Modeling and Simulating Organisations

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Abstract. The paper provides a survey comprising meaningful organisational approaches to Multi-Agent-Systems (MAS) that exist in the computational theory field. The organisational concepts are collected and represented as a metamodel of some commonly agreed organisational ontology of human systems. Next, this metamodel - a proposal for the extension of the Agent-Object-Relationship (AOR) simulation language with organisational constructs - will be analysed and improved by taking into consideration the organisational approaches originating from the fields of social sciences. Our account is exemplified by a case study where we model an academic environment with the help of the organisation-oriented concepts defined by the AOR simulation language.

Key words: multi-agent systems, human societies, organisations, organisational roles, social context, normative constraints, norms, computational theory, sociology, social philosophy, AOR simulation language

1 Introduction

In the actual literature different views on how organisations are considered coexist. We review in this article some meaningful works which, to the best of our knowledge, treat issues related to the organisational structural aspects and, in this context, they give rise to some fundamental questions: (1) how is it defined the organisation concept? (2) how does the organisation construct its positions and roles? (3) can one consider the organisations as simple aggregations of roles? (as AI approaches usually do) (4) how do we assign agents to specific roles?

We noticed that approaches which come from the Artificial Intelligence (AI) field (computational organisation methodologies) tend to construct role-oriented architecture of organisations ([2], [4], [6, AGR defines organisation as "a framework for activity and interaction through the definition of groups, role and their relationships"], [11], [22, Gaia defines organisation as "a collection of roles that stand in certain relationships to one another, and that take part in systematic institutionalised patterns of interactions with other roles"], [23], [24]). Often, in these approaches the organisational concepts are not considered to form a distinct set of social constructs and are not treated satisfactory: the social

concepts exist only at the abstract, metamodel level and the target implementation tools/languages (e.g. MadKit, RePast/Java, C++) need to perform a semantic mapping of the concepts (see [6, AGR defines organisation as "a structural relationship between a collection of agents"]). Although we noticed that in the AI field it is quite a general agreement that organisational approaches to MAS should come as an agent-independent, upper layer on the MAS's architecture, there are distinct approaches concerning how these organisational concepts should be named, structured and aggregated, what are their properties and relationships and how they succeed to naturally model and represent organisations. Altogether, if we want to extract the core concepts for an organisational ontology, then we should take into account the semantics of the constructs and not the etymology, which can be sometimes peculiar.

When we shift our attention to the organisation-oriented works influenced by or belonging to the social science fields, we noticed a more mature representation of the organisational structure enhanced with complex normative aspects [1], [7], [8], [9], [10], [15], [16], [19]. In these works the organisational structures can be viewed as means to manage complex dynamics in (human) societies. More organisational features are considered: (1) the fact that the organisation, as a social institution or institutional agent [20], can be represented as a composite entity comprising individuals (human agents [14]) and its sub-divisions [8, UFO-"mixin type"] or [13, EO-"organisational unit type"]; (2) the fact that the organisation model must comprise the environment which may contain many organisations and the relationships among them [1], [9]; (3) organisational structure is entirely based on normative constraints [10] or contrary (4) the fact that organisations do not comprise the individuals (which are part from the environment) and are not ruled by any kind of norms [9]. In general, organisational ontologies such as: DOLCE[1] and EO[13] or foundational ontologies such as UFO ([7] and [8]) try to provide means for a formal analyse of organisation-oriented modeling and simulation frameworks [14], by determining inappropriate elements of the organisational language under consideration, or by recommending appropriate improvements.

The purpose of this paper is to contribute to the understanding of the essential meanings behind the theories of organisation-modeling that co-exist in the literature. Moreover, taking into account the organisational concepts originating from the social sciences, mainly the *UFO ontology* we aim to develop a metamodel which enhances the AOR simulation language with an organisational structure. For the sake of a common understanding of the concepts, a high-level modelling using UML[1] class diagrams is used to represent the concepts behind the organisation structure of each of the approaches taken into consideration in our review. Even it can not provide an executable model, UML is used to define a rigorous and precise specification to which any language must conform. We use UML models to describe the abstract syntax of the AOR simulation language, and further to provide a common understanding of the concepts used to extend the AOR simulation language with organisational constructs.

[1] Unified Modeling Language (UML) - `http://www.uml.org/`

The remainder of the paper is organised as follows: Section 2 provides a review on the computational organisation methodologies from the AI field and concludes with a metamodel which subsumes the common concepts which target the organisational structure. Section 3 discusses some meaningful works from the social sciences area and underlines the adjustments or enhancements they add to the understanding of the organisational concepts. Based on the conclusions we draw from the Section 3 we extend in Section 4 the AOR simulation language with organisational constructs. The last Section discusses conclusions and future works.

2 Computational Organisation Methodologies - Modeling and Simulation Approaches

The aim of this Section is to identify the main concepts that are used to build organisational-oriented approaches in the computational organisation theory. The organisational-oriented works presented here are mainly methodologies, expressed by metamodels, that do not commit themselves to specific techniques for modelling organisational concepts. Usually, their outcome represents a technology-neutral specification, a methodology that should be further implemented using an appropriate programming language.

