDI. The Converter of desires to intentions thread includes opportunities detector, supervisor of needs, the contribution arbiter, managers of requirements, obligations, auto preservation, plausibility, viability, activation, expropriation, deactivation and the goal state machine. The Executor thread is in charge of administration of means and ends, the memory and experiences repository Manager and the decisions manager on actuators.

VII. BDI ARQUITECTURE APPLIED TO A SOCIAL SIMULATOR CASE

Concurrent BDI architecture was applied in a context of social simulation using the model MSSIN (Intelligent Social Simulation Model) [4]. This model allows developing simulations to analyze the response to stimuli of social assistance in vulnerable communities. The context of work was a colombian community, specifically in the work area covering by PROSOFI, which corresponds to a vulnerable community of scarce resources. The Simulator made use of BDI generic architecture for agents proposed in this paper, including methods such as fuzzy logic and Q-learning in its decision-making mechanism, based on the main concepts of the sociological theory of Bratman. In addition, the simulator constructs a model of social interactions that apply general concepts in specific contexts present in societies studied.

This case study focuses on a construction of a simulation that enables knowledge of the reasons or causes of dropout before the promotion of non-formal computing courses that PROSOFI offer in the community. Based in this case, develop all the components for the multi-agent system simulation and the main components for the construction of a BDI agent. BDI agents in this case are used to represent persons present in society that respond to stimuli of different sources, which in addition to PROSOFI, generate opportunities.

To implement the generic BDI model, a fuzzy decision-making mechanism is developed. A set of fuzzy modulating variables are incorporated into the belief system in order to use techniques based on fuzzy logic control into the agent's decisions. This definition allows modulating variables take a normalized value between zero and one [0-1], which is subsequently evaluated in a machine of fuzzy rules. This diffuse modulation machine represents the behavior of the agent according to the rules and actions configured. In a social context, an example of this representation is seen in the figure 6. The variables for an emotional state and the price of a product modulate the decision of the person around a situation of buying.

The use of fuzzy logic in the mechanism of modulation variables is appropriate because this technique allows evaluating rules using a mechanism similar to the human reasoning. This technique is classified by many researchers as a formalization of human thinking, so it is consistent with the objective of generating a model of agent-based social simulation. Furthermore, this technique is useful for managing the latent uncertainty in social simulation data and reduces the complexity of this type of models, allowing a higher level of scalability for the model operation.

Figure 6, Diffuse Modulating Variables.

The results of this simulation, after modifying some input variables, as the respect that people have to the institutions and the emotional state, are evaluated qualitatively by experts of the study area of PROSOFI, i.e., sociologists, psychologists and anthropologists. The final results show the usefulness of the MSSIN simulator in the social domain, which represents a contextualization in the colombian environment and allows us to collect evidence of the variables that influence decision-making of the members of that community.

VIII. BDI ARCHITECTURE APPLIED TO A ROBOT SOCCER PLAYER

The application of concurrent BDI architecture in the case of the robot was focused to the conception and design of a robotic platform that acted as a soccer player in a workout between two peers, assisted by a coach. This SMA aims to train passes alternating arcs, then tested different opportunities which include long passes, wall passes, shots to the arch and the act of dribbling. This case in particular is developed with three main phases: the first is the simulation of the robot using V-REP integrating the proposed architecture; the second phase is the synthesis hardware of the architecture to be tested on the physical platform. From these two results, co design techniques

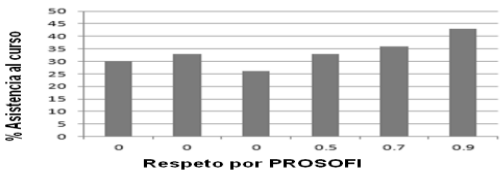
will be applied to segment the BDI architecture in hardware and software modules and thus have a first approximation to the BDI hybrids agents with domain migration.

IX. CONCLUSIONS

The work focused on the development and software validation of our BDI architecture allowed include the concurrent perspective of mental processes that occur in a rational agent making decisions within the framework of a real model of practical reasoning, close to which a human being used. In this way, we proposed a three-wire process scheme, each responsible for managing the components of the architecture: beliefs, desires, intentions, goals and actions. The management structure of goals, presents an innovative architecture consisting of the parallel evaluation of multiple targets, emphasized allowing a bio-inspired evaluation for the selection of the goal or intention that would guide action on actuators. The proposed BDI architecture is based on five categories of objectives that drive the decision scheme and that integrate diverse perspectives of an individual, their needs, their self-evaluation ability, management opportunities, obligations, their feelings, among others.

MSSIN evidence shows that the proposed BDI architecture is evaluated successfully raised simulation requirements, which shows its usefulness in a context of social simulation based on agents, where the entities belong to complex, distributed environments that require escalation; they make intelligent decisions based on formal sociological theories; and they can act in specific environments such as the Colombian.

Figure 5 shows how to increase respect for PROSOFI variables in the community, increases the percentage attending the course and reduces attrition.



The projection of our work includes a deep dive into the belief system of the model, and learning opportunities that can be detected in many of the mental processes of BDI. Additionally, we will validate the architecture in a hybrid case hardware software. For this purpose we study the case of robotic soccer, in which each player will be a concurrent BDI agent, implemented in hybrid domains hardware software and designed under co design techniques.

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