Modeling organizational level of agents with $\mathcal{M}$OISE$^+$ to a natural resources management RPG

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Abstract

Artificial intelligence and its applications have stood out over the last decade and presented effective solutions in the most diverse sectors and areas of knowledge. For example, in the environmental area, several challenges are faced, mainly in managing natural resources, due to numerous existing conflicts due to increased demand and scarcity of such resources. In this scenario, applications using multi-agent systems show promise. The main objective of this work is the presentation of modeling at the organizational level of agents to study the complexity and the functionalities of characters of a Role-Playing game. The case study of this work is the Gorim, an RPG Game developed in the scenario of the watershed of Lagoa Mirim and Canal São Gonçalo at the Rio Grande do Sul, Brazil. The organization modeling was developed in the $\mathcal{M}$OISE$^+$ model and implemented to verify it in the JaCaMo platform through hypothetical scenarios. We demonstrated that the results of such scenarios validate the structural, functional, and deontic/normative levels of the Gorim RPG.

Introduction

Artificial Intelligence (AI) is becoming increasingly popular in our society, given the range of applications developed in recent years in various areas of knowledge. In this scenario, Multiagent Systems (MAS) are seen as a practical possibility in the search for solutions to complex problems, providing flexibility and efficiency in the development and modeling of systems in different areas, such as Management of Natural Resources, Ecology, Biology, Hydrology or Environment (Adamatti 2007).

According to (Alvares and Sichman 1997) and (Bordini, Vieira, and Moreira 2001), we can cite some benefits of using a MAS: i) speed in solving problems, given the inherent concurrent processing; ii) increased flexibility and scalability by connecting multiple systems; iii) increased responsiveness to a given problem because all resources are located in the same environment; and, iv) the modularity obtained through this technique.

In addition to MAS, role-playing games (or RPG) is another technique widely applied in several studies (Farolfi, Müller, and Bonté 2010; Le Page et al. 2014; 2016; Le Page and Perrotton 2018). In RPG, players interpret a character playing a role and make decisions according to this to achieve a specific goal, be it individual or collective (Adamatti 2007). In this context, it is observed that the MAS presents flexibility and applicability in scenarios that use RPG to manage natural resources.

The Gorim RPG, the case study of this work, is being developed in the context of a Research Project entitled *Participative Management of Water Resources Using Computer Games and Multi-Agent Systems*[1], it is an RPG within the scope of the São Gonçalo and Lagoa Mirim watershed, where the actors in the scenario are considered the agents of the system, as well as its structure, rules and applied resources (Leitzke et al. 2019; Born et al. 2019a).

The Multiagent Systems platform used for the modeling and implementation of this paper was JaCaMo (Boissier et al. 2013), composed by the integration of Jason (Bordini, Hübner, and Wooldridge 2007), CArtAgO (Ricci et al. 2009b) and $\mathcal{M}$OISE$^+$ (Hübner, Sichman, and Boissier 2002). We developed the organization modeling in $\mathcal{M}$OISE$^+$ and its validation in JaCaMo. JaCaMo was chosen for the development of this model because it is based on the BDI architecture, and in the future, it will integrate Gorim's game engine designed in Java.

Theoretical Background

This Section aims to address the three areas of knowledge related to this work: i) natural resources, more specifically, water resources, considering the scope of the watershed of Lagoa Mirim and Canal São Gonçalo; ii) RPG and their applications in different areas; and, iii) MAS together with the widely used JaCaMo platform for programming multi-agent systems.

Natural Resources and Role-Playing Games

Natural Resources comprise the elements of nature that human beings use for survival. Therefore, we classified these elements as i) renewable, being the resources that can renew after being used, such as forests, water, and soil, and ii)

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non-renewable resources, which cannot renew themselves, so once extracted, their reserves decrease, such as oil, iron or gold (Lira and Cândido 2013).

Managing water resources is also one of the main challenges society faces today. Thus, management models' study, analysis, and development become relevant in searching for solutions in this context. Brazil has large hydrographic basins, so it presents several conflicts related to the distribution and sharing of the resource (Brito, Lopes, and dos Anjos Neta 2020; Born et al. 2019b).

