

EXTENSION SPECIFICATION

Modelling Multi-Agent Systems with Rational Agents: An iStar Extension based on PRISE

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PRESENTATION OF THE ISTAR EXTENSION: Modelling Multi-Agent Systems with Rational Agents: An iStar Extension based on PRISE

This document specifies the following iStar extension: Modelling Multi-Agent Systems with Rational Agents: An iStar Extension based on PRISE. The list of constructs included, their descriptions and representations are presented following. The metamodel is also presented.

This extension includes the representation Multi-Agent Systems with the Rational Agents in iStar, i.e. the representation of Environment, Organisation, four types of rational agents and their roles: Simple reflex agent, Model-based reflex agents, Goal-based agents and Utility-based agents. Additionally, we represented the agent defined in the work of Silva (*Silva, V. T. da (2004) From a Conceptual Framework for Agents and Objects to a Multi-Agent System Modeling Language, PhD Thesis in Informatics. Rio de Janeiro: PUC.*

This extension is part of a model-driven approach to developing rational agents. In previous works, it was proposed the support to Rational Agents development in architectural level (*E. Gonçalves, M. I. Cortés, G. Campos, Y. Lopes, E. Freire, V. T. Silva, K. OLIVEIRA, M. A. Oliveira, MAS-ML 2.0: Supporting the modelling of multi-agent systems with different agent architectures. The Journal of Systems and Software, p. 77-109, 2015*), Code generation (*Y. Lopes, E. Gonçalves, M. I. Cortés, E. Freire, A MDA Approach Using MAS-ML 2.0 and JAMDER. In: 13th International Workshop on Agent-Oriented Software Engineering in 11th International Conference on Autonomous Agents and Multiagent Systems, 2012, Valencia. Proceedings of 13th International Workshop on Agent-Oriented Software Engineering, 2012*) and test (*F. R. V. Silveira, G. A. L. Campos, M. I. CORTES, A Problem-Solving Agent to Test Rational Agents: A Case Study with Reactive Agents. In: 16th International Conference on Enterprise Information Systems (ICEIS), 2014, Lisboa. 16th International Conference on Enterprise Information Systems (ICEIS), 2014*). Therefore, this extension fills a gap in the requirements phase.

1 Analyse The Need For Extension Proposal

1.1 Study a domain/application area

We contacted three experts in agents when we were studying this application area. Additionally, we did a literature review (not systematic) to identify the agents' architecture and select a subset of them. The following list of references and contacted researchers follows:

ID_reference	Reference
REF_RA_01	Russell, S.; Norvig, P. (2004). <i>Inteligência Artificial: uma abordagem moderna</i> . 2 Ed. São Paulo: Prentice-Hall
REF_RA_02	Weiss, G. (1999). <i>Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence</i> . MIT Press, Massachusetts
REF_RA_03	Wooldridge, M.; Jennings, N. (1994). <i>Agent Theories, Architectures, and Languages: A Survey</i> . In: <i>European conference on Artificial Intelligence, 11, Netherlands, Proceedings of the Workshop on Agent Theories, Architectures and Languages</i> , p. 1-39
REF_RA_04	Wooldridge, M. (2002). <i>An Introduction to Multiagent Systems</i> . John Wiley and Sons Ltd, February
REF_RA_05	Silva, V. T. da (2004) <i>From a Conceptual Framework for Agents and Objects to a Multi-Agent System Modeling Language</i> , PhD Thesis in Informatics. Rio de

	Janeiro: PUC
REF_RA_06	Gonçalves, E., Cortés, M. I., Campos, G. A. L., Lopes, Y. S., Freire, E. S. S., Silva, V. T., Oliveira, K. S. F., Oliveira, M. A. MAS-ML 2.0: Supporting the modelling of multi-agent systems with different agent architectures. The Journal of Systems and Software, p. 77-109, 2015.

ID_researcher	Researcher	email
RES_RA_01	Gustavo Augusto Lima Campos	gustavo@larc.es.uece.br
RES_RA_P2	Mariela Inés Cortés	mariela@larc.es.uece.br
RES_RA_03	Viviane Torres da Silva	vivianet@br.ibm.com

1.2 Identify the concepts to be introduced by the extension

We identified 4 kinds of rational agents and their roles, environment and organisation beyond their internal element to be introduced by the extension, being 19 nodes and 4 links. A great part of these concepts is part of iStar or can be presented by the specialisation of the iStar concepts.

ID_concept	Name of the Concept	Reference
<i>Nodes</i>		
CON_RA_01	Simple reflex agent	REF_RA_01
CON_RA_02	Model-based reflex agents	REF_RA_01
CON_RA_03	Goal-based agents	REF_RA_01
CON_RA_04	Utility-based agents	REF_RA_01
CON_RA_05	Simple reflex agent role	REF_RA_06
CON_RA_06	Model-based reflex agent role	REF_RA_06
CON_RA_07	Goal-based agent role	REF_RA_06
CON_RA_08	Utility-based agent role	REF_RA_06
CON_RA_09	Goal	REF_RA_01, REF_RA_05
CON_RA_10	Belief	REF_RA_01, REF_RA_05
CON_RA_11	Perception	REF_RA_01
CON_RA_12	Planning	REF_RA_01
CON_RA_13	Plan	REF_RA_05
CON_RA_14	Next function	REF_RA_01
CON_RA_15	Formulate goal function	REF_RA_01
CON_RA_16	Formulate problem function	REF_RA_01

CON_RA_17	Utility function	REF_RA_01
CON_RA_18	Action	REF_RA_01, REF_RA_05
CON_RA_19	Organisation	REF_RA_05
CON_RA_20	Environment	REF_RA_05
<i>Links</i>		
CON_RA_21	Ownership	REF_RA_05
CON_RA_22	Inhabit	REF_RA_05
CON_RA_23	Play	REF_RA_05
CON_RA_24	Cause/effect	REF_RA_01

1.3 Contact experts in Domain/Application area

It was not necessary at this moment because there was not any doubt about them and since we will validate the extension with the experts.

1.4 Model an example with the identified concepts using iStar

The main goal of this task is to try identifying the domain concepts which is possible to represent with iStar without creating new representations and what is not possible to identify with iStar. Thus, we believe that it is possible to represent a set of concepts targeted by the extension using iStar. Consequently, we modelled a Multi-Agent System (MAS) to an environment of distance education named MOODLE to analyse the usage of these concepts.

MOODLE (Modular Object-Oriented Dynamic Learning Environment) is a software widely used in distance education courses. MOODLE is a free software available for download at <https://www.moodle.org>, this can be used without costs and has been allowed the development of courses in the distance education around the world. This software is available in a standard distribution which can be customised. This environment is used in courses of the Universidade Aberta do Brasil (UAB), a university of the Brazilian government that offer courses in distance education. Thus, we modelled a multi-agent system to courses of this UAB offered in partnership with the Universidade Estadual do Ceará (UAB/UECE).

Five agents were considered in the modelling:

Helper Agent: This agent is the simple reflex type and has a list of several insights into the difficulties the user has, and before this, it chooses the appropriate action. This agent realizes at what point the user is at the same time independently offers tips on how to make the best use of a particular functionality, specifically, the action for a particular job;

Companion Learning Agent: This type of agent should be able to choose independently among a predetermined range of affective interaction strategies such as messages of support. It presents encouraging messages (positive reinforcement) when the user, through the manifested interactions, gives evidence that is straightforward to follow discussions and/or the proposed tasks and/or content, and even when the student poses a lot of rhythms higher than the average in your class or workgroup. Because of the need to keep class notes for comparison and send messages quickly, this agent is characterised as a Model-based reflex agent;

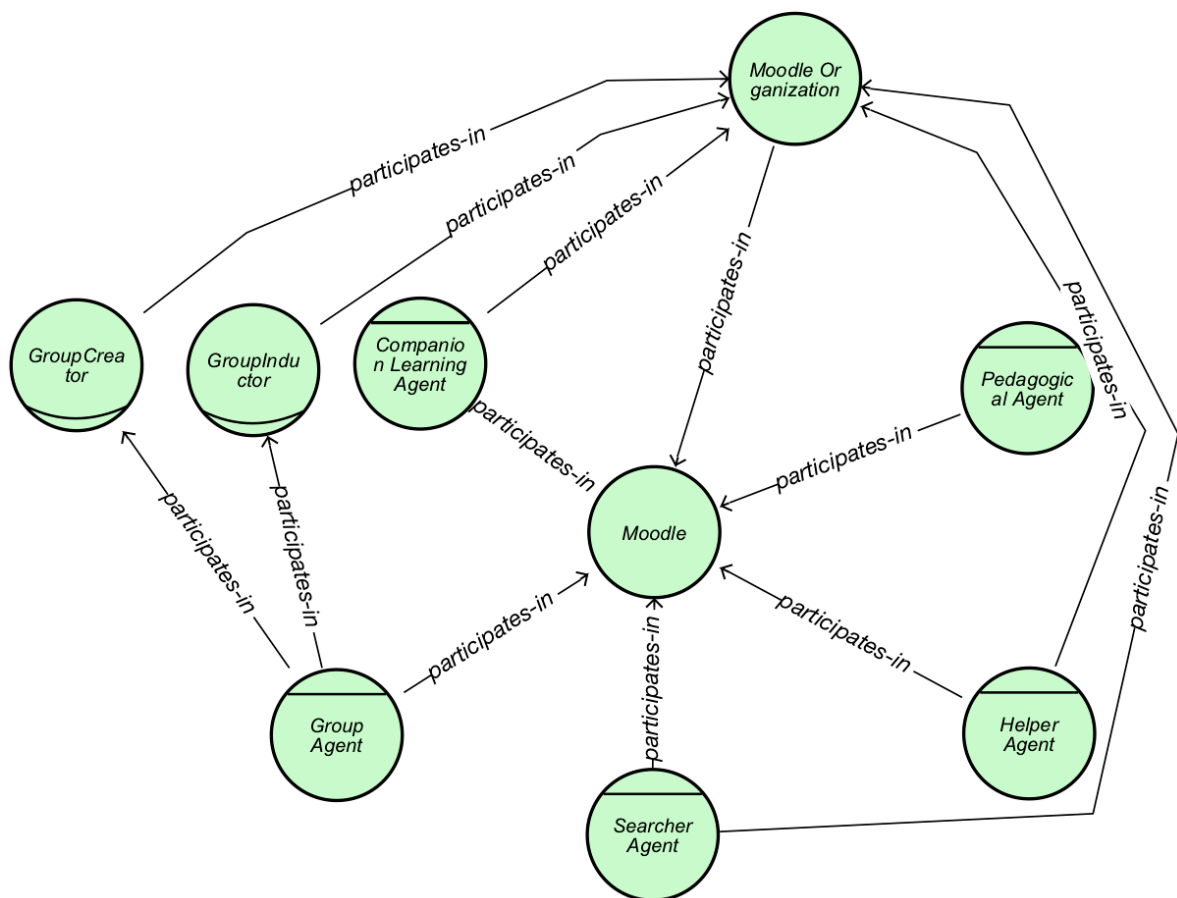
Pedagogical Agent: This agent should be able to accompany the student in the different disciplines that participate to contribute to the user through tips, suggestions and messages related

