BDI Agents Simulation Model with a Colombian Approach

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***Abstract*—The lack of social simulation models that meet all requirements suggested to support decision making in public or private community service is a problem. This phenomenon is managed by building MSSIN, an agent-based model. This solution, first proposed a generic model for BDI agents, using methods such as fuzzy logic and Q-learning in their decision-making mechanism, based on the main concepts of the sociological theory of Bratman. Then, build a model of social interactions and apply general and specific contexts concepts present in the studied societies.**

***Index Terms*—Intelligent Systems; Intelligent Agents; simulation; PROSOFI; society; BDI; goals; sociology.**

I. Introduction

There are a number of issues affecting societies around the world and are manifested in different ways in each region of the planet. According to partial reports on the millennium goals set by the ONU, the progress in the achievement of these objectives is not what they expected [1]. Thus, the study of such problems has become a challenge for researchers in different sciences, not been computation external to this phenomenon. At the Universidad Javeriana, through the PROSOFI program of the Faculty of Engineering, a set of studies about the community of Usme of the city of Bogota has been developed, where some unwanted social situations have been characterized [2]. Other works of this type are developed in Colombian universities, an example is that one developed by the "Engineers Without Borders" program of the Universidad de los Andes, where they have carried out some works in several low-income communities [3] . Similarly, the work developed by the social work area of the faculty of engineering of UniMinuto, where he has also reached an important management [4].

Social simulation models using multi-agent systems (SMA) have been providing important knowledge in recent decades for the solution of these problems around the world, building support processes through making decisions and social analysis. Techniques of artificial intelligence (AI) are used to build agents with an intelligent behavior, which are focus on the simulation of human actions within a society [5]. This type of behavior can be achieved through the implementation of models based on social sciences, providing entities of a rational behavior. Jaime Sichman [6], one of the leading researchers in this area, considers a need to associate the empirical knowledge generated through computational simulations with the scientific knowledge developed by social science professionals. Based on this theory, he develops social simulation model studies based on intentional computing, considering the need to go beyond the results of the experiments and develop models based on social theories with scientific accuracy.

Based on the study of multiple sources of knowledge and confrontation with social area experts who work with PROSOFI [7], it is proposed the construction of a simulator that allows experts from different sciences, engineers and social science professionals execute simulations that show as results the response of a community before external entities stimuli. The response to stimuli is represented in the actions that members of a community (agents) perform before the appearance of various internal and external events. These actions are defined by an intelligent decision-making mechanism that incorporates behavior of agents and concepts of sociology theories. In addition, interactions between agents incorporate characteristics of a general society, inspired by Colombian communities, specifically of the PROSOFI study area.

II. SOCIAL INTERACTION MODEL

The tasks performed during the interaction model development are described below.

A. Characterization of requirements for decision making

As a result of the study of different sources of information described in previous works and support of knowledge in the study area on the part of PROSOFI, the requirements for decision-making in the model are identified and defined. These requirements allow guiding the design process of interaction and behavior models for agents and are divided into two types described below.

1) Social behavioral requirements: This type of requirements is focused on the behavior of entities in the social simulation model. Each one of them is described below:

- Concept of community and multi-community (multiculture): This requirement refers to the need that the entities may belong to various types of Community Social Organizations, focusing on integrating social groups with similar interests.

- Competitive Nature: This requirement highlights the importance of taking into account the common and opposite objectives between entities, modeling human competitive nature.
- Predecessors: This requirement is related to some intrinsic behaviors that people have belonging to certain types of family.

- Social levels: In a social simulation model is very important to model the social levels that societies have and the influence of this concept on behavior. These levels are represented in the simulation of economic concepts and the pursuit of profit by acting.

- Rules and laws: the communities have a set of local and global rules that govern their behavior.

- Social fabric: A fundamental concept in current societies is the social fabric. For Romero [8], this concept refers to effective relationships that determine particular ways of being, producing, interacting and projecting in the family, community, labor and citizenship issues. The application of this concept generates in the model the need to simulate the effect of the social fabric in the response that the community delivers before different types of stimuli.

- Emotions: Substantial part of the process of human decision making. Thus, the internal emotional state of entities is taken into account in the model to define its way of behavior.

- Thalman Requirements: In the study of knowledge sources there is a rigorous revision work of the topic of social simulation based on agent developed by Thalman [9]. This work shows analytically the requirements of some current works focusing on multi-performance architecture.

- PROSOFI- Colombian Context: The model to be oriented to Colombian communities' social work should facilitate the construction of simulations with special features of the Colombian environment, and specifically of the area on which PROSOFI works. These features are: (a) spatial division of Colombian communities: department, city, town, location, area, family, community, (b) Colombian social structures, such as: artistic and cultural unification through community social organizations (OSC) and unification by proximity in territorial Organizations, such as criminal gangs, (c) objectives of entities consistent with the ONU social research in the world, Colombia and the PROSOFI working community, (d) statistics data of the Colombian social behavior intrinsic in the agents (e) characterization of projects executed by PROSOFI in communities of Bogota, focusing on the building of a model on ease of modeling of this type of projects by part of experts in the social sciences area.