According to (Fuller et al. 2007), observing from the technological perspective, the computational challenges correlated to managing natural resources are data management and communication, data analysis, and control and optimization. To solve such challenges, using computational tools with AI techniques, among them multi-agent systems, is a good solution since they have the necessary flexibility to deal with the dynamics existing in natural resources (Born et al. 2019a).

RPGs are a widespread technique in training because they allow players to be placed in decision-making situations similar to real-world problems but with no concrete results. In addition, due to the playfulness involved in games, large corporations have used RPG in training courses to facilitate training and learning of specific subjects (Perrotton et al. 2017). RPG is a game in which players take on the role of a character created for a particular scenario (also called environment). The characters follow rules that help them organize their actions and determine the limits of what they can accomplish (Pereira 2003).

As a result, RPG may reveal some aspects of social relationships by allowing direct observation of player interactions (Barreteau, Page, and D'aquino 2003). Role-playing games have a collaborative aspect rather than a competition, so there are no winners or losers. In the end, players must have completed a story based on the game's rules to achieve individual or collective goals (Adamatti, Sichman, and Coelho 2007).

Multi-agent Systems and JaCaMo platform

A Multiagent System (MAS) is composed of several agents interacting in an environment with autonomous behavior for each of them, as well as interaction and communication (Wooldridge 2002).

Biological models, as well as social interactions, serve as inspiration for the development of systems where intelligent agents can be conceived through *hardware* and *software* devices (Artero 2009). The agents represented by these devices or programs must be able to perceive their environment through sensors and to act on it through actuators (Russell and Norvig 2013).

According to (Nwana 1996), agents have three essential characteristics: *cooperate*, *learn* and *act autonomously*. (Bordini, Vieira, and Moreira 2001) also add coordination, competition, and negotiation as relevant aspects in the conception of agents. Based on these characteristics, there are different ways of classifying agents: reactive, cognitive, collaborative, communication, and learning, among others (Nwana 1996; Artero 2009; Coppin 2013).

The JaCaMo multi-agent programming framework (Boissier, Hübner, and Ricci 2016) integrates: i) the Jason platform, used in the development of autonomous agents (Bordini, Hübner, and Wooldridge 2007); ii) the CArtAgO, applied in the development of shared environments (Ricci, Piunti, and Viroli 2011); and, iii) $\mathcal{M}$OISE$^+$ developed for modeling multi-agent organizations (Hübner and Sichman 2007). This integration provides developers with a complete and well-consolidated *framework* for MAS applications.

JaCaMo has three dimensions: agent, environment, and organization, to facilitate the developer to model and implement complex multi-agent systems (Thomasi 2014). Based on this integration, composed of agents, environment, interaction, and organization, the platform offers a resource for the scalability of complex applications, thus allowing its distribution on several nodes. Also, each tool that makes up the platform uses a set of abstractions, models, and meta-models for programming.

Jason is a platform for developing multi-agent systems that incorporates an agent-oriented programming language that implements and extends AgentSpeak(L) (Bordini, Hübner, and Wooldridge 2007; Rao 1996). Thus, agents in Jason are based on the BDI model (*Belief – Desire – Intention*) (Bratman, Israel, and Pollack 1988; Rao and George 1995), representing the information, motivational, and deliberative states of the agent. An agent in Jason is an entity composed by: i) a set of beliefs (the agent's information about the world); ii) a set of goals/desires (tasks that the agent wants to achieve); iii) a set of intentions (what the agent is committed to doing); and, iv) a set of plans (a plan is a course of action that is triggered by an event). Events include adding or removing goals and changes in the agent's belief base.

CArtAgO is a framework and infrastructure for the environment's programming and execution in multi-agent systems based on the A&A (Agents and Artifacts) meta-model (Ricci et al. 2009a; Omicini, Ricci, and Viroli 2008). In this model, the environment can be designed and programmed as a dynamic set of computational entities called artifacts (that provide services to the agents), collected into workspaces, and possibly distributed among various network nodes. An agent that uses the *focus* action to focus on an artifact receives its *observable properties* as perceptions and can perform *operations* (i.e., actions) made available by that artifact.

$\mathcal{M}$OISE$^+$ is a framework that implements a programming model for the organizational dimension (Hübner and Sichman 2007). This approach includes a language for the specification of MAS organization and infrastructure, with support for organization-based reasoning mechanisms at the agent level. Usually, we wrote the specification via an XML file containing three different specifications: structural, functional, and normative.