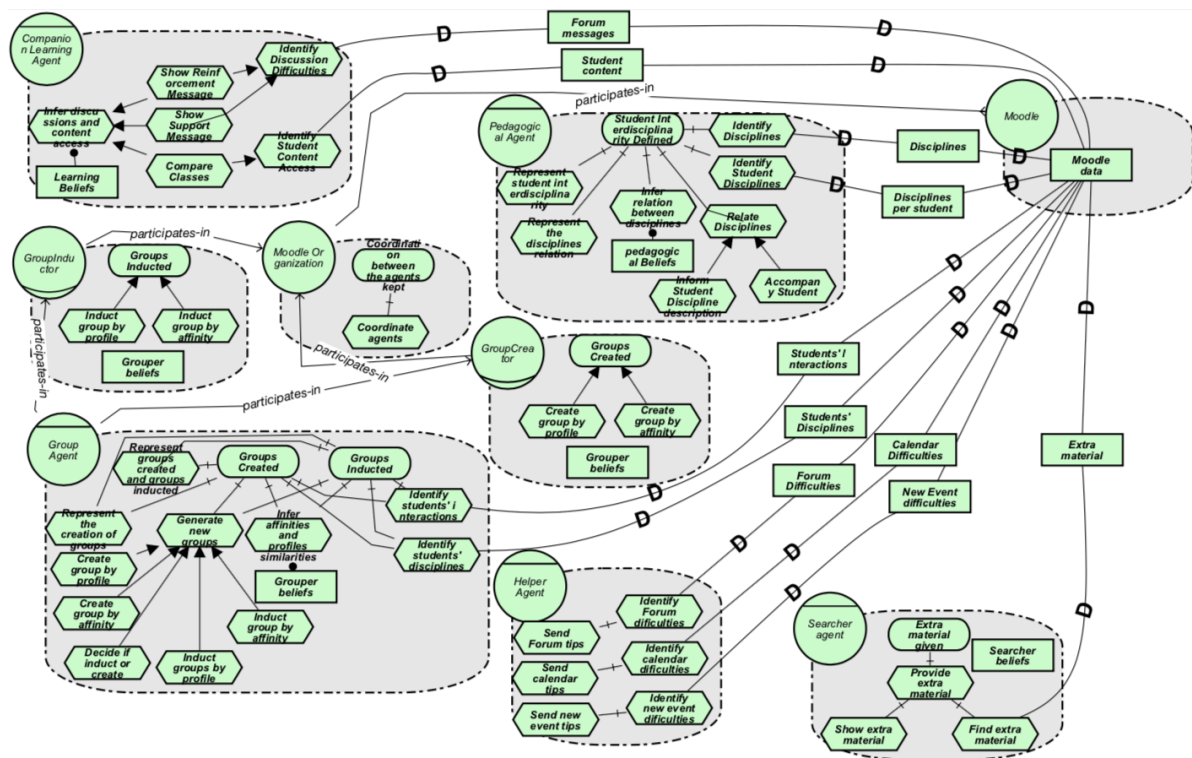
to the topic ongoing and not only affective nature of messages (support). It is a goal-based agent because he needs to create a study strategy, suggesting disciplines for the student based on the disciplines that the student is doing. This agent is modelled as a Goal-based agent;

Group Agent: This agent is a utility-based agent. It should be able to assist autonomously users, students and educators, the composition of working groups taking into account affinity themes or learning profiles. For this, it must consider certain criteria established by a trainer of one or more classes, or by the user interested in integrating the working groups;

Searcher agent: This agent finds extra material (pages, projects, and other digital objects) related to the courses in the MOODLE and sent to the students. This agent is modelled as a MAS-ML default agent.

The iStar sr and sd models of this multi-agent system follows below. Then follows the report of the experience of how to model the system.





1.1.1 Observations

When modelling MAS, the type of modelling agent is not very clear in the models. It is also not possible to differentiate when a task is action, perception, planning. It is not appropriate to model belief as a resource. The Organisation and environment are represented in the same way, using an actor, so it is not possible identify which of them is the organisation and which is the environment.

Besides the visual and conceptual gap, this proposal is being proposed in a Model-driven approach context. It is being proposed to model rational agents to fill the gap of our approach that just model the architecture of these kinds of software (E. Gonçalves, M. I. Cortés, G. Campos, Y. Lopes, E. Freire, V. T. Silva, K. OLIVEIRA, M. A. Oliveira, MAS-ML 2.0: Supporting the modelling of multi-agent systems with different agent architectures. The Journal of Systems and Software, p. 77-109, 2015.), generate code automatically (Y. Lopes, E. Gonçalves, M. I. Cortés, E. Freire, A MDA Approach Using MAS-ML 2.0 and JAMDER. In: 13th International Workshop on Agent-Oriented Software Engineering in 11th International Conference on Autonomous Agents and Multiagent Systems, 2012, Valencia. Proceedings of 13th International Workshop on Agent-Oriented Software Engineering, 2012.) and make possible testing (F. R. V. Silveira, G. A. L. Campos, M. I. CORTES, A Problem-Solving Agent to Teste Rational Agents: A Case Study with Reactive Agents. In: 16th International Conference on Enterprise Information Systems (ICEIS), 2014, Lisboa. 16th International Conference on Enterprise Information Systems (ICEIS), 2014.). Therefore, it is necessary a modelling proposal in requirements level to make feasible the model-to-model transformation from iStar to MAS-ML 2.0. The iStar extension is necessary for this context.

Finally, we can conclude that there is a need to extend.

1.5 Identify if there are extensions related to the current proposal

It was searched in the repository for agent term and eight extensions were found. Two of them are related to our extension.

Search Term	Extensions	Year
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Agent	SNet: A Modelling and Simulation Environment for Agent Networks Based on i* and ConGolog	2006
	Tropos: An Agent-Oriented Software Development Methodology	2004
Action	Designing Law-Compliant Software Requirements	2009
Filter the results by links and identified the effect	Towards Augmenting Requirements Models with Preferences	2009
Plan	Tropos: An Agent-Oriented Software Development Methodology	2004
	Using Empirical Studies to Mitigate Conflicts in iStar Extensions (To appear)	2019

For the next process gateways, the flow is: To Is there an extension suitable for your need? - Is not the extension related to a domain / application area? - No. Thus, activity 1.2. Study a domain / application area is started.

2 Conceptualise the iStar extension

2.1 Search and select constructs to be reused.

The list of found constructors is shown below:

ID_concept	Name of the Concept	Reference of Extension to be reused
<i>Nodes</i>		
CON_RA_10	Belief	From the previous version of iStar (http://istar.rwth-aachen.de/tiki-index.php?page=iStarQuickGuide)
CON_RA_13	Plan	Using Empirical Studies to Mitigate Conflicts in iStar Extensions
CON_RA_18	Action	A new representation from: Using Empirical Studies to Mitigate Conflicts in iStar Extensions
CON_RA_24	Cause-effect	Towards Augmenting Requirements Models with Preferences

2.2 Define extension's concepts

The definition of the extension's concepts is presented in the following table.

ID_concept	Name of the	Definition	Reference
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Concept			
Nodes			
CON_RA_01	Simple reflex agent	It is considered the simplest internal architecture. Condition-action rules are used to select the actions based on the current perception. These rules follow the form “if condition then action” and determine the action to be executed if the perception occurs. This architecture assumes that at any time the agent receives information from the environment through sensors.	REF_RA_01
CON_RA_02	Model-based reflex agents	The structure of this kind of agent is similar to the Simple Reflex Agent since it deals with the information by using condition-action rules. To reach a more rational performance, the agent is also able to store its current state in an internal model. Model-Based Reflex Agents select actions by using the information in their internal states.	REF_RA_01 REF_RA_02
CON_RA_03	Goal-based agents	Sometimes, the knowledge about the current state of the environment is not enough to determine the next action and additional information about desirable situations is required. Goal-Based Agents have explicit goals and select the actions that lead to their goals. This allows the agent to choose a goal state among multiple possibilities	REF_RA_01
CON_RA_04	Utility-based agents	Considering the existence of multiple goal states, it is possible to define a measure of how desirable a particular state is. In this case, aiming to optimize the agent performance, the utility function is responsible for mapping a possible state (or group of states) to that measure, according to the current goals	REF_RA_01
CON_RA_05	Simple reflex agent role	A role related to a Simple reflex agent	REF_RA_06
CON_RA_06	Model-based reflex agent role	A role related to a Model-based reflex agent	REF_RA_06
CON_RA_07	Goal-based agent role	A role related to a Goal-based agent	REF_RA_06

CON_RA_08	Utility-based agent role	A role related to a Utility-based agent	REF_RA_06
CON_RA_09	Goal	A targeted state of the world. When goals are associated with roles, they can be of two types: right (optional) or duty (obligation)	REF_RA_01, REF_RA_05
CON_RA_10	Belief	it is an internal model to storage of the history of the current states of the environment	REF_RA_01, REF_RA_05
CON_RA_11	Perception	It consists of the representation of state aspects that are used by the agent for making decisions	REF_RA_01
CON_RA_12	Planning	It is the activity devoted to finding the sequence of actions that can achieve the agent's goals	REF_RA_01
CON_RA_13	Plan	Plan is a sequence of pre-established actions which make the agent to reach a goal.	REF_RA_05
CON_RA_14	Next function	The next function is introduced to map perceptions and status current internal state to a new internal state, which will be used to select the next action.	REF_RA_01
CON_RA_15	Formulate goal function	Receive status and return goal formulated, i.e., a subset of states of the world that meet the goal	REF_RA_01
CON_RA_16	Formulate problem function	It is a function that represents the problem to be solved in a formal way	REF_RA_01
CON_RA_17	Utility function	Returns the utility degree according to the current goals of the agent	REF_RA_01
CON_RA_18	Action	An action that is performed by an agent. When represented in roles there is extra information if the action is mandatory (duty) or optional (right).	REF_RA_01, REF_RA_05
CON_RA_19	Organisation	It is an element that groups agents	REF_RA_05
CON_RA_20	Environment	It is an element that is the habitat for agents and organisations	REF_RA_05
Links			
CON_RA_21	Ownership	It is used to link an organisation and the roles that can be played in the organisation	REF_RA_05
CON_RA_22	Inhabit	It represents that an agent, organisation or role inhabit an environment	REF_RA_05

CON_RA_23	Play	It is used to link an agent and the roles that can be played by him in the context of an organisation	REF_RA_05
CON_RA_24	Cause-Effect	It is a link used to connect the perceptions and the actions	Identified during the proposal due practical aspects

2.3 Analyse how the extension constructs can be integrated with the iStar constructs

We related the concepts to be introduced with the iStar standard concepts. Thus, we concluded that we could specialise eleven iStar constructs. Simple reflex agent, Model-based reflex agents, Goal-based agents and Utility-based agents specialise iStar Agent. Next function, Formulate goal function, Formulate problem function, Utility function and Action specialise iStar Task. Organisation and Environment specialise Actor. Agent goals are represented by iStar goals without changes, agent beliefs are represented by beliefs in the iStar initial version without changes and ownership and inhabit links are represented by iStar participates-in without changes. The list of the relation between extension and iStar constructs is given in Table VI. The concepts which specialise the iStar constructs inherit the same characteristics of the base, so the specifics kinds of agents have a boundary for example.