Ferber and Gutknecht [5] introduce the *Aalaadin* organisation-oriented metamodel of a MAS back in the '98. [6] reuses the same model and tries to offer a more rigorous explanation of the abstract concepts introduced by the Agent-Group-Role (AGR), formal Aalaadin, methodology. Although minimal and simple, the AGR metamodel gathers the basic concepts and their relationships that should represent the ground of any organisational oriented approach: *agent*, *role*, *group*, organisation represented as instances of their abstract types agent class, role type, group type and organisation type. Instead of using the *type* concept whose meaning is by now well know in the software engineering area (e.g. UML) the authors define and use the term *structure* e.g. group structure. The fundamental distinction between individuals and their types is important in any modeling approach and should be always considered. The organisational concepts defined in the Aalaadin metamodel form only an abstract terminological layer which lays on top of concrete concepts that MAS implementations may adopt for representing social systems (e.g. MadKit). The authors also give two distinct definitions for the *organisation* concept. First definition involves the abstract concepts used to describe an organisation i.e. [5, a framework for activity and interaction through the definition of groups, roles and their relationships]. The second definition of what an organisation is, describes the concrete implementation of an organisation-oriented framework based on the Aalaadin metamodel i.e. [5, a structural relationship between a collection of agents]. The meaning of the second definition suggests that the agents and their types are in fact the basic, key constructs inside of an organisation.

The agents perform different functions which are considered to be the roles that agents play inside of the organisation. Moreover, another important aspect

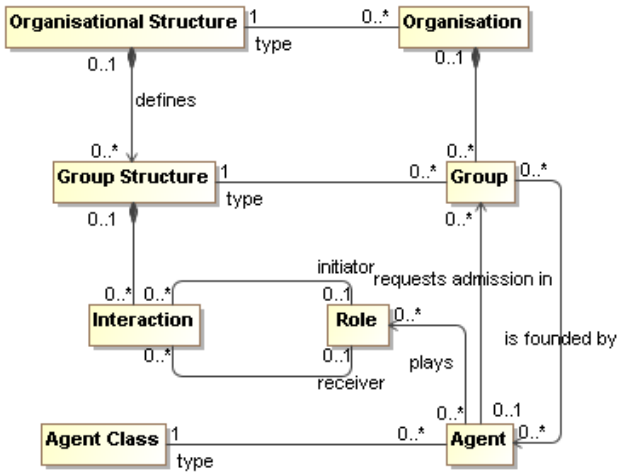

Fig. 1. AGR - Organisational structure.

mentioned in the article refers to the agent's capabilities of satisfying certain constraints in order to be able to play the roles.

The group construct is poorly defined as an atomic set of agent aggregation. The group can be founded by any agent. The agents must request admission into an existing group of agents. It is not clear enough how the admission or the rejection of the agents willing to join certain group is performed.

The Gaia methodology introduced in [22] and [23] by Wooldridge et al. focuses on describing organisations by means of roles and the interactions among roles. The definition that authors give to the *organisation* concept describes their approach: [23, a collection of roles that stand in certain relationships to one another, and that take part in systematic institutionalised patterns of interactions with other roles]. Gaia takes into consideration the normative aspect of roles inside of an organisation and tries to construct a norm ontology associated to the role concept and which consists of four attributes: *responsibilities*, *permissions*, *activities* and *protocols*. Responsibilities are of two types: liveness properties - the role has to add something good to keep the system in good functions, and safety properties - the role has to prevent and disallow that something bad happens to the system. Permissions represents what the role is allowed to do, in particular, which information it is allowed to be accessed.

Activities are *tasks* (this is a common terminology in AI) that a role performs without interacting with other roles. Protocols are defined as specific patterns of interaction between two roles. One single pattern of interaction is defined to comprise many messages exchanges between the same agents. However, in Gaia methodology, the normative concepts such as: permissions, rights and responsibilities are not receiving a clear and formal semantics. Also, Gaia proves to be unsuitable for modeling open systems because it assumes a static organisational structure, a prior known at the design phase, and a static set of role interactions.

The role concepts are mapped into agent types concepts at the implementation level and often there is a one-to-one mapping procedure.

Gaia v.2 [24] and also Soda [11] are focused on describing the environment as a first-order abstraction in the organisational methodology. The idea that the organisation and its constitutive roles should be situated and immersed in the normative context is followed also by other organisational approaches from AI, but originates from the area of social sciences. We have included Brain [2] methodol-

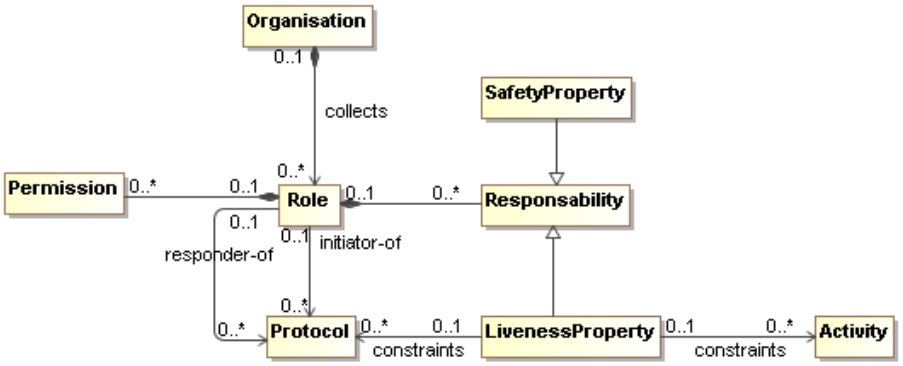

Fig. 2. Gaia - Organisational structure.

ogy in our survey not because of its importance towards the organisation-oriented features it employs. Brain (Behavioral Roles for Agent INteraction) is not an organisational-oriented methodology, but rather a role-based interaction model based on a XML notation. It describes the reactive and proactive behaviour of the agents that play roles in terms of events, consequences of role actions delivered to other roles. Therefore, the role is viewed as a set of *capabilities* and *expected behaviour*. The terminology employed by Cabrio et al. refers mainly to the set of actions or rights the agent is allowed to perform (the agent's capabilities) and respectively, to the set of duties or events the agent is obliged to react (the agent's behaviour).