Organizational Modeling

This Section presents the modeling for a multi-agent organization based on the representation of fundamental interactions between agent roles in the system and their performance in the environment, according to the specification proposed in (Born et al. 2019a). Here, we classify agents according to the roles they assume, and we divide them into three main groups: regulators, supervisors, or producers, according to Figure 1.

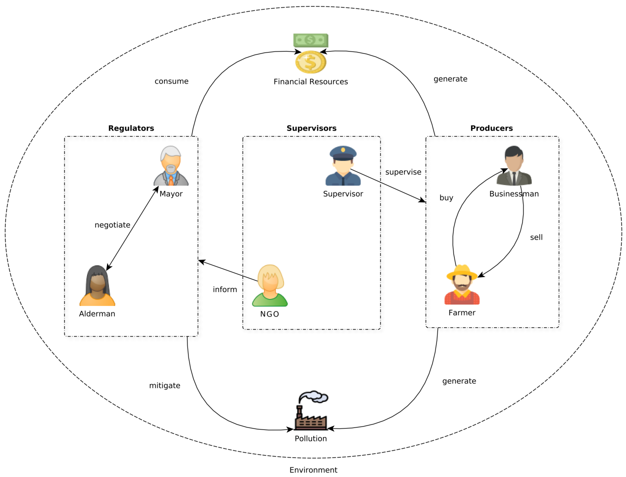

Figure 1: Integration diagram of the proposed model (Born et al. 2019a).

In (Born et al. 2019a), Gorim characters are divided into Regulators, Supervisors, and Producers. The **Regulators** are responsible for managing financial resources arising from taxes and charges linked to society to control/mitigate pollution (through the creation of laws, tax incentives, works to reduce pollution, etc.) without harming the production mechanisms. Regulatory agents assume the role of *mayor* or *alderman* and can interact/negotiate with each other to decide what actions to take in the environment.

The purpose of **Supervisors** is to supervise or report irregularities linked to the production and exploitation of the environment. The inspection agents assume the role of *environmental inspector* or *NGO* (Non-Governmental Organization). The environmental fiscal agent is responsible for inspecting the other agents that belong to the group of producers; that is, the inspector can, for example, impose fines on producer agents who violate any law/rule imposed by the regulatory agents. The NGO is responsible for informing regulatory agents of the current status of environmental pollution levels to raise awareness/pressure on other agents to take actions that reduce pollution levels. However, it is essential to point out that we defined the ONG as an NPC (*Non-Player Character*), that is, it represents an interface of the current situation of the game that provides information about the environment (Born 2022).

The **Producers** are the agents responsible for exploiting the environment with the primary objective of obtaining financial resources. They are the biggest generators of pollution and, consequently, of financial resources in the environment, being able to assume the roles of *businessman* or *farmer*. The entrepreneur is responsible for providing equipment and inputs necessary for production. However, the farmer is responsible for using the equipment and inputs he deems most appropriate for his production. In this way, the producer agents interact through the purchase/rent and sale of equipment and inputs (Born 2022).

The Gorim RPG has as scenery the cities of Atlantis and Cidadela (fictional cities that represent the cities of Pelotas and Rio Grande/Brazil), which are located in the hydrographic basin of Lagoa Mirim and Canal São Gonçalo. This RPG is based on the environmental dynamics of allocation of natural resources, in this case, more specifically, water resources, and the integration of agents involved in the system. The game's purpose is to seek environmental balance based on the use of water resources and the possible interactions/negotiations between the actors in the system (Born 2022).

The modeling of this organization must have three dimensions: i) *structural*, constituted by groups, roles, and connections; ii) *functional*, encompassing global plans, goals, and missions; and iii) *deontic*, which defines the obligations and permissions of the roles. It is also relevant to mention that we based the modeling of the organization of Gorim RPG on the work of (Hübner, Sichman, and Boissier 2002) with the necessary adaptations and particularities of the MAS organization of the case study.