ID_concept	Name of the Concept	Relation with iStar constructs
Nodes		
CON_RA_01	Simple reflex agent	<i>Specialise iStar Agent</i>
CON_RA_02	Model-based reflex agents	<i>Specialise iStar Agent</i>
CON_RA_03	Goal-based agents	<i>It specialises iStar Agent</i>
CON_RA_04	Utility-based agents	<i>It specialises iStar Agent</i>
CON_RA_05	Simple reflex agent role	<i>It specialises iStar Agent role</i>
CON_RA_06	Model-based reflex agent role	<i>It specialises iStar Agent role</i>
CON_RA_07	Goal-based agent role	<i>It specialises iStar Agent role</i>
CON_RA_08	Utility-based agent role	<i>It specialises iStar Agent role</i>
CON_RA_09	Goal	<i>It is represented by iStar</i>

		<i>Goal</i>
CON_RA_10	Belief	<i>It is represented by iStar Belief (from the first version of iStar). It can be related to belief by neededby relationship</i>
CON_RA_11	Perception	<i>It can be used as a source of a refinement link.</i>
CON_RA_12	Planning	<i>It specialises iStar Task. It can be decomposed in actions and utility-function. It relates with goal by refinement.</i>
CON_RA_13	Plan	<i>It specialises iStar Task. It can be refined in actions.</i>
CON_RA_14	Next function	<i>It specialises iStar Task. It can be related to belief by neededby</i>
CON_RA_15	Formulate goal function	<i>Specialise iStar Task</i>
CON_RA_16	Formulate problem function	<i>Specialise iStar Task</i>
CON_RA_17	Utility function	<i>Specialise iStar Task</i>
CON_RA_18	Action	<i>Specialise iStar Task</i>
CON_RA_19	Organisation	<i>Specialise iStar Actor</i>
CON_RA_20	Environment	<i>Specialise iStar Actor</i>
Links		
CON_RA_21	Ownership	<i>It is represented by iStar participantes-in link</i>
CON_RA_22	Inhabit	<i>It is represented by iStar participantes-in link</i>
CON_RA_23	Play	<i>It is represented by iStar participantes-in link</i>
CON_RA_24	Cause-Effect	<i>Connect perceptions to actions</i>

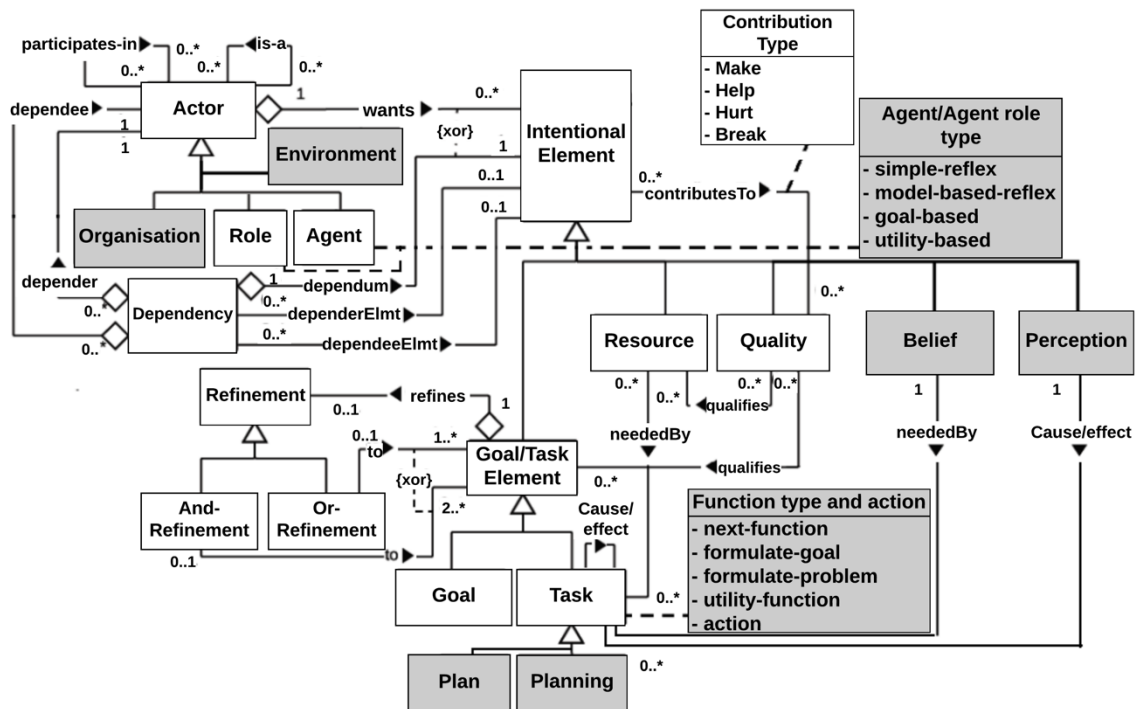
3 DEVELOP ISTAR EXTENSION

3.1 Define metamodel of extension

We included the concepts identified in the List of concepts to be introduced in the iStar metamodel. We considered the relationship of extension's constructs and iStar constructs in this step. The result is presented in the figure below.

We represented each kind of rational agent and their roles by a stereotype associated with Agent metaclass. Thus, we created four new stereotypes: simple-reflex, model-based-reflex, goal-based and utility-based, they are represented by the Agent/AgentRole Type. These stereotypes were applied to agent role too. We did not create a stereotype to represent the agents of the MAS-ML work because this kind of agent will be represented by agent without any additional stereotype.

Organisation and Environment are represented by new metaclasses which specialise Actor metaclass. Planning and plan are represented by a new metaclasses which specialise Task. Perception is a new metaclass that specialises Intentional Element. Therefore, Belief, a metaclass that was removed in iStar 2.0, was added as an intentional element again. Finally, we represented the stereotypes of next-function, formulate-problem, formulate-goal and utility-function and action by the Function Types and Action related to Task metaclass. The relationship needed by was extended to link beliefs and next-function tasks. The Cause/effect was included to connect perception and Action (represented by task metaclass) and to connect next-function and action (both represented by task metaclass).



3.2 Define validation rules of extension

We created a set of validation rules to analyse the well-formedness of the four kinds of agents. We

represented these rules using Object Constraint Language (OCL). These rules are applied to agent metaclass.

Rule	OCL rule
Rule 01 - if it is a simple reflex agent, it should not have goal, belief and planning and should have perception and plan	<pre>self.ownedAgentSemantics->value() = 'simple-reflex' implies self.ownedgoal -> isEmpty() = true and self.ownedbelief -> isEmpty() = true and self.ownedplanning -> isEmpty() = true and self.ownedperception -> isEmpty() = false and self.ownedtask -> isEmpty() = false</pre>
Rule 02 - if it is a model-based reflex agent, it should not have goal and planning and should have tasks, perceptions and belief.	<pre>self.ownedAgentSemantics->value() = 'model-based-reflex' implies self.ownedgoal -> isEmpty() = true and self.ownedplanning -> isEmpty() = true and self.ownedperception -> isEmpty() = false and self.ownedtask -> isEmpty() = false and self.ownedbelief -> isEmpty() = false</pre>
Rule 03 - if it is a goal-based agent, it should have goal, planning, perception, task and belief	<pre>self.ownedAgentSemantics->value() = 'goal-based' implies self.ownedgoal -> isEmpty() = false and self.ownedplanning -> isEmpty() = false and self.ownedperception -> isEmpty() = false and self.ownedtask -> isEmpty() = false and self.ownedbelief -> isEmpty() = false</pre>
Rule 04 - if it is a utility-based agent, it should have goal, planning, perception, task and belief	<pre>self.ownedAgentSemantics->value() = 'utility-based' implies self.ownedgoal -> isEmpty() = false and self.ownedplanning -> isEmpty() = false and self.ownedperception -> isEmpty() = false and self.ownedtask -> isEmpty() = false and self.ownedbelief -> isEmpty() = false</pre>
Rule 05 - if it is a MAS-ML agent, it should have goal, plan, task and belief	<pre>self.ownedAgentSemantics->isEmpty() = true implies self.ownedgoal -> isEmpty() = false and self.ownedplan -> isEmpty() = false and self.ownedtask -> isEmpty() = false and self.ownedbelief -> isEmpty() = false</pre>

Similarly, we created rules to validate the agent role.

Rule	OCL rule
Rule 01 - if it is a simple reflex agent, it should have tasks and should not have goal, belief, planning and	<pre>self.ownedAgentRoleSemantics->value() = 'simple-reflex' implies</pre>

perception.	<pre> self.ownedgoal -> isEmpty() = true and self.ownedbelief -> isEmpty() = true and self.ownedplanning -> isEmpty() = true and self.ownedperception -> isEmpty() = true and self.ownedtask -> isEmpty() = false </pre>
Rule 02 - if it is a model-based reflex agent role, it should have tasks and belief and should not have goal, planning and perception.	<pre> self.ownedAgentRoleSemantics->value() = 'model-based-reflex' implies self.ownedgoal -> isEmpty() = true and self.ownedplanning -> isEmpty() = true and self.ownedperception -> isEmpty() = true and self.ownedtask -> isEmpty() = false and self.ownedbelief -> isEmpty() = false </pre>
Rule 03 - if it is a goal-based agent role or utility-based role, it should have goal, task and belief and should not have planning and perception.	<pre> self.ownedAgentRoleSemantics->value() = 'goal-based' or self.ownedAgentRoleSemantics->value() = 'utility-based' implies self.ownedplanning -> isEmpty() = true and self.ownedperception -> isEmpty() = true and self.ownedtask -> isEmpty() = false and self.ownedgoal -> isEmpty() = false and self.ownedbelief -> isEmpty() = false </pre>

3.3 Define concrete syntax of extension

This section presents the list of the constructs of this extension, how the new graphical representations were chosen and how to model a system using the extension.

3.3.1 List of the graphical representation of the constructs

The representations of extension's constructs are presented in the next table. We used the iStar extensions catalogue to identify the representation of reused constructs and reused the representations to action and cause-effect. We also used the iStar original constructs to represent some domain concepts.

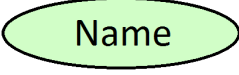
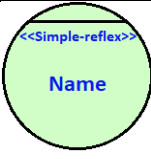
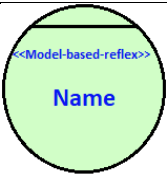
We classified the representations of the extension concepts in three groups:

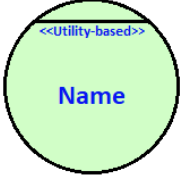
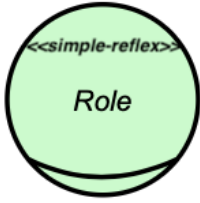
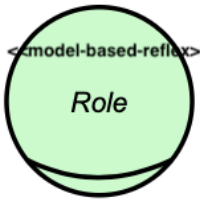
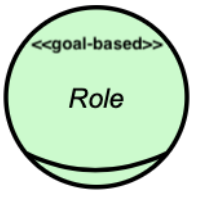
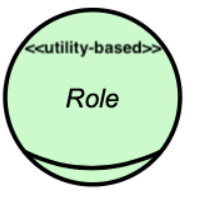
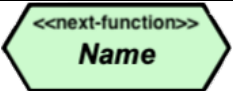
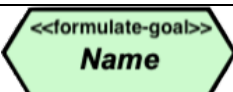
1. Constructs represented by iStar constructs as proposed: Five domain concepts are represented by the iStar constructs. They are used by the extension but have not impact on the graphical representations;
2. Constructs represented by iStar constructs added with textual markers: fifteen domain concepts are represented by textual representations added to iStar constructs. These Constructs have a similar meaning of the iStar constructs and specialize them by textual markers. The impact of this representations is not high since we are using the original representations, not creating new ones.
3. Constructs represented by iStar new graphical representation: Five domain concepts are not represented by textual markers of the iStar concepts since they are conceptually different. We found the Plan in previous extensions and reused it. Thus, we proposed

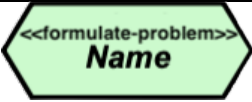
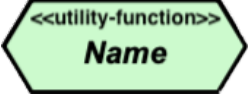
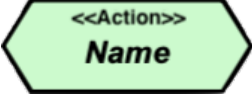
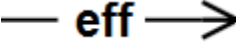
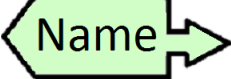
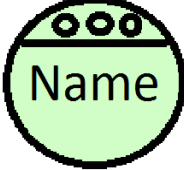
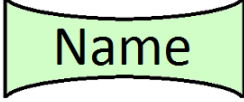
new graphical representations for the other four constructs. The details about how these graphical representations were chosen are presented in Section 3.3.2.