There are some important characteristics of roles that Brain methodology underlines: (1) roles are temporary, (2) roles are generic and (3) roles are related to contexts, meaning that contexts can impose their own rules and can grant some local capabilities forcing agents to assume certain roles. As an consequence, the environment can be seen as a set of contexts. The agents themselves can interact among them or with the environment. Another characteristic of Brain that catch our attention is the concept of *role descriptors*, which are considered to be the semantic representations of the roles. The claim is that the role descriptors allow agents to choose the roles they have to play by their meaning.

OperA (Organisations per Agents) methodology [4] describes the structure of the organisation in its *organisation model* as consisting from a *social structure* which defines the *roles* played by the agents, the *groups* which aggregate

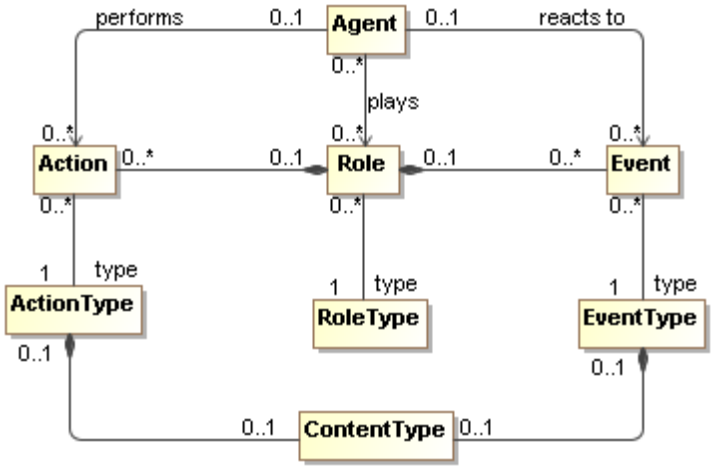

Fig. 3. Brain - Organisational structure.

roles and the *dependency* relationships between roles. The *dependency* relationships between roles imply a hierarchic structure of the roles governed by some *power relationships* e.g. *dependerRole* and *dependeeRole*. The roles have associated goals or *objectives* which, based on the hierarchic structure of the roles, can be organised in sub-objectives and further distributed to the *dependeeRole*(s). The normative layer is also comprised in the *organisation model* as a *normative structure* which defines the norms. The norms are associated with the roles and to the groups of roles. The *organisation structure* defines also the *interaction structure* which represents the interaction layer of the organisation comprising the existing relationships of the social entities inside of the organisation. In OperA, the roles are assumed and played by the agents based on some *social contract* which stipulates the contractual *clauses* between the *agent* and the presumed *role*. The *social contract*(s) are aggregated by the *social model* which, at its turn, is determined by the *organisation model*. To the OperA methodology is offered an implementation platform: Brahms [3]. Developed by NASA, Brahms (Business Redesigned Agent-based Holistic Modeling System) is defined in [17] as an environment which includes an agent-oriented language, compiler and virtual machine, as well as a development environment and a post-execution viewer of agent execution, communication and interaction.

Initially, Brahms was defined as a business process modeling and simulation tool for systems which deal with work practice (how people actually behave within a physical and social environment), meaning that it targets the social science area. Brahms language is a declarative, BDI-oriented language which includes: facts, beliefs about facts, activities, workframes (production rules) and thoughtframes (inferences). A Brahms model is an agent model that defines the work activities of agents in a work process. Activities are [17, socially constructed engagements situated in the real world, which take time, effort and application

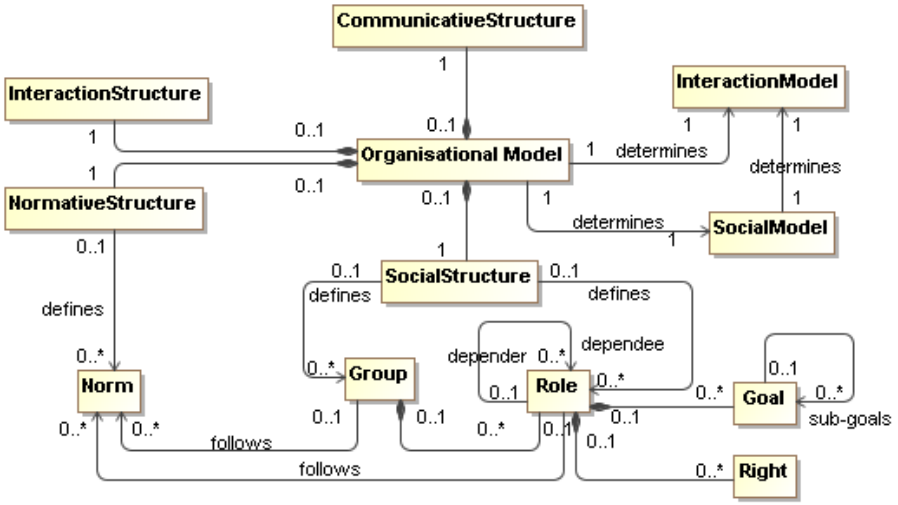

Fig. 4. OperA - Organisational structure.