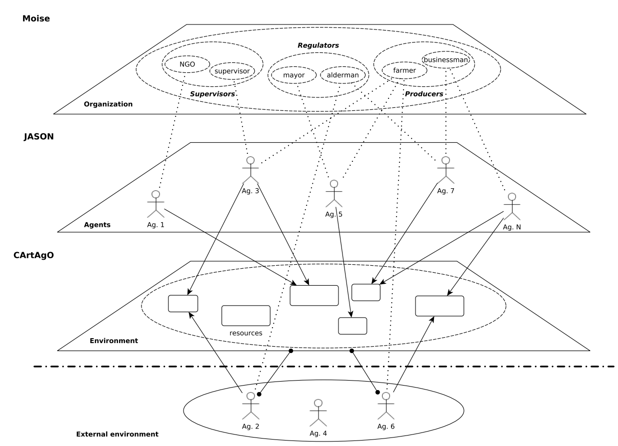

Figure 2: Overview of proposed model dimensions in JaCaMo.

From the perspective of the Organizational Entity (OE), that is, considering the agents of this system, Figure 2 shows the four dimensions from the point of view of the platform JaCaMo to which Jason, CArtAgO and $\mathcal{M}$OISE$^+$. The first dimension, $\mathcal{M}$OISE$^+$, where the main roles and their respective sub-roles are presented, communicating with the Jason dimension. In the second dimension, of Jason, the three types of groups of agents that make up society are presented, which communicates with the dimension of CArtAgO.

The third dimension presents the environment, in CArtAgO, considering that this environment is the hydrographic basin of Lagoa Mirim and Canal São Gonçalo and its resources, considering that this comprises two cities, Atlantis and Cidadela. This environment has four companies: seeds, fertilizers, pesticides, and machines, two in each of these cities. This dimension also communicates with that of real agents. The fourth dimension comprises virtual agents, who can assume roles and sub-roles mentioned in $\mathcal{M}\text{OISE}^+$. Therefore, this dimension corresponds to the implementation of this multi-agent system, that is, an online system, where each agent (considering this agent is a person) with their respective role can play on a different computer and in different places physically or be controlled by intelligent agents.

Structural Specification

The $\mathcal{M}\text{OISE}^+$ model has three central concepts regarding its structural specification: roles, relationships between roles, and groups (Hübner 2003). The **individual level** (role of each agent) is a set of behavioral restrictions that the agent accepts when joining a group. In $\mathcal{M}\text{OISE}^+$, the role represents the link between the agent and the organization. Thus, a role is an identifier on which relations with the other elements of the organization are defined (Hübner 2003).

In $\mathcal{M}\text{OISE}^+$, there is also the abstract role specification used in the structural specification of this case study, which no agent can assume. In this case, this particular role type establishes the inheritance relationship, so all player roles defined for this organization inherit properties from the player role.

At the **social level** (links and compatibilities), the roles are related to other roles, and thus there are restrictions on interaction between one and the other (Hübner 2003). One type of restriction between the roles is the links, divided into three types. In the description of the formalization of connections proposed by (Hübner 2003), we have *ack* (knowledge), where the agents who assume this type of connection are allowed to know the other agents in the system. Furthermore, agents can communicate with each other in the connection type *com* (communication). And, in the type *aut* (authority), an agent has control over another agent(s).

We considered the communication link for the structural specification of the Gorim RPG, and all agents have permission to interact in the system. However, we initially did not specify the other connections and the compatibility between the roles in the Gorim RPG.

Considering the **collective level** (groups), roles are only assumed within a group. In a group, a particular set of agents has closer or common affinities and objectives (Hübner 2003). The specification of a group consists of: i) the roles that can be assumed in the group; ii) the sub-groups that can be created within a group; iii) connections and compatibility valid for group agents; and iv) the cardinalities that establish the formation of the group (Hübner 2003).

Figure 3 represents the organization's structural specification for this case study, based on the interaction diagram of Figure 1. This structural specification has four groups: *Game*, *Regulator*, *Supervisor*, and *Producer*, considering that the interaction can be internal and external to these. All roles are inherited from the *Player* role, so this role is regarded as an abstract role in the organization and has two-way interaction. Also, each group and role have cardinalities corresponding to this study.