Furthermore, we extended the neededby relationship to connect next-function and beliefs establishing that beliefs are needed by the next-function. The agent actions can be represented in the agent roles as rights using the property type='right' or as duties using the property type='duty'.

The results are presented in the table below.

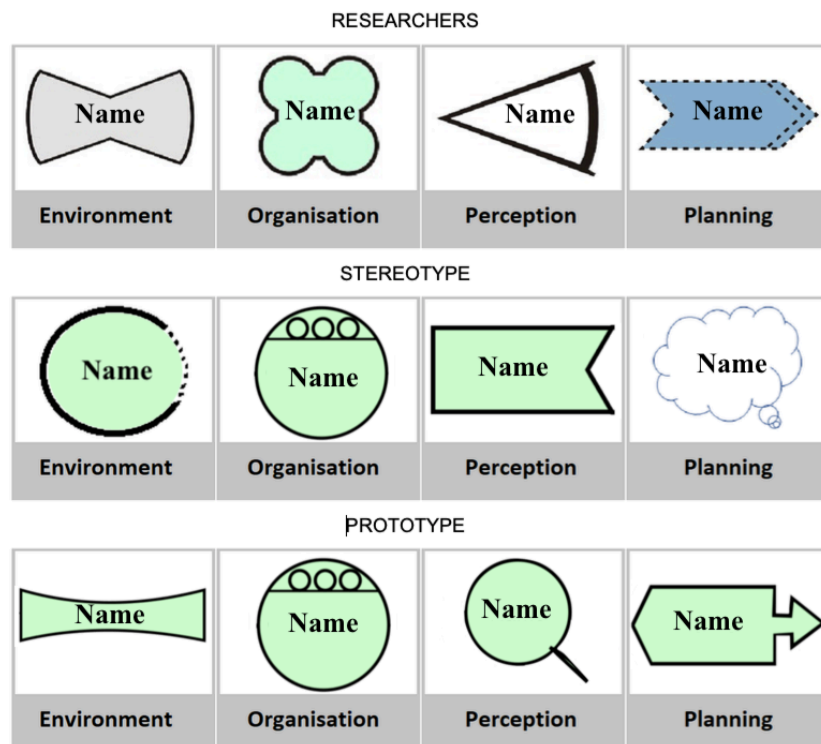
ID_concept	Name of the Concept	Representation	Explanation about the graphical representation	Reused?
<i>Constructs represented by iStar constructs as proposed</i>				
<i>Nodes</i>				
CON_RA_05	Goal		The same construct used in the default iStar 2.0	Yes
CON_RA_06	Belief		From the initial version of iStar	Yes
<i>Links</i>				
CON_RA_17	Ownership		It is represented by the iStar participates-in link	Yes
CON_RA_18	Inhabit		It is represented by the iStar participates-in link	Yes
CON_RA_19	Play		It is represented by the iStar participates-in link	Yes
<i>Constructs represented by iStar constructs added with textual markers</i>				
CON_RA_01	Simple reflex agent		The kinds of agents were proposed in this extension as an agent stereotype. This kind of agent must have perceptions and actions into his boundary.	No
CON_RA_02	Model-based reflex agents		The kinds of agents were proposed in this extension as an agent stereotype. This kind of agent must have perceptions, next function, beliefs and actions into his boundary.	No
CON_RA_03	Goal-based agents		The kinds of agents were proposed in this extension as an agent stereotype. This kind of agent must have goals, perceptions, next function, belief,	No

			formulate goal function, formulate problem-function and actions into his boundary.	
CON_RA_04	Utility-based agents		The kinds of agents were proposed in this extension as an agent stereotype. This kind of agent must have goals, perceptions, next function, belief, formulate goal function, formulate problem-function, utility function and actions into his boundary.	No
CON_RA_05	Simple reflex agent role		The kind of agent role related to simple-reflex agents	No
CON_RA_06	Model-based reflex agent role		The kind of agent role related to model-based reflex agents	No
CON_RA_07	Goal-based agent role		The kind of agent role related to goal-based agents	No
CON_RA_08	Utility-based agent role		The kind of agent role related to utility-based agents	No
CON_RA_09	Next function		Next-function is represented as a stereotype related to a task	No
CON_RA_10	Formulate goal function		Formulate goal function is represented as a stereotype related to a task	No

CON_RA_11	Formulate problem function		Formulate problem function is represented as a stereotype related to a task	No
CON_RA_12	Utility function		Utility function is represented as a stereotype related to a task	No
CON_RA_14	Action		The Action is represented as a stereotype related to a task. When represented in roles there is extra information about if the action is mandatory (type=duty) or optional (type=right).	Yes
CON_RA_20	Cause-effect		It uses the contribution link and adds a textual marker eff. Used to link perceptions/next-function to actions in reactive agents	Yes
Constructs represented by iStar new graphical representation				
CON_RA_07	Perception		It is based on a magnifying glass, which is used to perceives things of the environment	No
CON_RA_08	Planning		It is like a task, but there is an arrow in the right edge	No
CON_RA_15	Organisation		Organisations are actors that join agents. Thus, this representation is a specialisation of the actor with an analogy for a group of agents in the top	No
CON_RA_16	Environment		It is like a window from which is possible to see the environment	No
CON_RA_13	Plan		It is like a task, but there is not an arrow in the left edge	Yes

3.3.2 Choosing the new graphical representations of this extension

The new symbols proposed by this extension for Organisation, Environment, Perception and Planning were created using an experiment based on the work of Caire et al. (2013)¹. We performed this five-steps experiment with 152 participants. We created graphical representations for these concepts to be used in the studies 4 and 5 of this experiment. 70 participants made drawings for these four concepts (Step1). Following, we analysed the drawings, grouped them and identified the stereotype of the population (the most significative drawing from the most frequent group) (Study 2). Then, we submitted questionnaires to identify the prototype (Study 3) to 29 participants, the semantic transparency (Study 4) to 48 participants and the recognition (Study 5) to 45 participants. The graphical representations of the subsets are presented in the figure below.



We presented the results of the Hit rate of study 4 (Semantic transparency experiment) in the table below. Bolded values indicate the best hit rate of a concept among all factors.

Hit rate (in %) means per concept per factor in Semantic Transparency experiment

Concepts	Factors		
	Researchers	Stereotype	Prototype
Environment	26.67	22.22	46.67
Organisation	33.33	61.11	60.00
Perception	53.33	27.78	60.00
Planning	53.33	33.33	46.67
Mean	41.66	36.11	53.33

¹ Caire, P., Genon, N., Heymans, P., Moody, D. Visual notation design 2.0: Towards user comprehensible requirements engineering notations. 21st IEEE International Requirements Engineering Conference (RE), 2013

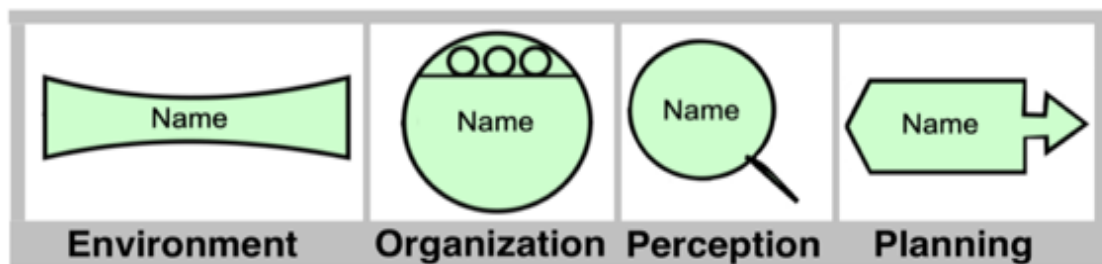
Group size	15	18	15
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We presented the results of the Hit rate of study 5 (Recognition experiment) in the table below. Bolded values indicate the best hit rate of a concept among all factors.

Hit rate (in %) means per concept per factor in Recognition experiment

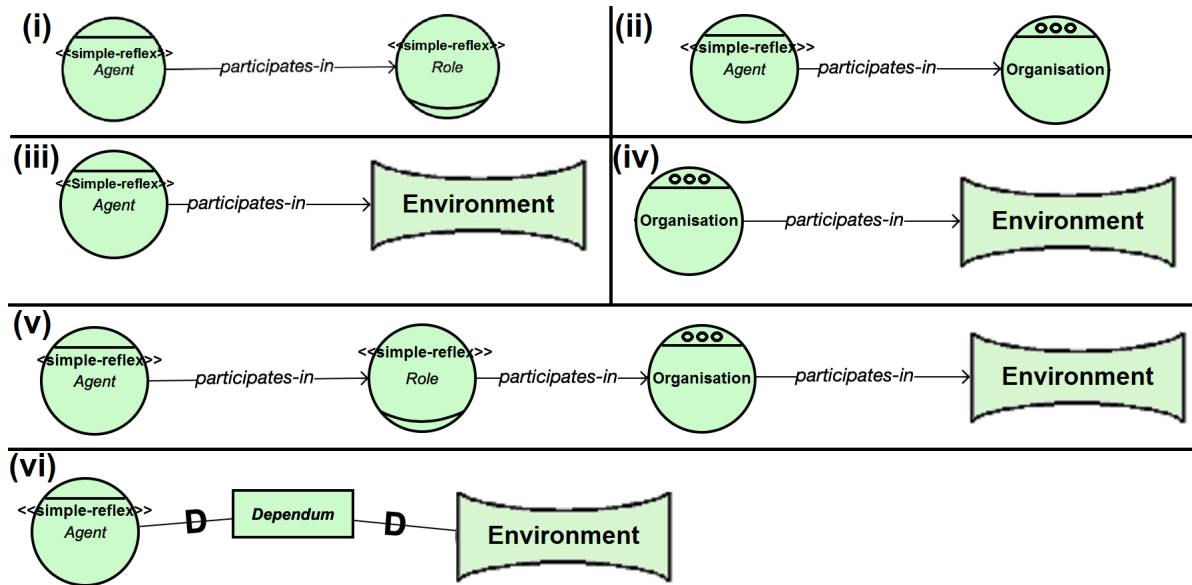
Concepts	Factors		
	Researchers	Stereotype	Prototype
Environment	81.25	94.12	83.33
Organisation	87.5	88.24	91.67
Perception	87.5	82.35	91.67
Planning	68.75	82.35	100
Mean	81,25	86,76	91,66
Group size	16	17	12

Finally, we selected symbols based on results of studies 4 and 5. These symbols are used in this extension to represent the new concepts. The Figure below shows the selected symbols.