of knowledge]. An *agent* in Brahms represents an individual assuming a role in the organization. Agents in Brahms are considered to be socially situated in the context of work, the organization, and its culture. Individuals are members of groups and inherit the behavior of the groups. Individuals can also have additional behavior that distinguishes them from other individuals, and they can be a member of multiple groups. Groups can be organised in a hierarchical way, to define behavior at different levels of abstraction. Sub-groups inherit the behavior of super-groups. A special kind of norms, called [17, cultural norms] are defined in Brahms as a consequence of the environment. The environment is considered to be able to [17, model and simulate work practices of human organisations]. The claim is sustain by the proposed integration (and mapping of the concepts pp. 8-9) of the OperA organisational methodology and the Brahms language which is used to implement the agents behavior [12].

Summary The Figure 5 displayed below comprises the main constructs identified by our survey on computational organisation theory literature. The computational organisation methodologies define the organisation structure at least as a set of aggregated roles ([4], [5], [6], [11], [22], [23], [24]) played by the agents. The organisation can further be divided into sub-organisations or groups ([4], [11], [5], [6], [22], [23], [24]). Roles and groups are created to accomplish certain goals on behalf of the organisation ([4], [11], [5], [6], [22], [23], [24]). Human agents apply for a position inside of the organisation which confer them a certain status and oblige them to assume and play certain roles aggregated by the position concept ([14], [18]). The organisation is also seen as a set of coordinated agents (which assume and play roles) in order to obtain (1) their own objectives;

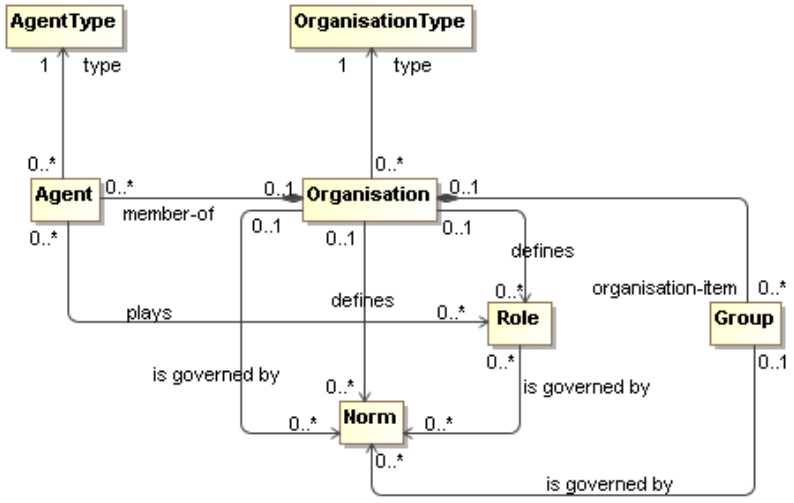

Fig. 5. Organisational structure - Core Concepts.

Concept	AGR	Gaia2	Brain	OperA	Brahms	Aris	Tropos
Organisation	x	x	–	x	–	x	–
Group	x	–	–	x	x	x	–
Position	–	–	–	–	–	–	x
Role	x	x	x	x	–	x	x
Human agents	–	–	–	x	x	x	x
Goal-oriented	–	x	–	x	x	x	x
Situated environment	–	x	–	x	x	x	x
Dynamic	–	x	x	x	x	x	x

(2) the objectives of the organisation ([2], [4], [5], [6], [11], [22], [23], [24]). The organisation is placed in the environment ([4], [11], [24]). The organisational concepts are dynamic: they may change over time ([2], [4], [11], [24]).

3 Ontological analysis of Organisations

This Section provides a review on organisational works which are influenced by social sciences approaches such as: social philosophy and sociology.

Similarly to our work, Bottazzi et al. try to provide in [1] an ontological analysis of the organisations, by taking into account also philosophical views from the literature. One important aspect is the assumption that when we talk about organisational concepts we talk in fact about a distinct category of objects which they all agreed to call them: *social objects* (see Searle [16], Bottazzi et al. [1] or [14]).

Another meaningful idea is that social objects are always considered to exist in some specific context, a normative context or a description often called

normative description), in which they comply with specific functions or roles, imposed by the context, that they cannot perform only in virtue of their physical characteristics. [1], [14] and [16] refer to the context of a social object as *social object description*: [16][Something is a social object only under certain descriptions (and not others)]. In this view, [1] defines organisations as *social entities*, (more concrete *social individuals*) which are created and sustained by human agents. Organisations can play roles (by delegating them to the human agents) and can define normative aspects (contexts or normative descriptions) connected with these roles.