2) Non-functional requirement of simulation: This type of requirements is focused on those features that are not part of the behavioral model of the agent, but that are essential to facilitate the development of social simulations. In this case, the model must meet two characteristics:

- Simulation time management: The model manages simulation times that allow accurately, representing society state changes without generating causal problems.

- Scalability: The model can simulate large geographical areas with a high number of entities.

B. Collective characterization of entities

Using the analyzed requirements, the framework for design science in information systems research [10] is applied in the characterization of entities for the model of agents. Then, an incremental design process is performed comparing the information in knowledge bases with requirements identified in the social field. The advantage of this strategy is the rigor that it delivers to the results obtained from the research.

The characterization of the information obtained in an agent approach is performed using the AOPOA methodology [11], by means of which the interactions and structures can be represented on the behavior of entities from an organizational viewpoint. This methodology is appropriate for collective characterization required in this stage due to it allows, first, perform an organizational breakdown of the entities and then identify its cooperative ties. As a result of this work, the most representative individual and collective entities are characterized in the social context. These entities are described below.

1) social entities: Entities that represent organizations in the community.

- Promoter entity: Represents external organizations and institutions that expose an opportunity or a promotion based on welfare services to the community.

- Environment modifier entity: Entity responsible to modify the environment, affecting the behavior of other social entities. One example is an entity in charge of putting garbage in the streets.

- Territorial entity: Represents those entities whose actions generate a general response for the territory over which generates stimuli. Examples of such entities are Community Action Boards (JAC) and called red alert territories (security in risk).

- Community Social Organizations Entity (OSC): Represents associations whose duties are related to cultural, artistic, sportive unions, among others. These associations do not necessarily generate positive stimuli as they can be characterized from entities for the care of the environment to youth cultures that do not take care of it.

- "Neighborhood" entity: It represents the union of different blocks that are grouped into a larger geographical group.

- Block entity: It represents the union of families in a small geographical area. The same as the neighborhood entity, it can be taken as a special type of territorial entity that is standard for any type of simulation.

- Receptor entity: Represents entities that respond to stimuli. Depending on the case, it can be a family, i.e, an entity that represents the union of family members; or in other cases, individual entities that represent people.

2) Domain complementary entities: Entities that facilitate interaction between social entities; and form them with the environment.

- World entity: Responsible for communicating the status of the social agent environment. For example, it shows the cleanliness of the streets. This entity has a spatial approach of communication that depends on the distribution of probability

chosen to communicate the information. In one particular case a Gaussian distribution function can be used for transmission.

- Channel entity: Works as a communicator of promotions from the promoter entities for the other social entities. This organization works in different ways depending on its form of communication (loudspeakers, voice-voice, etc...) Like the world entity, it has a spatial approach of communication that depends on the chosen probability distribution of the data transmission.

C. Interactions between entities

The interaction process between social entities begins when the promoter entities present promotions related to the eight social problems to the community. With the purpose of transmitting the promotions to the receptor entities, they must pass through the communication channel entity and a set of interactions between social entities. Furthermore, they must be taken into account in the state of the world entity and its modification by part of the environment modifier entities.

Internal interactions between social entities are based on the concept of social fabric. For this reason, territorial entities, OCS entities and receptor entities have a set of gradual variables that measure the recognition of a receptor entity to collective social entities to which they belong. These variables are called variables of social fabric and any action of a person belonging to a group, affects the variables of the group of people that compose it.

III. DECISION-MAKING MODEL

After the development of the social interactions model, a collective characterization of entities and types of collaboration among them are obtained as results. These results feed back the decision-making model design focused on the sociological theory of Bratman [12] and the BDI model (Belief-Desire-Intention), applied to the entities described in the previous section. To accomplish this task, a generic BDI model is built [13] which works for both software agents. Its Implementation provides to the decision making process, characteristics of a formal sociological theory simulating a mode of acting closer to that of real human.

In the building of this model, Wooldridge is used as a general bibliographical reference [14]. According to this author, BDI is defined as an instantiation model for goals which assesses the commitment of the agent with the same goals and the feasibility of the actions at the level of resources and capabilities. This instantiation process is of evolutionary type, i.e., guide of the evolution process since an agent has a goal as part of its reason for living, until the execution of a set of actions related to this.

A. Beliefs, desires and intentions

The main concepts of the BDI model are beliefs, desires and intentions. These concepts are present during the goals instantiation flow; each one of these concepts is explained below.

Beliefs: Beliefs are state of mind elements that make up the life cycle of an agent; they are modified through the perception and communication. In the decision-action process, beliefs are one of the essential elements to define the agent's intentions. Beliefs include the capabilities of the agent and the cause-effect model of its actions, in its intrinsic state. Additionally, beliefs provide the world model indicating who or what the agent interacts with, what is its internal state, means and resources that it has; in its extrinsic state.