3.3.3 How to use the extension

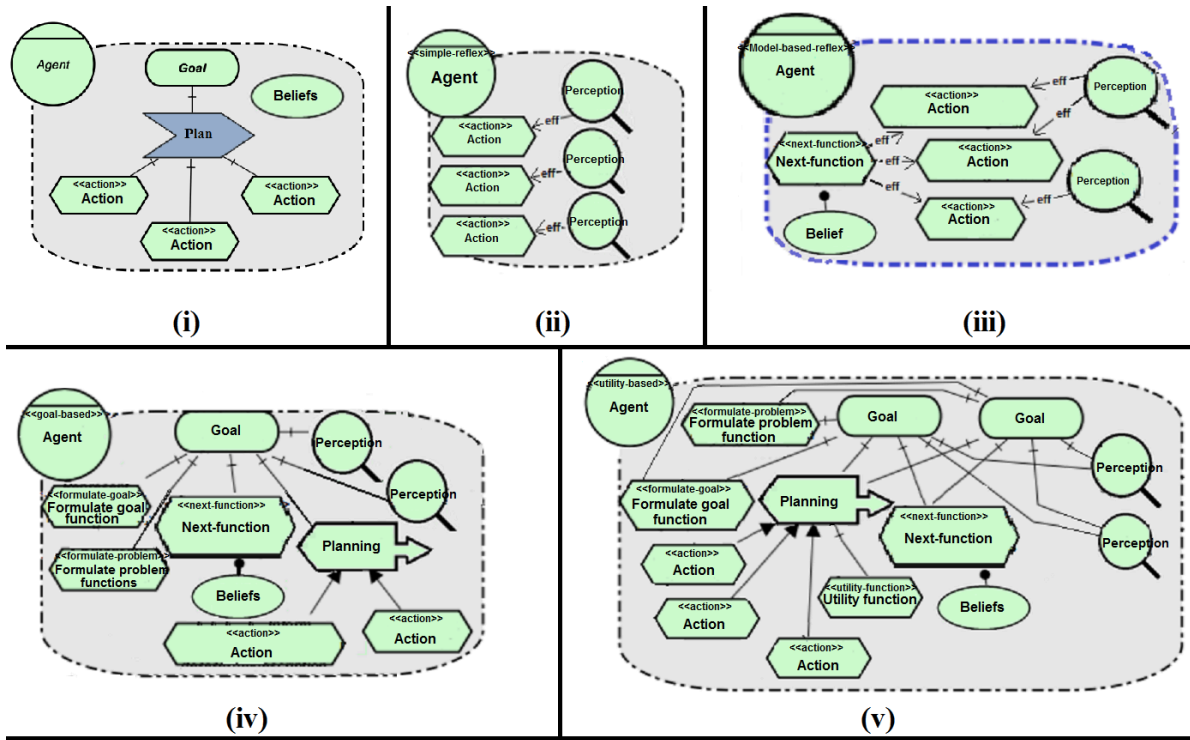
The SD model should be created to represent the agents, roles, organisations and environments involved in the Multiagent System, and representing the relationship between them. An agent can play a role, inhabit an environment and be part of an organisation (Ownership). These relationships are represented by the iStar link *participates-in* as presented in the table above. The dependencies between agents, roles, organisations and environment can be expressed too. The main objective of this modelling is representing the Multiagent system to be developed in the early phase when the MAS is starting to be proposed and the decisions about the agents' intentional elements like goals, tasks, planning, perceptions and internal details of the agents' intentional elements is not clear yet. The figure below shows an agent playing a role (i), an agent being part of an organisation (ii), an agent inhabits an environment (iii), an organisation inhabits an environment (iv), an agent playing a role in an organisation which inhabits an environment (v) and a dependency between an agent and an environment. We used simple-reflex agents and roles to illustrate, these links can be used with all kinds of agent.



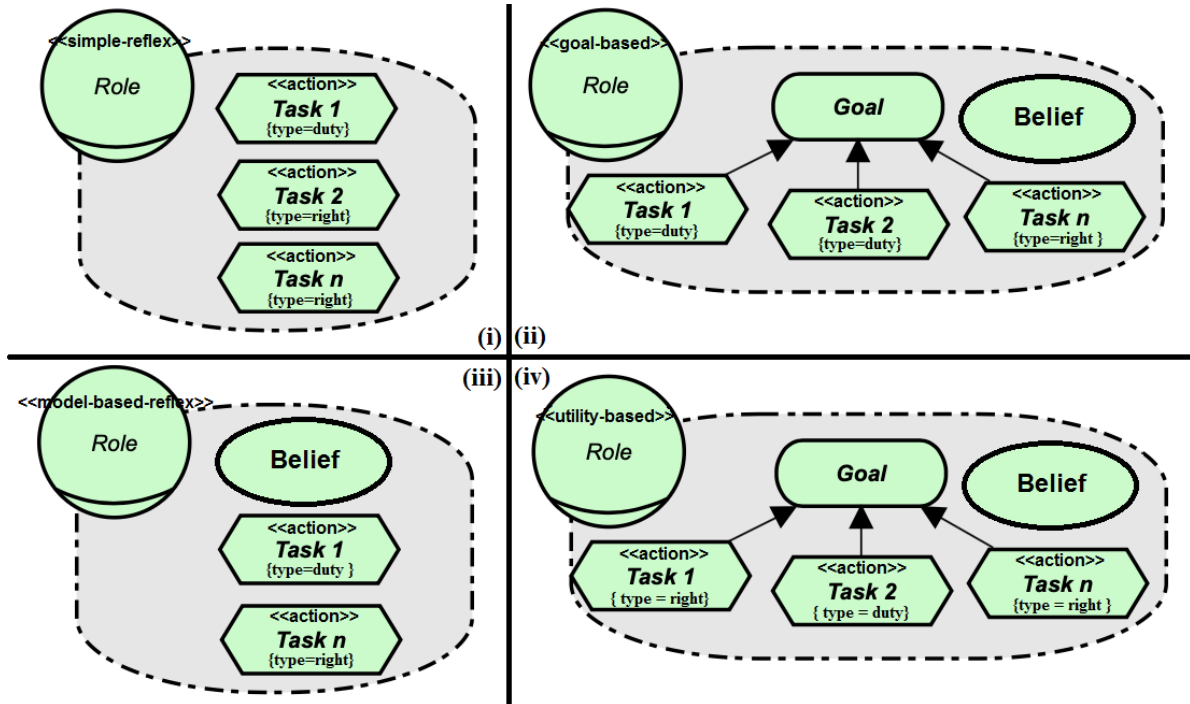
Following, the SR model should be created to represent the internal details of the agents, roles, organisations and environments involved in the Multiagent System, and representing the relationship between them. The SD model is the start point to the creation of this model.

In our approach, we consider the modelling of the agents' intentional elements as a refinement of their internal elements. In a similar way that the approach used by Mouratidis, H., Giorgini, P., (2007) *Secure tropos: a security-oriented extension of the tropos methodology*. *International Journal of Software Engineering and Knowledge Engineering* and Lapouchnian, A., Lespérance, Y., (2006) *Modelling mental states in agent-oriented requirements engineering*. *International Conference on Advanced Information Systems Engineering, Lecture Notes in Computer Science*.

The boundaries of the agents should be detailed regarding their intentional elements according to the validation rules presented in Section 3.2. The kind of agent defined by MAS-ML is represent by agent without any stereotype and its boundary is composed by goals, beliefs, plans and actions (i). In the reflex agents (Simple reflex (ii) and Model-based simple reflex (iii)), the perceptions and actions (and next-function in case of model-based reflex agents) should be related by the refinement link with the action as the source. Goals of the goal-based (iv) agents are decomposed on perceptions (which are decomposed on next-function) and planning (which are decomposed in actions). The same to utility-agents (v), but these ones have a utility-function related to the planning by an and-refinement. The beliefs are represented by a neededby link connecting beliefs and next-function. The figure below presents the boundary components for each kind of agent on SR diagram.

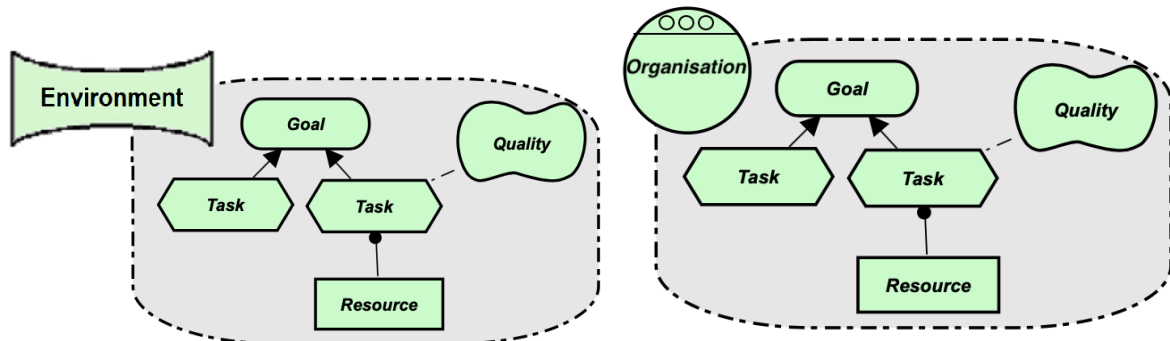


The boundaries of roles related to goal-based and utility agents and kind of agent defined by MAS-ML should represent goals, beliefs and actions related to the role. The boundary of roles of model-based-reflex agents should contain beliefs and actions related to the role and the roles of simple-reflex agents should contain actions related to the role. The actions in roles related to agents should have the information about which of them are mandatory (duty) and which are optional (right). The figure below presents the boundary components for each kind of agent role on SR diagram.



Additionally, the environment and organisation can be composed of the default iStar nodes and links such as goal, quality, resource and task nodes and refinements, qualification, neededby and contribution.

Notice 1: Organisations are represented in MAS-ML with the all internal elements of the agents that are part of the organisation. However, iStar has scalability problems related by many works and the creation of a node with all elements can be a problem. In the approach based on the model transformation that will be proposed, the replication of the agents' elements will be done in the architecture level. Therefore, the organisation should represent additional intentional elements not present on the agents.



Notice 2: As mentioned in the begging of this document, we are proposing this extension in the context of a Model-driven approach which will consider MAS-ML as architectural models. MAS-ML presents more two nodes to represent object and object roles, these will be represented in iStar by Actors and roles without the need to include new stereotypes. The iStar default nodes and links just are used in MDD approach to representing objects and roles in works as *Melo, J., Brito, A., SA FILHO, C., Junior, J., Alencar, F. Formalização de Regras de Mapeamento de i* para Diagrama de Classe em UML. Simpósio Brasileiro de Engenharia de Software 2015.*

Section 4.1 presents an example of the usage of this iStar extension to model a Multi-agent system to moodle.

3.4 Check completeness, consistency and conflicts

This section presents the analysis about the completeness (i.e. analysis about the levels that the extension was defined: conceptualisation, abstract syntax and concrete syntax), Consistency, i.e. the analysis about if each one of these new concepts were represented in these three levels and conflicts, i.e. analysis about the occurrence of conflicts with other constructs of the existing iStar extensions.