The main characteristics of the roles are also underlined: (1) roles are relational in the sense that their definition may depend on the definition of other roles e.g. child-mother; (2) roles can inherit one another; and (3) roles are subject to a forced path: in order to get a certain position and play a certain role, the human agent must play a number of other roles in some particular order. Normative aspects of organisations are also taken into consideration by Bottazzi et al. Norms are considered to represent the context in which organisations and their roles are defined. Inspired by the works of Tuomela[19] and Searle[16] they provide an ontology of norm types: (1) constitutive norms; (2) deontic norms - they regulate the agents behaviour; and (3) technical norms. UFO's aim [Unified

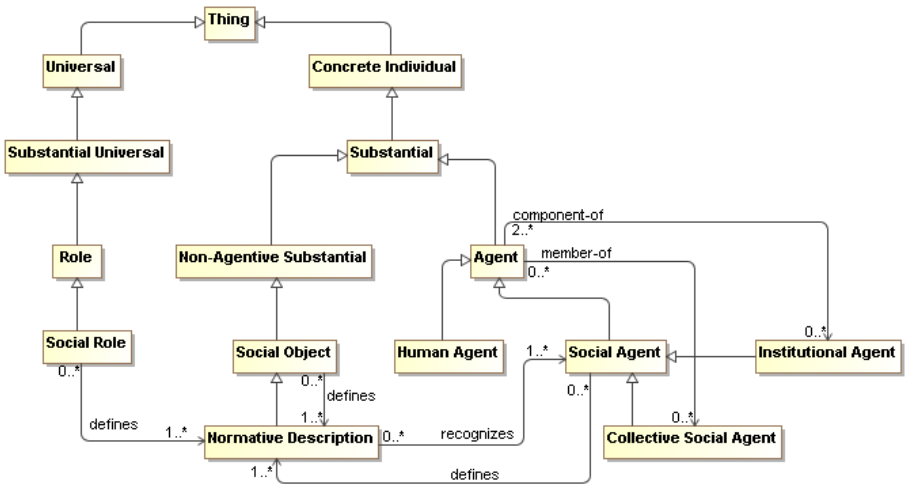

Fig. 6. Unified Foundational Ontology (UFO) - Organisational structure.

Foundational Ontology - ([7], [8])] is to provide a reference ontology that can be used to lay the ontological foundations for general conceptual modeling concepts. In general, besides providing a formal semantics to the concepts of some conceptual modeling language, the ontology provides means for the analyse and re-design of modeling and simulation languages. Above, (see Figure 6) we show a small excerpt from the UFO metamodel. The notations from UFO metamodel

that we will use them later in the paper, and some of them also in our works, are those of: social object, social role, normative description, human agent (individual person), social agent, institutional agent or organisation as specification of the social agent. They belong to the UFO-C (ontology of intensional, social and linguistic things).

When defining its social reality, Searle constructs the social concepts with the help of the mnemonic formula "x counts as y in c". The formula is in fact a constitutive rule which defines the social concepts as constitutive elements of some social form. The explanation Searle gives is the following: [16, I find the formula "x counts as y in c" immensely useful because it gives us a way of articulating the distinction between those functions where the function is performed in virtue of an intrinsic physical feature of the object, and those functions which are performed in virtue of collective recognition of a status.]

Based on this explanation we are capable to understand that individuals have the capacity to impose status functions (social roles) on objects and people; and the last ones cannot perform the functions just in virtue of their physical structure. The performance of the function requires that there is a collectively recognised status that the person or object has, and it is only in virtue of this status that they can perform the function in question. e.g. consider this small, rectangular piece of plastic (x) inside my pocket. The collectively accepted constitutive rule: *This piece of a small, rectangular piece of plastic (x) issued by the BTU Cottbus, containing my personal data in a machine-readable form, is a semester-ticket (y) used to obtain deduction on every means of transportation in the Brandenburg state (c)*, gives to the physical object (x = piece of plastic) a new status (y = semester ticket) and functions (transportation deductions) in the social context (c = Brandenburg state) .

We can equate Searle's *status functions* with the *agent positions* and the *social roles* that are defined in the context of the social form (c). The status functions are also the carriers of the normative constraints which regulate the behaviour of the social objects (y). Same as in [8], by assuming a position, an entity will be recognised as a social entity and further constrained by some normative descriptions which are defined by the organisation and recognised by all the other social entities inside of the organisation. One significant work concerning organisation structure and its normative behaviour is developed by Santos et al. in [14]. The Aris organisation modeling language is the subject of an ontological analysis based on UFO. UFO is a complex ontology used in [14] to provide the missing semantic foundation for organisational modeling elements in Aris (see Figure 7). Initially, Aris organisational constructs were defined taking into account the EO ontology[13]. The ontological analyses succeeded to determine inappropriate elements of the Aris organisational language and also to recommend improvements. It is important for our work to look closely to the identified elements which form the basic core of organisational structure. One main idea preserved from the works of Bottazzi et al. [1] is the concept of *normative description* which is used as a social description for all the social constructs. The social entities [14, are considered to exist for the agents that recognise these normative descriptions].