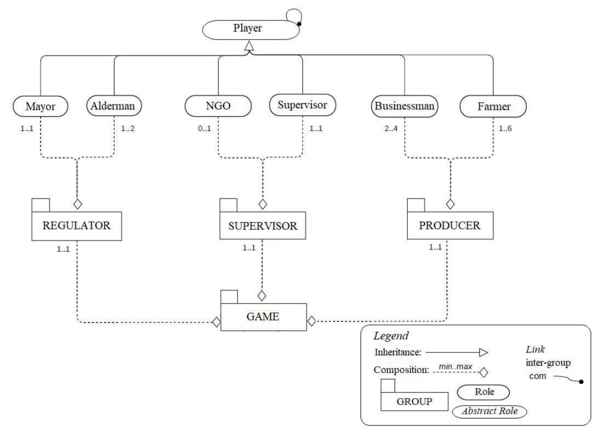

Figure 3: The Proposed Structural Specification.

In the *Regulator* group, the agent can assume the role of *Mayor* or *Alderman*, allowing for one mayor and two aldermen. In the *Supervisor* group, the agent can assume the role of *NGO* or *Supervisor*. It was considered that an agent or none could assume the role of the NGO since this role is an NPC in the modeling of the case study and that at least one environmental inspector is mandatory. In the *Producer* group, the agent can assume the role of *Busineesman* or *Farmer*, with at least one agent for each role and, in the case of the entrepreneur, a maximum of four, and the farmer, in the case of maximum six. Finally, the *Game* group must contain at least one group of each of the others.

In Figure 3, the cardinalities of both the three main groups and the roles of each of them are observed. For the groups, it was defined that there should be at least one group *Regulator*, one *Supervisor*, and one *Producer* and also, at most, one group of each, characterizing the cardinality *one for one*. As for roles, the *Regulator* group defined at least and at most one *Mayor* and at least one and at most two *Aldermen* for each city (Atlantis and Cidadela). In the *Inspector* group, there is the NGO that in the Gorim RPG has been represented by an NPC and at least one and at most one *Environmental Inspector* per city. Finally, in the *Producer* group, there are at least two and a maximum of four *Businessmans* (Seed, Fertilizer, Pesticide, and Machine) and a minimum of one and a maximum of six *Farmers*, three in each city.

Still, in the structural specification, the three groups, together with each of their roles, have a compositional relationship with the group *Game*. And, all roles are inherited from the *Player* role, and there can be communication between all roles in the Gorim RPG.

Functional Specification

A Functional Specification (EF) is composed of global goals, individual level, and collective level. A **global goal** is represented by the state of the world that a MAS wants to achieve. Then, all or more than one agent in the system carry out actions based on plans so that this global goal is achieved. The social scheme is composed of missions at the

individual level of EF. Missions correspond to a set of objectives/goals assigned to agents through a role. Thus, when an agent commits to a mission, he is responsible for achieving all the objectives/goals of that mission (Hübner 2003).

At the **collective level** of an EF, the Social Scheme (ES) is elaborated, where a decomposition tree of global goals is built, the root of which is the objective/goal of the ES. In this decomposition of objectives/goals, plans indicate how to satisfy a certain objective/goal. To build a plan, three types of operators are used (Hübner 2003):

Sequence: represented by "," in plan $g_1 = g_3, g_4$, where goal g_1 will be satisfied if goal g_3 is satisfied and then goal g_4 also go.

Selection: represented by "|" in the plane $g_8 = g_{11} \mid g_{12} \mid g_{13}$, where the target g_8 will be satisfied if one, only one, of the goals g_{11}, g_{12} or g_{13} is satisfied.

Parallelism: represented by "||" in the plan $g_0 = g_1 \mid\mid g_2$, where the goal g_0 will be satisfied when the two goals g_1 and g_2 are however the two sub-goals can be pursued in parallel.

In the EF modeling, we constructed the social schemes and the preference relationship between the missions that the roles involved must achieve. For space reasons, the functional specification of the *Regulator* group will be presented in this paper, as shown in Figure. However, the details of all functional specifications developed for this work are presented in (Born 2022).