Completeness

Which level the iStar extension was applied

[X] Concepts definition [X] Metamodel [X] Well-formedness rules (optional) [X] Concrete syntax

Consistency

List following the concepts in each level

Concept	Concept's definition	Metamodel	Concrete syntax
Simple reflex agent	[X]	[X]	[X]

Model-based reflex agents	[X]	[X]	[X]
Goal-based agents	[X]	[X]	[X]
Utility-based agents	[X]	[X]	[X]
Simple reflex agent role	[X]	[X]	[X]
Model-based reflex agent role	[X]	[X]	[X]
Goal-based agent role	[X]	[X]	[X]
Utility-based agent role	[X]	[X]	[X]
Goal	[X]	[X]	[X]
Belief	[X]	[X]	[X]
Perception	[X]	[X]	[X]
Planning	[X]	[X]	[X]
Plan	[X]	[X]	[X]
Next function	[X]	[X]	[X]
Formulate goal function	[X]	[X]	[X]
Formulate problem function	[X]	[X]	[X]
Utility function	[X]	[X]	[X]
Action	[X]	[X]	[X]
Organisation	[X]	[X]	[X]
Environment	[X]	[X]	[X]
Ownership	[X]	[X]	[X]
Inhabit	[X]	[X]	[X]
Play	[X]	[X]	[X]
Cause-effect	[X]	[X]	[X]

Presence of nodes and links of iStar default syntax		
Construct	Metamodel	Concrete syntax
Goal	[X]	[X]
Quality	[X]	[X]
Resource	[X]	[X]
Task	[X]	[X]
Actor	[X]	[X]
Agent	[X]	[X]
Role	[X]	[X]

Refinement		[X]	[X]
Qualification		[X]	[X]
Contribution (make, help, break, hurt)		[X]	[X]
NeededBy		[X]	[X]
Dependency		[X]	[X]
Association links	is-a	[X]	[X]
	Participates-in	[X]	[X]

Conflicts				
List the concepts and verify the occurrence of conflicts between the constructs of the extension and the existing extensions.				
Concept	Conflicts			
	One construct with two or more Symbols	Two of more constructs with only one Symbol	Wrong representation of iStar constructs	Construct which is not part of the extension
Simple reflex agent	[0]	[0]	[0]	[0]
Model-based reflex agents	[0]	[0]	[0]	[0]
Goal-based agent	[0]	[0]	[0]	[0]
Utility-based agent	[0]	[0]	[0]	[0]
Simple reflex agent role	[0]	[0]	[0]	[0]
Model-based reflex agent role	[0]	[0]	[0]	[0]
Goal-based agent role	[0]	[0]	[0]	[0]
Utility-based agent role	[0]	[0]	[0]	[0]
Belief	[0]	[0]	[0]	[0]
Perception	[0]	[0]	[0]	[0]
Planning	[0]	[0]	[0]	[0]
Plan	[0]	[0]	[0]	[0]
Next	[0]	[0]	[0]	[0]

function				
Formulate goal function	[0]	[0]	[0]	[0]
Formulate problem function	[0]	[0]	[0]	[0]
Utility function	[0]	[0]	[0]	[0]
Action	[0]	[0]	[0]	[0]
Organisation	[0]	[0]	[0]	[0]
Environment	[0]	[0]	[0]	[0]
Ownership	[0]	[0]	[0]	[0]
Inhabit	[0]	[0]	[0]	[0]
Cause-effect	[0]	[0]	[0]	[0]
Details about the problem(s): Problems were not identified.				

3.5 Apply the extension to a modelling tool

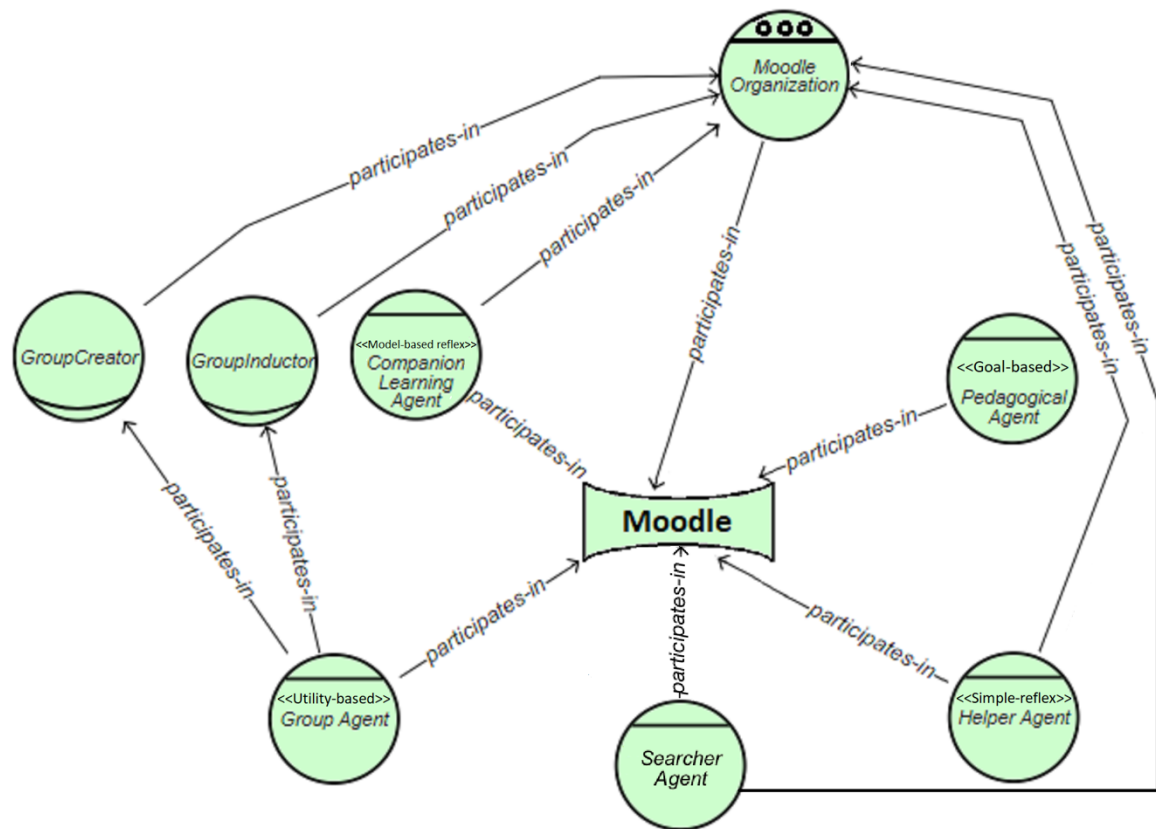
We created a modelling tool for the extension using Metaedit+. The tool was tested, and we did not find corrections to be made. The tool is available to download at <https://github.com/enyogoncalves/istarextensionrationalagents/tool>.

4 Evaluate and validate iStar extension

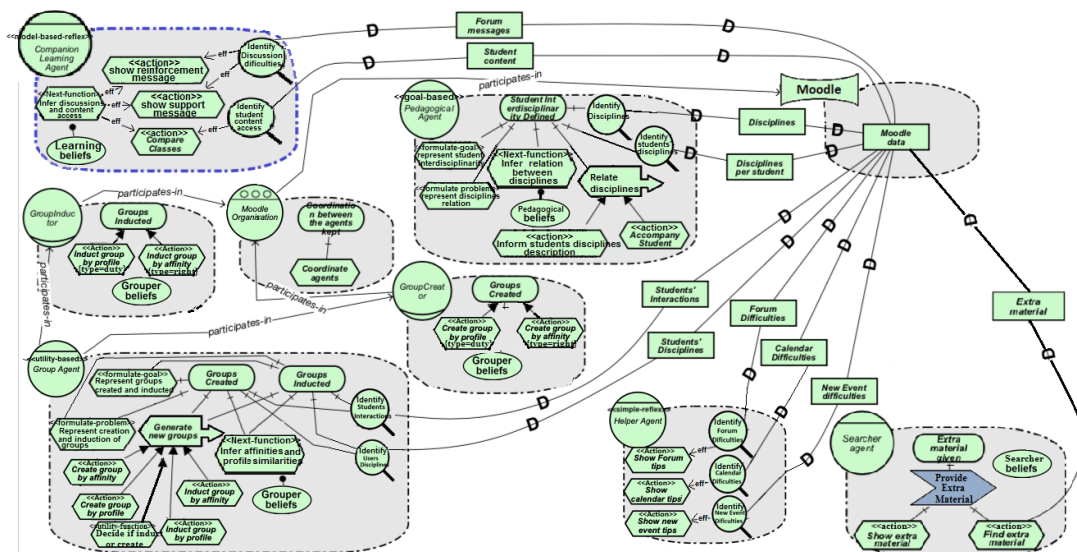
4.1 Use the iStar extension proposed to model a system

We modelled the MAS to MOODLE presented in Section 1.4 with our extension proposed here.

Initially, the requirements engineer should model the SD-extended diagram with the representation of the kind of agents with the specific stereotype. Their roles should be represented following. The organisation and the environment should be represented following. Finally, the participates-in link should be used to represent the roles played by the agents and the environment that they inhabit. The participates-in is also used to represent the ownership of the agents by their organisations. The SD diagram to MOODLE MAS represents the MOODLE as the environment where the agents can perceive and act. We modelled one organisation to coordinate the agents' behaviours. Finally, the diagram represents four agents and two roles performed by two of them. The figure below shows the SD diagram to MOODLE MAS.



The SR diagram shows the internal elements of the agents. The set of related elements depends on the kind of agent. The possible combinations are defined by the rules presented in Section 3.2. The perceptions of the agents are related to the environment by a dependency relationship.



4.2 Evaluate the iStar extension

In this sub-section we presented the results of the sub-process 4-Evaluate and validate iStar extension.

1.1.1 Use the iStar Extension Proposed to Model a System (Task 4.1)

We modelled the MAS to MOODLE with our extension proposed here. Initially, the requirements engineer should model the SD-extended diagram with the representation of the kind of agents with the specific stereotype. Their roles should be represented and also the organisation and environment. Finally, the participates-in link should be used to represent the roles played by the agents and the environment that they inhabit. The participates-in is also used to represent the ownership of the agents by their organisations. The SD diagram to MOODLE MAS represents the MOODLE as the environment where the agents can perceive and act. We modelled one organisation to coordinate the agents' behaviours. Finally, the diagram represents four agents and two roles performed by two of them. Figure 4.1 shows the SD diagram to MOODLE MAS.