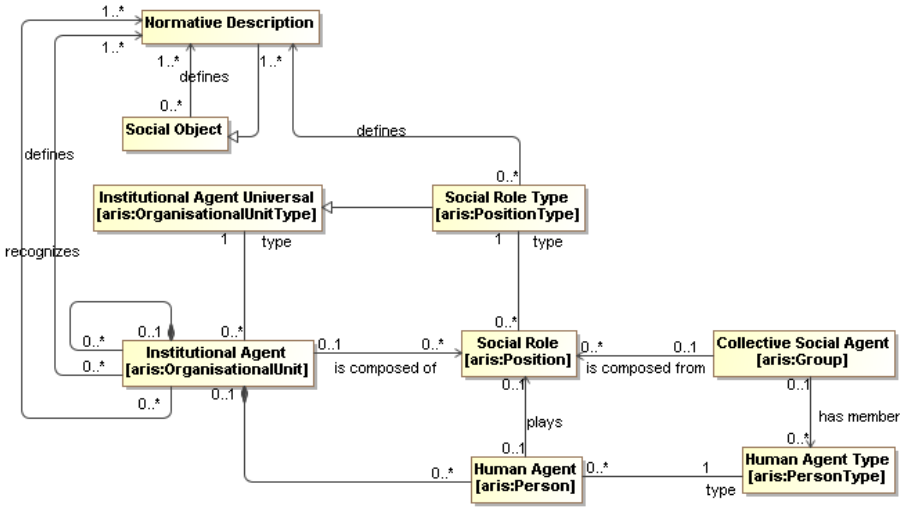

Fig. 7. Aris based on UFO - Organisational structure.

Another approach to the organisational structure, belonging to the sociology area, is represented by the Niklas Luhmann's system theory which relies on the following aspects: (1) the social systems are capable of communication; (2) the social systems are self-producing communications, i.e. a communication produces further communications and hence a social system can reproduce itself as long as there is dynamic communication (Luhmann's autopoiesis theory). The societal theory of Niklas Luhmann [9] considers two disjunctive concepts: the society and the environment. The society is considered to be determined by its boundaries between itself and other societies which form the environment. The environment is expected to be more complex and chaotic than the system. The distinction between the system and its environment reflects a relationship between the two of them: the system is always influenced by its environment or by other systems. One aspect of Luhmann's theory on societies is considering the human being as distinct part of the society. The human beings are part of the environment and they act like some sensors for the systems. Luhmann also defines the organisation construct, as being characterized by the fact that it formalises the behavioural expectations of their members.

Summary Based on the review of the research works inspired from social sciences such as social philosophy ([1], [7], [8], [14], [16]) and sociology [9] we draw the following conclusions regarding the core concepts the organisational structure must define:

- a distinct class of constructs is introduced in metamodel and consequently referred as the class of social concepts
- some entity is a social concept only under certain normative descriptions

- the organisation (institutional agent or organisational unit) is a social concept represented as a special type of agent
- the organisation defines the context descriptions which are normative and they regulate the other social concepts
- each social concept defines its description in order to be recognised in the organisation by the organisation itself and by all the other social concepts
- the organisation concept is a composite entity aggregating individuals (human agents) belonging to the organisation but also its sub-divisions (groups, organisation units)
- the organisation defines certain functions or positions which aggregate roles
- the normative descriptions, the agent positions and the agent roles are social concepts
- human agents perform certain roles within organisation by assuming positions defined by the organisation

Concept	EO	DOLCE	UFO	Searle	Luhmann
Organisation	x	x	x	x	x
Group	x	x	x	x	x
Position	x	x	–	x	x
Role	–	x	x	x	–
Human agents	x	x	x	x	x
Goal-oriented	x	x	x	x	–
Situated environment	x	x	x	x	x
Dynamic	x	x	x	x	x

4 Extending the AOR simulation language with Organisational Constructs

Our work is focused on defining social concepts which build an organisational structure on top of existing AOR simulation language. The social system (as referred in [19] or [16]) is etymologically defined as an *institutional agent* and represented in our metamodel by its corresponding UML class (see Figure 8) .

We consider the *institutional agent* to be defined as a complex unity formed of many, often heterogeneous, parts subject to a common plan or serving a common purpose (see goal-oriented organisations in the literature). We conceptually define the social institution as composed of individuals (*HumanAgent*(s)) which act on behalf of it and groups of individuals (*InstitutionalAgent*(s)) who interact and mutually influence each others behavior. Moreover, the organisation itself constitute a single entity (*InstitutionalAgent*), but in the same time can be considered as a bounded set of interrelated positions (*AgentPosition*) which aggregate role types (*AgentRole* instances) that together confer to the social institution its in-

ternal structure. We only briefly[2] take into account the normative dimension. In this sense, we define the *Norm* concept, as an UML abstract class, which lays the basis for the definition of the normative context constraining the social system. The definition of the *Norm* concept also implies the existence of some pre-defined, reactive rules which defines the behaviour of the *InstitutionalAgent* and of the *HumanAgent*(s).

4.1 AOR Organisational Metamodel

The ER/AOR simulation language and framework[3] is defined in [20] and some of the basic ER/AOR concepts were briefly introduced and explained in [21]. We focus here only on the new introduced concepts regarding the organisational approach.

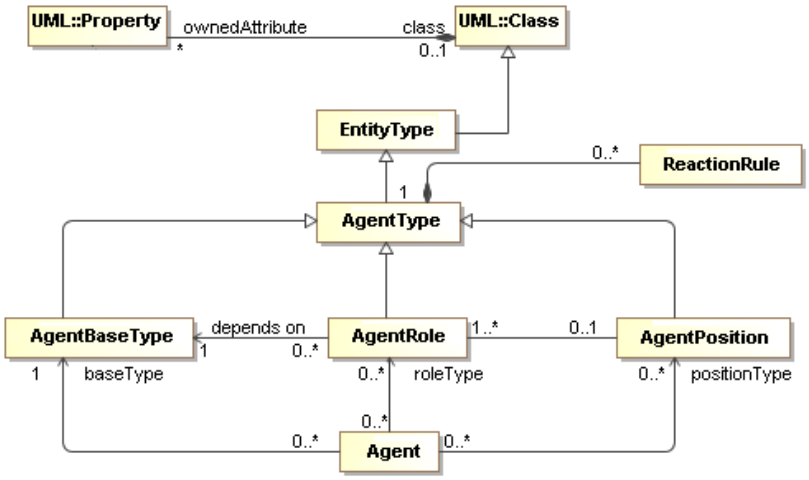

Fig. 8. AOR Types.