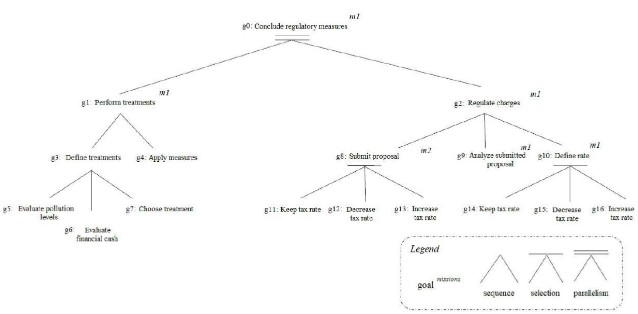

Figure 4: The functional specification for *Regulators*.

The group of agents *Regulators* has two roles, *Mayor* and *Alderman*. Thus the mission numbered as m_1 refers to the missions that the role *Mayor* has obligation or permission to perform, and the mission numbered m_2 refers to the missions that the *Alderman* role can and cannot perform. Figure 4 is the representation of the decomposition of the tree of the Regulator group of the MAS organization. The decomposition trees are traversed by the depth search method. Table 1 presents the objectives that must be met to reach the global goal of the *Regulator* group.

Deontic/Normative Specification

In the Deontic Specification (DE) or Normative, the relationship between the EE and the EF is established, specifying which mission(s) each role has permission or obligation to commit to in the system. The DE group *Regulator* will be displayed (*Mayor* in Table 2 and *Alderman* in Table 3). In this case, the two roles, mayor and alderman, are obliged to carry out the missions, represented by O in the tables.

Table 1: The objectives/goals description for *Regulator*.

Objective Goal	Description
g_0	The overall goal is to complete the regulatory measures
g_1	Carrying out the treatments
g_2	Fee regulation
g_3	Definition of which treatments to perform
g_4	Application of measures to be carried out
g_5	Assessment of pollution levels in the administered city
g_6	Valuation of the city's cash register
g_7	Choice of treatment to be carried out (water, garbage or sewage)
g_8	Forwarding of the proposal by the role of alderman
g_9	Analysis, by the role of mayor, of the proposals forwarded
g_{10}	Setting the tax rate amount
g_{11}	Maintain the tax rate for the role of alderman
g_{12}	Decrease the tax rate for the role of alderman
g_{13}	Increase the tax rate for the role of alderman
g_{14}	Maintain the tax rate by the role of mayor
g_{15}	Decrease the tax rate for the role of mayor
g_{16}	Increase the tax rate for the role of mayor

Table 2: Missions and Plans for *Regulator – Mayor*.

Missions	$m_1 = \langle O, \{g_0, g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_9, g_{10}, g_{14}, g_{15}, g_{16}\}$, Mayor$\rangle$
Goals	g_0: Conclude regulatory measures g_1: Perform treatments g_2: Regulate charges g_3: Define treatments g_4: Apply measures g_5: Evaluate pollution level g_6: Evaluate financial cash g_7: Choose treatments g_9: Analyze submitted proposal g_{10}: Define rate g_{14}: Keep tax rate g_{15}: Decrease tax rate g_{16}: Increase tax rate
Plans	$[g_0]$, $[g_1]$, $[g_2]$, $[g_3]$, $[g_4]$, $[g_5]$, $[g_6]$, $[g_7]$, $[g_9]$, $[g_{10}]$, $[g_{14}]$, $[g_{15}]$, $[g_{16}]$ $g_0 = g_1 \mid\mid g_2$ $g_1 = g_3, g_4$ $g_3 = g_5, g_6, g_7$ $g_2 = g_9, g_{10}$ $g_{10} = g_{14} \mid g_{15} \mid g_{16}$

Table 3: Missions and Plans for *Regulator – Alderman*.

Missions	$m_2 = \langle O, \{g_8\}, \text{Alderman}\rangle$
Goals	g_8: Submit proposal
Plans	$[g_8]$
	$g_8 = g_{11} \mid g_{12} \mid g_{13}$

Scenario Example

In this scenario, we considered ten agents that were instantiated in order to select two that will assume the roles of *mayor* and *councilman*, one agent `mayor` and one agent `alderman`. The main objective of this scenario is to verify the organizational specification of the proposed modeling from the interaction of these two agents. We modeled the MAS of the Gorim RPG using the $\mathcal{M}$OISE$^+$ tool and the XML language, and we implemented the agents and their beliefs using the Jason tool in the AgentSpeak multi-agent programming language.