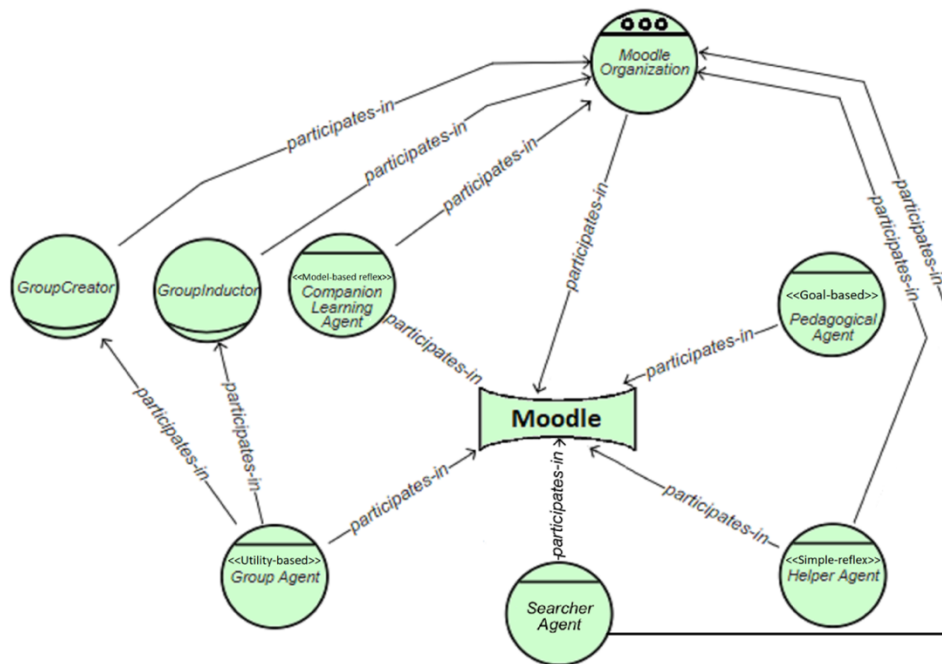


Figure 4.1: Modelling of iStar SD model to MOODLE using the new iStar.

The SR diagram shows the internal elements of the agents. The set of related elements depends on the kind of agent. The possible combinations are defined by the rules presented. The perceptions of the agents are related to the environment by a dependency relationship. Figure 4.2 shows the SR diagram to MOODLE MAS.

Additionally, the MAS presented in these models were designed at architectural level, coded, tested and implanted in two courses in distance education. The first one is the courses of Universidade Aberta do Brasil, a federal university that offers courses in distance education, in association with Universidade Estadual do Ceará (<http://www.uece.br/sate/>) and the second one is the distance education in software development to people with disabilities (<http://projetoled.com.br>). It shows that this iStar extension is valid to be included during the development of MAS.

It was not necessary to perform the tasks 4.2, 4.3 and 4.4. Task 4.5 was performed and it is presented in next sub-section.

1.1.2 Evaluate the iStar Extension (Task 4.5)

[Objective] The purpose of this evaluation is to identify the point of view of the researchers in multi-agent systems extensions about this extension. It will contribute to improving the extension.

[Study Design] We used a study based on a survey with multiple-choice and open questions to analyse the opinion of the researchers in multi-agent systems about this extension. We followed the steps suggested by Kitchenham and Pfleeger (2002).

[Population] The universe of this research (population) consists of researchers of multi-agent systems from Brazil. We considered the authors of papers of Brazilian events as WESAAC, AUTOSOFT, BRACIS and CBSOFT.

[Sample of Participants] We selected authors of the last 5 editions of these events. Thus, we contacted 164 researchers from 37 different universities/companies.

We received a total of 22 responses from 13 universities and 3 companies. Their profile is summarised as follows: Regarding the degree, four (4) are PhDs, nine (9) are PhD students, five (5) masters, three (3) master students and one (1) bachelor.

Regarding current work/research position, Eleven (11) are professors, one (1) is post-doc student, three (3) are system analysts/software architects, six (6) are PhD students, one (1) is developer and master student and one (1) master student. Regarding to the expertise level in MAS, Nine (9) mentioned to be advanced knowledge about multi-agent systems, nine (9) mentioned to be an intermediate knowledge and four (4) emerging. Figure 4.3 synthetizes the level of experience in MAS of the participants.

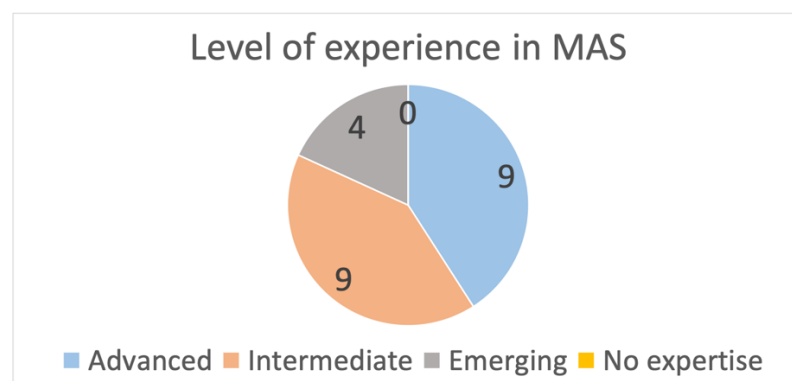


Figure 4.3: Level of experience in MAS of the iStar4rational agents' evaluation participants.

Regarding to the kind of expertise with MAS (the participants could choose more than one option), five (5) created textual requirements, six (6) modelled requirements (using iStar, Kaos, TROPOS or others), twelve (12) modelled the architecture (using MAS-ML, AML, ANOTE or others), twelve (12) studied an existing model, nineteen (19) coded MAS and eleven (11) tested MAS. Figure 4.4 presents the kind of expertise of the participants.

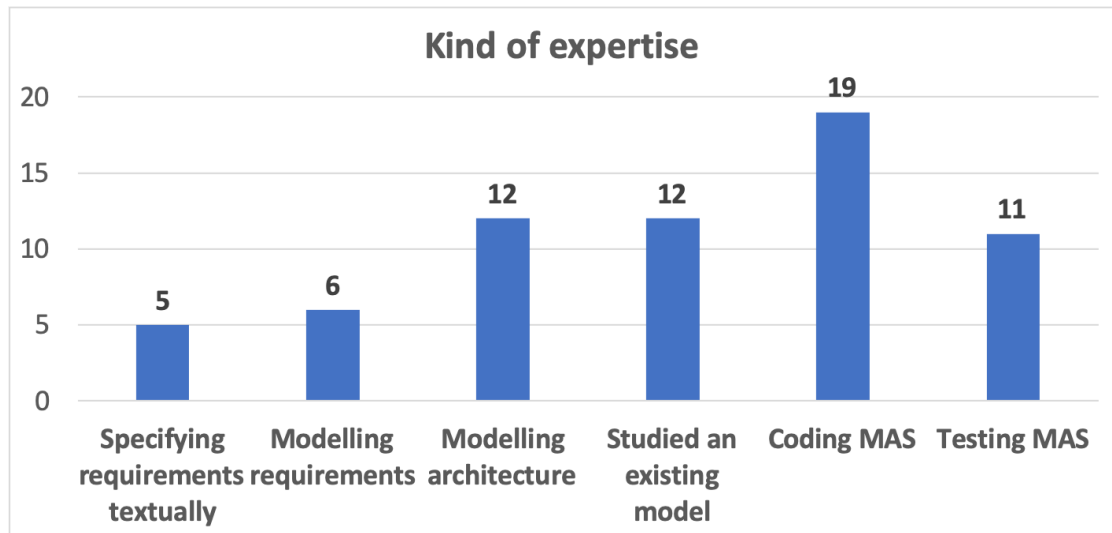


Figure 4.4: Expertise of the participants of the iStar4rational agents' evaluation.

[Collection Preparation] A survey was submitted with a set of multiple-choice questions and open questions. The complete structure of this survey is available at <https://www.cin.ufpe.br/~ler/iStar4rationalagents/evaluationsurvey>.

Initially, we analysed the profile, background and demographics. The initial form required the following fields:

- Email, Degree (PhD, PhD student, MSc, MSc student, BSc, Current Work/Research Position (Students fill in with "student")),
- Current work/research institution,
- How experienced are you with multi-agent systems? (Advanced, Intermediate, Emerging, No expertise),
- Which kind of experience do you have with Multi-agent systems? (Creating textual requirements specification, Modelling requirements (using iStar, Kaos, TROPOS or others), Modelling the architecture (using MAS-ML, AML, ANOTE or others), Studying an existing model, Coding, Testing, Other).

The first section of the survey presents a conceptualisation about rational agents and iStar, shows the modelling of a MAS to TAC-SCM using iStar without the extension and asks some questions regarding to identify entities in the diagrams and about the difficulty level to identify these entities.

The following questions are related to this first part. Question 1.1 asks the participant to select the correct concept related to each entity/node. We selected one construct per kind of construct in the model, presented their names and asked to select the correct kind of concept that it represents. We used a multiple-choice grid to relate the values of the lines (Buyer agent, Production agent, Delivery agent, Manager agent, Seller agent, Buyer agent, TAC-SCM, TAC-SCM Main) with columns (Simple reflex agent, Model-based reflex agent, Goal-based agent, Utility-based agent, Default agent, Organisation, Environment, Agent role).

Question 1.2 asks to select the difficulty level to identify the entities/nodes (Scale from 1- Very easy to 10-Very hard).

Question 1.3. is related to select the correct concept related to each Internal element (Use the scroll bar to see all options). We used a multiple choice grid to relate the values of the lines (Offer Product (in Seller Agent), Identify Supplier Quotation (in Buyer Agent), Infer Business Similarities (in Manager Agent), Stock of parts and pcs (in Production Agent), Delivery Products (in Delivery Agent), Represent Demand (in Production Agent), Represent maximization (in Manager Agent), Estimate selling price (in Manager Agent), Produce Computers (in Production Agent), Offer Bid (in Buyer), Pay (in Buyer)) with columns (Action, belief, perception, plan, planning, next-function, formulate goal function, formulate problem function, utility function, duty, right).

In question 1.4, the participant should select the difficulty level to identify the agent's internal elements (Scale from 1-easy to 10-hard). Question 1.5 asks about the participant's opinion about the representation of Multi-Agent Systems with rational agents using the original iStar syntax. The following options are presented: *It is expressive enough to represent this kind of systems and an extension is not necessary*, *It is not expressive enough to represent this kind of systems and an extension is necessary* or *I don't know*.

The second part of the survey presents the extension (According to the previous sections of this chapter), shows the modelling of a MAS to MOODLE using the iStar extension and asks some questions regarding identifying entities in the diagrams and about the difficulty level to identify these entities (questions similar to the first part). We highlight that the systems modelled in these two parts have similar complexity and number of nodes and links. Finally, the third and last part asks the opinion of the participants about the strongest and weakest points, need to propose the extension, existence of problems in the extension, the usefulness, the opinion about the representation of the introduced concepts, difficulty to understand, the feasibility and intention in use and finally if it is useful for the iStar community and if it will be recommended to other researchers.

The survey was validated by two experts in iStar extensions (one of them has experience with multi-agent systems). We tested the survey with a computer science professor from Universidade Federal do Ceará with experience in multi-agent systems. The pilot data were not used during the analysis. [Data Collection] Survey was written in English and submitted by the google forms between December 2018 and February 2019. [Data Analysis] we represented the results of the survey's questions by graphics and table which present an analysis in descriptive statistics. Data of this survey is available at www.cin.ufpe.br/~ler/iStar4rationalagents/data.

4.2.1 Results and Discussion

In this section, we describe the results of the survey. We could not compare the data of our results and data of similar studies because this is the first study to evaluate this extension. We start

our analysis comparing the perception of the participants about the modelling of the MAS using iStar and the iStar extension.