Desires: Desires refer to action alternatives that are not materialized, i.e., goals to accomplish imposed by the context. The agent will have different opportunities of acting and the election of the best opportunity is slanted to the general goal of the system and the maximization of the efficiency measure thereof. When a goal represents the best opportunity of action, it executes an expropriation process and becomes the agent's current intention.

Intentions: Intentions are the projection of desires in a future, focusing on the action to meet a general goal. For the proposed agent model, such intentions become a reality through the actions implementation. These actions can be of reactive or deliberative type (for which it becomes essential to consider an action plan). Intentions represent the last step of the goals instantiation flow to turn into action. Only the goals whose application viability is high, they achieve this state and guide the implementation of the general objectives of the agent.

B. Type goals in BDI model

In the BDI model, the goal concept is fundamental to understand the decision flow in an agent, since he/she perceives the environment information, until he/she executes a set of actions. This concept refers to a set of responsibilities that an agent assumes through the expropriation of a role. These responsibilities represent the purpose of the entity in a given environment and its activation process occurs through stimuli that appear in the environment. For example, in an encouragement event to collect garbage, the agent may have a goal to keep the environment cleaned, which becomes a possible action.

The agent's goals include an action plan which is linked to the role concept. Roles are mechanisms that identify a BDI agent with the meeting of a goal; it must run using an action plan and taking profit of its skills. The fulfillment of a goal is always guided by the general goal development, which makes that the agent's job has a specific purpose defined by its role. However, there are several contradictory general goals between them, which cause that the derived goals shall to compete to become the intention.

To define which goals become intentions, agents have a competition mechanism based on two main stages that form a hierarchical pyramid. The first stage classifies the goals into five types with different levels of importance:

- Survival: Are those goals that are focused on allowing the agent's subsistence. If the agent does not meet these goals, it cannot fulfill others.

- Obligation: Are goals that represent high importance sudden obligations that the agent must fulfill. In many cases, the agent should leave other tasks to accomplish these regulation goals.

- Opportunity: Are goals that represent growth opportunities for the agent; they appear generally through external entities.

- Requirements: Are goals that the agent must meet promptly to achieve the implementation of activities in other goals such as those of opportunity.

- Need: Are goals that allow guiding the agent's actions towards the achievement of its general objectives. They allow the assessment of the fulfillment of the other goals and facilitate the solution of the needs that the agent has in case of being unfulfilled.

The second stage of the competition mechanism, introduces the goals already classified by types, in an assessment flow on each level. This flow let to know the feasibility of execution of the goal using the world model and beliefs that the agent has, guiding the selection process and competition for those that become intentions.

C. Goals states in the BDI cycle

In the performed main processes, a flow for instantiation of goals is carried out. This flow includes a set of assessment and progress tasks that make that the goals pass through a group of states before executing the corresponding action plan.

- Potential state: The potential goal are defined to agents at the moment of its creation, all these goals belong to the agent's state.

- Active state: A goal of any of the five types defined in the hierarchical pyramid is recognized by a general function of detection and becomes an active goal. This function of detection allows recognizing whether an event of the world has belonging patterns to any of the potential goal. In case of not having any belonging pattern, the event is ignored.

- Legal state: The legality of the active goal is then assessed. This assessment allows recognizing if the goal represents an illegality depending on the state of the world and the agent's beliefs. In case of being illegal, the goal is ignored and returns to the potential state, in case of being legal, it becomes a plausible goal. In the case of the social simulator, the illegalities can be detected early, when using patterns like: steal, bribe, hurt, etc.

- Viable state: After knowing that the goal is legal, viability is assessed using the beliefs and agent's experiences. Whether this assessment is positive, it becomes a viable goal; in case of not being positive, the goal is ignored and returns to its potential state.

The described feasibility function, delivers a value that is expressed based on the agent's experiences and beliefs, the feasibility of its implementation in the current world model. In this case, the evaluation function is simple and no detailed (soft), because it does not take into account the agent's abilities to meet the goal. By knowing that the goal is feasible and legal, a contribution function is used to assess whether the goal exceeds a threshold contribution to the agent's general goals. With the legality, feasibility and contribution values, the goal is evaluated in the competitive hierarchical pyramid. This pyramid has a feasibility constant evaluation executed by a garbage collection process. In this way, some of the goals that lose their viability level over time go back to the list of potential goals.

- Dominant state: The goal that has the highest level in the pyramid (the first of the superior level), becomes the dominant goal (intention). This goal will be the defining role with the actions to be executed by the agent. Over the dominant goal, a feasibility analysis is again applied using an assessment detailed method (strong), i.e., it takes into account the agent's skills. By knowing that the viability assessment is positive, an illegality prediction process is carried out over the immediate action. In this way, a goal whose actions cannot be inconvenient is ignored and it returns to the list of potential goals. The BDI model may involve a multiple intentions scheme, in such case a contingency verification stage is delivered among dominant goals.

IV. FUTURE WORK

MSSIN is being tested in different contexts of social simulation in Colombia. For future work the effort should be aimed at generating social simulations in the PROSOFI´s work area.

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