Here, the `alderman` sends to `mayor` a proposal to increase the tax rate, it is necessary to establish some criteria for objectives g_{11}, g_{12}, g_{13}, g_{14}, g_{15} and g_{16}. So, it was defined that:

- Let P the variable assigned to the proposal:
  - if $(P < 10)$, then "Keep tax rate";
  - if $(P >= 10$ and $P < 20)$, then "Decrease the tax rate";
  - if $(P > 20)$, then "Increase the tax rate".
- Let T the variable assigned to the rate:
  - if $(T < 10)$, then "Keep the tax rate";
  - if $(T >= 10$ and $T < 20)$, then "Decrease the tax rate";
  - if $(T > 20)$, then "Increase the tax rate".

In Figure 5, we show the result of the interaction between these two agents where the functional specification defined in the XML is covered. In this case, it did not necessarily run a depth search because just the objectives specified in the code were accomplished. We can carry the objectives g_1 and g_2, then it is up to the agent who assumes the role of `mayor` to traverse one side or the other of the tree. The agent `ag4` representing the `alderman`, sends a request to `g8--Submit proposal` to the `mayor`, represented by `ag3` suggesting `Increase the rate of tax` and this, in turn, accepts the alderman suggestion.

Conlusions and Future Works

We developed the hypothetical scenarios proposed in this work from the modeling presented at the organizational level of agents as previously mentioned by the specifications: structural, functional, and deontic/normative.

In the scenarios, the agents can assume the roles of the groups defined in the functional specification scheme of the $\mathcal{M}$OISE$^+$ tool and, therefore, go through the objectives added as the agents' belief in the Jason tool, as can be seen in the work (Born 2022).

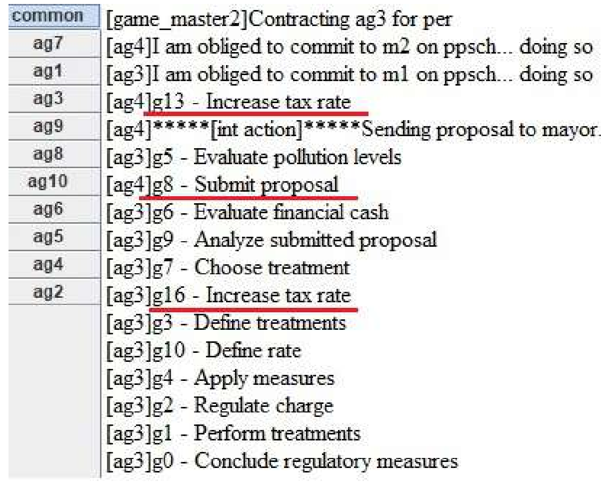

Figure 5: An example of execution for *Regulators*.

An interesting particularity of the Gorim RPG is that the negotiation of receipt or transfer of values (kickback) can occur at any time in the game and between any agent of this system. This aspect makes the game exciting but, at the same time, brings greater complexity to the development of cognitive agents.

In this way, the scenarios developed for this case study are coherent with organizational modeling at the level of agents in aspects of structural, functional, and deontic/normative specifications.

The case study presented in this paper is part of the context of the Participatory Management of Water Resources project using Computational Games and Multiagent Systems in the watershed of Lagoa Mirim and Canal São Gonçalo. Thus, we developed the Gorim RPG to understand the problems involved in this environment and the agents and interactions.

The modeling at the organizational level of agents was formalized from the definitions of the Gorim RPG, observing all the agents involved, their interactions, actions, and game rules. In this way, it was possible to model the structural specification regarding groups, roles, and interactions that may occur between agents. The functional specification represents how these agents perform their functions in the system and what order of actions they can or should follow. Also, the deontic/normative specification represents the missions that the groups' roles are obliged or allowed to carry out. The tool used in this modeling was $\mathcal{M}$OISE$^+$.

The main objective of the hypothetical scenarios was to verify whether the agents could form the groups (regulators, inspectors, and producers) of the specified scheme and whether they could carry out the correct in-depth search of the modeled objectives/missions.

However, based on this organizational modeling, future works are related to (i) integration and testing of this organizational modeling with the Gorim RPG engine (Martins 2021) and (ii) simulations with all agents defined in the Gorim RPG.

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