The results of the identification of MAS entities point to the following percentage of correct responses **without** the extension (first part): Simple reflex agent – 27.3% (6/22), Model-based reflex agent – 50% (11/22), Goal-based agent – 59% (13/22), Utility-based agent – 68.1% (15/22), MAS-ML default agent – 9% (2/22), Agent role – 63.6% (14/22), Environment – 63.6% (14/22) and Organisation – 36.4% (8/22).

The results of the identification of MAS entities point to the following percentage of correct responses **with** the iStar extension (third part): Simple reflex agent – 77.3% (17/22), Model-based reflex agent – 72.7% (16/22), Goal-based agent – 90% (20/22), Utility-based agent – 72.7% (16/22), MAS-ML default agent – 72.7% (16/22), Agent role – 68.2% (15/22), Environment – 90.9% (20/22), Organisation – 95.4% (21/22).

The comparison between the two representations of MAS entities is summarised in the Figure 4.5. It is possible identify that all representations with the extension had a higher number of right responses than the representations without the extension.



Figure 4.5: Comparison between the two representations of MAS entities (with and without the extension).

We also analysed the internal elements of the agents. The results of the identification of MAS internal elements point to the following percentage of correct responses **without** the extension (first part): Action – 54.5% (12/22), Belief – 27.3% (6/22), Perception – 31.8% (7/22), Next function – 27.3% (6/22), Formulate goal function – 18.2% (4/22), Formulate problem function – 0 % (0/22), Utility function – 9.1% (2/22), Plan – 22.7% (5/22), Planning – 18.2% (4/22), Duty – 9.1% (2/22), Right – 9.1% (2/22).

The results of the identification of MAS internal elements point to the following percentage of correct responses **with** the extension (third part): (third part): Action – 90.9% (20/22), Belief – 72.3% (17/22), Perception – 72.7% (16/22), Next function – 63.6% (14/22), Formulate goal function –

63.6% (14/22), Formulate problem function – 59.1% (13/22), Utility function – 59.1% (13/22), Plan – 68.2% (15/22), Planning – 59.1% (13/22), Duty – 40.9% (9/22), Right – 27.3% (6/22).

The comparison between the two representations of MAS internal elements is summarised in Figure 4.6. It is possible identify that all representations with the extension had a bigger number of right responses than the representations without the extension.

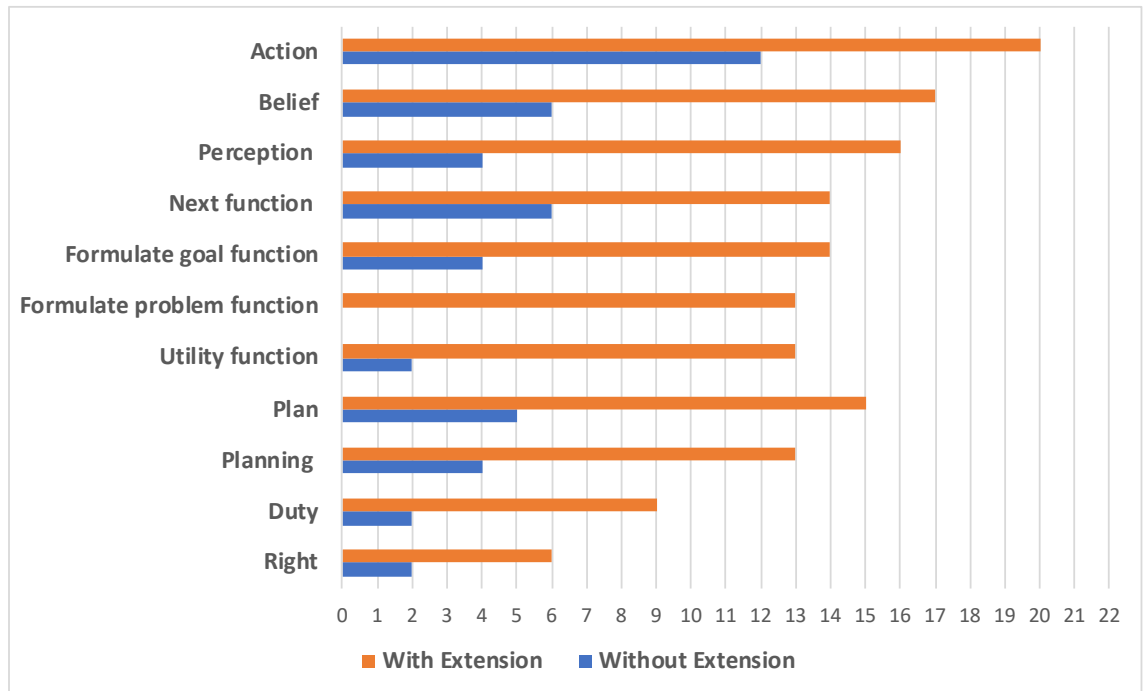


Figure 4.6: Comparison between the two representations of MAS internal elements (with and without the extension).

The extension improved the perception of the MAS constructs introduced by the extension. Table 4.1 shows the general results about the correct identification of the entities to iStar without extension and with extension.

Table 4.1: Comparison of correct identification.

Criteria	iStar without extension	iStar extension
1. Correct identification of MAS entities (Agents, agent role, environment and organisation)	47.12%	80.1%
2. Correct identification of MAS internal nodes and links (plan, planning, action, belief, next-function...)	20.7%	62%

We also analysed the difficult level perceived by the participants to identify the MAS entities and internal nodes and links. The extension reduced the difficult level to identify the MAS entities and internal nodes and links in about 50%. Table 4.2 shows the results of the difficult level without extension and with extension.

Table 4.2: Comparative of the difficult level.

Criteria	iStar without extension	iStar extension
1. Difficulty level to identify MAS entities (mean – scale 0-10)	6.3	2.9
2. Difficulty level to identify MAS internal nodes and links (mean – scale 0-10)	7.5	3.8

The last question of the first part of the survey was about the opinion about the representation of the rational agents with the iStar default syntax (without the extension). 72.8% (16/22) of the participants informed that *It is not expressive enough to represent this kind of systems and an extension is necessary* and 13.6% (3/22) considers *It is expressive enough to represent this kind of systems and an extension is not necessary* and 13.6% (3/22) answered *don't know*.

The second part consists of the presentation of the extension. Consequently, there are no responses in this part.

The third part is composed of three initial open questions to inform the strong points and weaknesses, improvements and identification of problems. They recognised that the extension facilitates the identification of MAS entities and their internal elements, this is a common strong point mentioned by 13/22 participants. The weakness mentioned by two participants is that with the extension, new concepts are represented in iStar and there is the need to learn and represent these elements in the models. We believe that it is not something related to this extension, but it is a general consequence of all extensions. One participant questioned us about the representation of the protocol of communication between different MAS. We understand that it is part of the representation of a MAS, but this representation is considered only in the architectural level in our approach. The participants did not identify any problem in the extension.

The extension received a good evaluation of the experts that participated in the survey. Table 4.3 shows the results for the questions 3.4 – 3.6, 3.8, 3.10 and 3.11. Median, mode and number of responses received for each option (Strongly Agree, Agree, Don't Know, Disagree and Strongly Disagree) were presented for each question.

Table 4.3: Results of the validation survey – Questions 1-8, 10, 13 and 15-17.

Questions	Median	Mode	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree
3.4. There is a lack of an iStar extension to model rational agents.	3	Agree	5			0	1
3.5. The proposal of an iStar extension to model rational agents is useful.	3	Agree	0	1	0	0	0
3.6. The representations of the new constructs are suitable.	3	Agree	7	5		0	0
3.8. The use of this extension is feasible for model Multi-Agent Systems with rational	3	Agree	8	3		0	0

agents.							
3.10. The Multi-Agent Systems community can benefit from the usage of this extension in the modelling of their next systems.	gree	/	ee	Agr	7	3	0
M	gree	/	ee	Agr	5	3	0

The participants answered about how suitable the proposed extension is to be used to model the next MAS, the results point five (5) participants consider *Very Suitable*, sixteen (16) consider *Suitable* and one (1) *Don't know*. Also, the difficulty level to understand this extension (question 3.7) was mentioned by the participants: two (2) *very easy*, twelve (12) *easy*, six (6) *medium*, two (2) *hard* and none answer very hard. Finally, 86.4% (20/22) of the participants mentioned the intention to recommend this iStar extension to other researchers (question 3.12), 13.6% (3/22) of the participants mentioned maybe to recommend it and none answer.

4.2.2 Threats to validity

According to Kitchenham and Pfleeger (2002), there are four aspects that we need to consider: Criterion Validity, Construct Validity, Face Validity and Content Validity.

The Criterion Validity is a measure of how well an instrument compares with another predecessor instrument. Construct Validity is the observation of how an instrument “behaves” when in use. It can be convergent or divergent. Face Validity is a superficial analysis of items by naive people, to test their understanding of it. Finally, Content Validity is an assessment of how appropriate the instrument looks to part of the participants. In this section, we presented threats to the validity of the survey.

Criterion validity. We did not find a previous qualitative study for this purpose. Thus, we could not compare this evaluation with other previous.

Construct validity. We created the survey with different kind of questions: Likert Scale questions (3.4 – 3.11), Measure effort or contribution questions (1.2 and 2.2), Yes/no/maybe question (3.12), Open questions (3.1, 3.2 and 3.3), Specific options (1.5) and multiple-choice relation questions to analyse the understanding of the models (1.1, 1.3, 2.1, 2.3). Thus, it could make the execution confuse. We mitigated this threat to construct validity presenting an explanation of the kind of questions at the beginning of the survey to clarify the structure of the survey to the participants. Furthermore, there are invited participants whose first language is English. Consequently, we created the questions of the survey in English. It could cause misunderstandings of the other participants whose first language is Portuguese. However, we did not receive any comment about these threats to construct validity during the pilot or the execution.

Face validity. We tested the survey with a computer science professor of the Universidade Federal do Ceará with experience in Multi-agent systems. We can consider this previous evaluation a limitation because of the small number of participants (1 participant). We mitigated this threat, however, by asking him to evaluate again after the corrections of their comments.

Content validity. We performed the pilot involving one researcher. It was done to test the understanding of the participant in the survey. We analysed the feedback sent by the participant of the pilot and applied the suggested improvements in the survey.

During the application of the survey, we received some comments from two participants. We tried to mitigate these threats to Content Validity with the participation of two experts in iStar extensions in the development of this research, which validated the survey before the submission to the participants.

We consider the profile of the participants suitable for this evaluation since a great part of the participants (18/22) mentioned have advanced/intermediate expertise in multiagent systems and there was none answer indicating do not know MAS. However, the answers about the kind of knowledge in MAS point to the creation of textual requirements/ model requirements were mentioned by eleven (11) participants and twelve (12) mentioned that had studied models. Thus, there was no high number of participants with expertise in modelling (about half part); it can be a threat to content validity. We tried to mitigate this threat presenting iStar in part of the survey.

Conclusion validity. In this survey, we did not have a large number of participants. We could not then make statistical inferences or to reveal a true pattern in the data. Furthermore, we restricted the responses to the Brazilian community. These threats to the conclusion validity can be mitigated by invitation of researchers from other countries as a next step.

We did not identify new constructs to be introduced (Task 5-Main process). Therefore, the last sub-process was performed (Sub-process 6 - Publicise the iStar extension).

5 Publicise the iStar extension

The iStar extension was publicised in the catalogue of iStar extensions and published in the International Conference on Conceptual Modeling 2019.