AgentType The *AgentType* class defines the common set of properties and behavior expressed by means of *ReactionRule*(s) for all agent type's instances. The concept inherits the *EntityType* class, meaning that in our model the agents are considered to be entities. The reactive rules define some default normative behavior: the duty to react to a certain set of events by triggering the reaction rules which model the behaviour of the base types and of the role types instances.

[2] We postpone the definition of an appropriate, normative layer for the social structure as future works. By introducing in our metamodel an abstract, UML class for representing the *Norm* concept we want to stress the fact that we consider our social system a social normative system.

[3] ER/AOR Modeling and Simulation Framework - http://code.google.com/p/aor-javasim/

ReactionRule *ReactionRule*(s) are the main AOR simulation language constructs which model the default behaviour of the agents. In the literature they are also called ECA(Event-Condition-Action) rules. They define the agent's reactive behavior in response to perception events (and internal time events). Reaction rules are aggregated by the *AgentType* concept (see Figure 8), therefore the *AgentBaseType*, *AgentPosition* and *AgentRole* concepts can define the reactive behaviour of its agent's instances. Reaction rules can also be specified at the level of the *InstitutionalAgent*. This means that one can specify additional behaviour at the level of institutions and organisations.

AgentBaseType Following the approach defined in [7] and [8] the agents must be of a certain *AgentBaseType*, also called a *rigid type* in [8], which determines the fundamental characteristics of the agents and also provides the identity criterion for its instances.

AgentRole The concept *AgentRole* defines the common characteristics of the roles which exist inside of the institution, therefore it must be understood as a concept *type*. The roles are aggregated into *AgentPosition*(s) which are assumed by individuals which are members of the social system and perform roles on behalf of the system. We borrowed the *AgentRole* concept's semantics from [7] and [8], where it is defined as an anti-rigid entity: [7, its instances could possibly also not be instances of it without losing their identity]. For example: an agent can have a base type *Person* and can play the role type *Student*. It is natural that the role Student is temporal and as soon as the person is not anymore a student she does not loose its identity. There exist also some dependencies between roles, in the sens that they may be disjunctive (a reviewer of an article can not be an author of the same article) or conjunctive (in order to assume a particular role, one should previously assume another role).

AgentPosition The concept *AgentPosition* defines the common characteristics of the agent positions existing inside of the *Organisation*, therefore it must be understood as a concept *type*. Individuals may assume certain positions within the hierarchy of the organisation they belong to. Each position may aggregate one or many role types. When the *AgentPosition* corresponds to exactly one *AgentRole* the position equates with that particular role.

Agent We distinguish between:

- institutions represented by the *InstitutionalAgent* concept such as: the institution of English language
- organisations and their sub-unities represented by the *Organisation* concept such as: universities and their organisation units: faculties, chairs etc.
- simple forms of institutions defined by the concept of *Group* (Tuomela's sense of weak organisation)
- people represented by the concept *HumanAgent* such as: persons or individuals
- other kinds of artificial agents represented by the superclass *Agent* such as: computers or trees

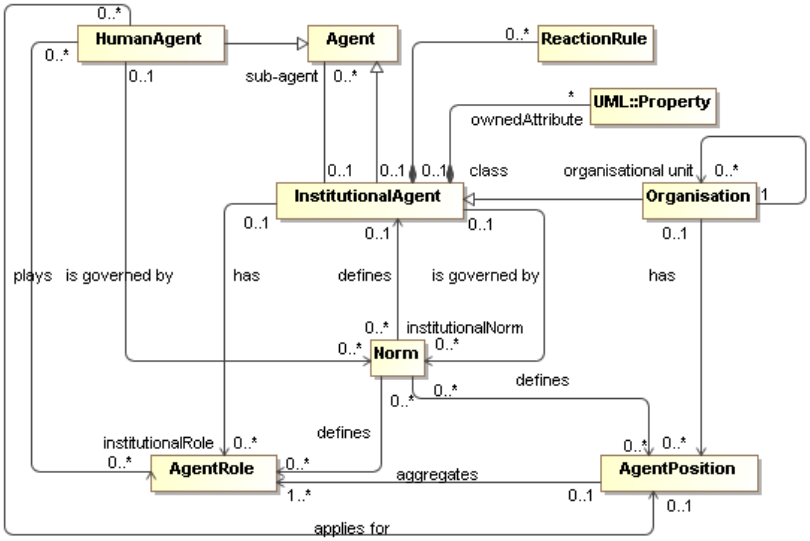

Fig. 9. AOR - Organisational structure.

Each *Agent* must be an instance of: (1) an unique *AgentBaseType* which provides to its instances the existential criterion; (2) zero or many *AgentPosition*(s); and (3) zero or many *AgentRole*(s) (see Figure 8). There must be a dependency relationship between the *AgentBaseType* and the other *AgentRole*(s) in the sense that an individual can instantiate only the role types which are in the dependency relationship with their base type e.g. the roles types Student and Professor are in a dependency relationship with the base type Person, but not with another possible base type e.g. Child.

Institutional Agent We use the concept *InstitutionalAgent*(s) (first mentioned in [20]) to represent an institution. The *InstitutionalAgent* subsumes its members (sub-agents), which can be human agents or organisation units (notice the association between the *InstitutionalAgent* class and the *Agent*). The *InstitutionalAgent* is a subclass of the *Agent* class, therefore one should not considerate it as a *type*.

The concept it is used to represent institutions such as: human languages, governments, academic environments, political, economic and legal institutions. Further on, one should distinguish the concept of *InstitutionalAgent* from: (1) more complex social forms such as societies which usually comprise institutions; (2) more simple social forms such as: rituals, social groups, social roles, social norms or even organisations which are constitutive elements of institutions. In this context, we differentiate institutions from social forms which are not subject of an organisational hierarchy such as: universities or enterprises. In order to represent these concepts we introduce the *Organisation* concept detailed below. There are also other kinds of simpler social forms which do not need a hierar-

chical structure, for example a group of friends. For simplicity, we do not define the *Group* concept, as our first concern is to model business processes inside organisations and not simple social gatherings such as a coffee break meeting inside of an University's chair.

Organisation The *Organization* concept is defined in our metamodel as a subclass of the *InstitutionalAgent* enhanced with the following characteristics: (1) the possibility to have as constitutive elements zero or many *AgentPosition*(s) which aggregate roles; and (2) the possibility to define a hierarchy of organisation units inside of the organisation by using the one-to-many aggregate association of the *Organisation* class with itself. E.g. University is an example of organisation.

Human Agent Human agents are members of the social system. They assume positions inside of institutions and organisations and play roles aggregated by positions.

4.2 Organisation Case Study - Modeling an Academic Environment

We choose for our case study to model an academic environment and the concept of Faculty's Chair is the first choice to reach. BTU Cottbus[4] is an example which successfully can instantiate such an organisation structure. We represent the organisation structure together with its official positions and aggregated roles in terms of concepts defined by the AOR simulation language and with the help of the UML class diagram. The UML diagram represents the *individuals* on the bottom of the UML diagram, the organisational concept *types* and the *meta-types*, elements of the AOR simulation language represented on the top of the UML diagram (see Figure 10).

5 Conclusion and Future Works

The paper presents an ongoing work which describes a preliminary proposal for extending the AOR simulation language with organisational constructs. The extension is realised based on the AOR abstract syntax (an UML metamodel). Further on, we enhance our AOR simulation language with organisational constructs originating from the fields of social science. Our approach is now limited at some default normative behaviour of the agents: the duty to react to certain events and the right to perform certain actions. Our future works will be focused on defining an appropriate, normative layer for the organisational structure and on developing means for representing the collective (but reactive) behavior of the agents inside of the organisation.

[4] Brandenburg University of Technology Cottbus - `http://www.tu-cottbus.de/btu/`

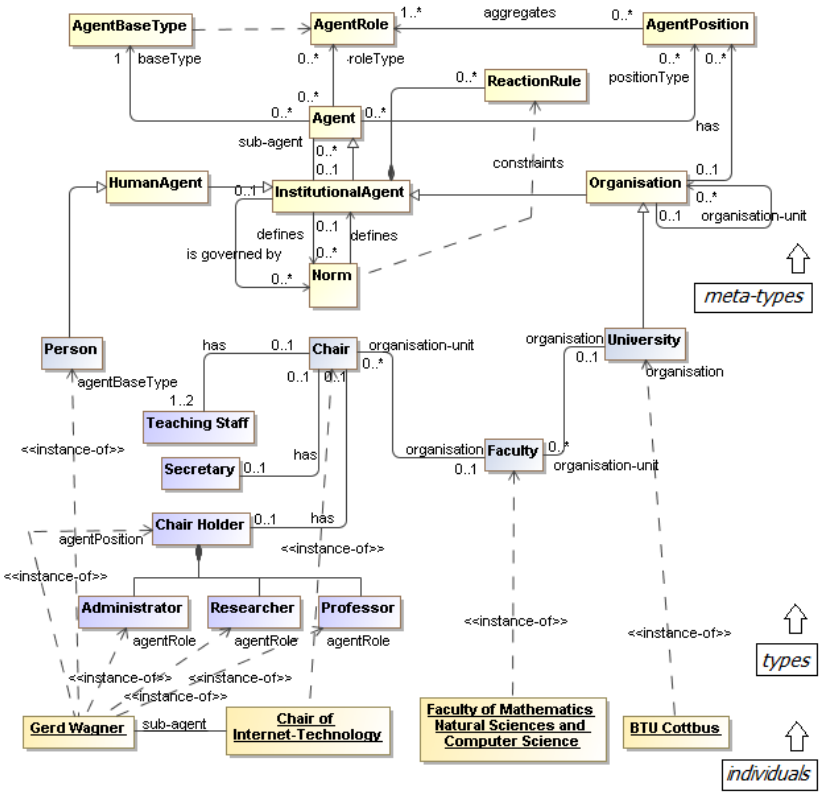

Fig. 10. Modeling an Academic Environment using AORSL.

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