An Ontology for Modeling Complex Inter-relational Organizations

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Abstract. This paper presents an ontology for organizational modeling through multiple complementary aspects. The primary goal of the ontology is to dispose of an adequate set of related concepts for studying complex organizations involved in a lot of relationships at the same time. In this paper, we define complex organizations as networked organizations involved in a market eco-system that are playing several roles simultaneously. In such a context, traditional approaches focus on the macro analytic level of transactions; this is supplemented here with a micro analytic study of the actors' rationale. At first, the paper overviews enterprise ontologies literature to position our proposal and exposes its contributions and limitations. The ontology is then brought to an advanced level of formalization: a meta-model in the form of a UML class diagram allows to overview the ontology concepts and their relationships which are formally defined. Finally, the paper presents the case study on which the ontology has been validated.

1 Introduction

Organizational modeling has been the subject of tremendous works during the last 15 years. Among these, the models developed in the context of i* (i-star) [1,2] have driven lots of research notably through the "Tropos" project [3]. Such models are however principally targeted for information systems development. The use of organizational modeling could however be much larger. Managers or business strategists can, on the basis of adequate models, study several aspects of organizations, like the transactions and relationships that take place between these organizations. This would help to answer essential questions as: *"What are the different aspects of our business? What are we responsible for? Who are we dependent of? What are the goals we pursue? How can we achieve them? What should be watched out? Etc.*

The aim of this paper is not to define a specific model but rather to develop a genuine ontology for studying complex organizations. We define complex organizations as networked organizations involved in a market eco-system that are playing several roles simultaneously. By generalization, market or enterprise

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ontologies model economic actors and their interactions. To achieve such an objective multiple dimensions have been considered (an intentional, operational and environmental) so that the different views and abstraction levels necessary for understanding all the business aspects are covered. With a focus on that purpose, a series of concepts (and their relationships) are defined and formalized. The ontology can be instantiated for studying market relationships as well as to dispose of a knowledge base for strategic and tactic decision taking.

This paper firstly overviews related work and points to the contributions and limitations of the developed ontology. The latter is then exposed. An UML class diagram exposes and defines formally the concepts of the ontology, including their mutual linkages. Next, the paper overviews the possible instantiation of the framework concepts to the particular an online market intermediary, eBay.

2 Problem Statement

This section overviews related work which discusses existing models and ontologies and identifies a gap in literature about modeling complex organizations. It also envisages the variables yet uncovered (e.g. environmental ones). The contributions and limitations of the ontology proposal are then exposed.

2.1 Related Work

The crux of our argument is that lots of firms may play several roles at the same time because they are involved in complex market relationships. Most of current modeling frameworks do not allow an integrated view of these specific market relationships. We argue that an integrated view of market relationships within complex (or multi-role) organizations should take into account several analytical dimensions. In this paper, we propose three of them: intentional, operational and environmental. These dimensions are more specifically outlined in Section 3.

Moreover, we think that a reliable framework modeling complex organizations should be rather dynamic (considering interactions and dependencies between several actors) than static. This argument is shared by Ku, Wensley and Kao in [4] who provide a framework for analyzing the knowledge management processing of joint ventures in a particular industry. From our point of view, joint ventures are a relevant example of complex market relationships where organizations interact to achieve a common goal. As emphasized by authors: "when enterprises engage in strategic joint venture projects, communication, knowledge sharing and management issues are inevitable and complex problems" [4]. Nevertheless, since only the cooperative role is tackled, the lack of multi-role analysis seems to be a limit of the study. In [5], an agent-oriented meta-model for enterprise modeling is depicted. The model is described using a class diagram but its instantiation focuses on organizations taken individually rather than on the relation between multiple organizations. Moreover, the framework only proposes descriptions of the concepts without presenting a large example of instance to demonstrate the increase in value of each of the concepts. As an answer to

the prior limitations, [6] propose a meta-model for enterprise modeling. In this meta-model, the framework is applied in a multi-plant context (each plant is a different organization).

Before modeling organizational relationships, it is necessary to establish an axiomatic set of definitions and inter-related concepts. Indeed, across the literature it is possible to find different definitions or representations for equivalent concepts. For example, the notion of role should be clear-cut before developing an analytical model. In [7], a role is defined as "a combination of several tasks in an enterprise that are likely to change drastically". In the current paper however, a combination of several tasks constitutes a goal rather than a role (See Section 3). In object-oriented development methodologies as the Unified Process [8] giving a framework to the Unified Modeling Language, a role is defined as "the behavior and responsibilities of an individual, or a set of individuals working together as a team, within the context of a software engineering organization" [9], which is oriented for the software engineering field. Even if the knowledge contained in a particular ontology can be used in different applications, for different purposes and by different people [10], we nevertheless want a framework less focused on software application development and relying more on the description and analysis of a multi-organizational environment as stated in the introduction.

As reminded by [11], one of the problems of using different representations and terminologies to model the same "thing", is the absence of any formal mapping between high-level ontologies. In response to this limitation, conceptual modeling can offer useful and solid tools for actor relationship study. For example, [12] suggest a method of ontology construction where different ontologies are merged within the same subject into a single ontology that unifies all of them.

2.2 Contributions and Limitations

The main contribution of the paper is the market ontology itself as described and formalized in the next section. It covers several aspects of primary importance for the study of organizational modeling in the context of market relationships. Also, the ontology exposes the concepts and their relationships through a meta-model and brings concepts to an advanced level of definition and formalization. So far, the proof of concept remains in the application of the theoretical framework on the eBay case study.

The model does, however, not provide metrics to evaluate for example the involvement of an actor into a particular role, the relative importance of a goal (low, medium, critical), the required effort to achieve a task, etc. Exceptions however exists since we evoke in the formal definitions of next section the notions of quality of service (QoS), probability of happening and improvement rate. Metrics definition and evaluation are left for future work.

3 The Ontology

The aim of this section is to expose our market ontology. We propose a class diagram which provides modeling elements relevant for specifying both strategic and

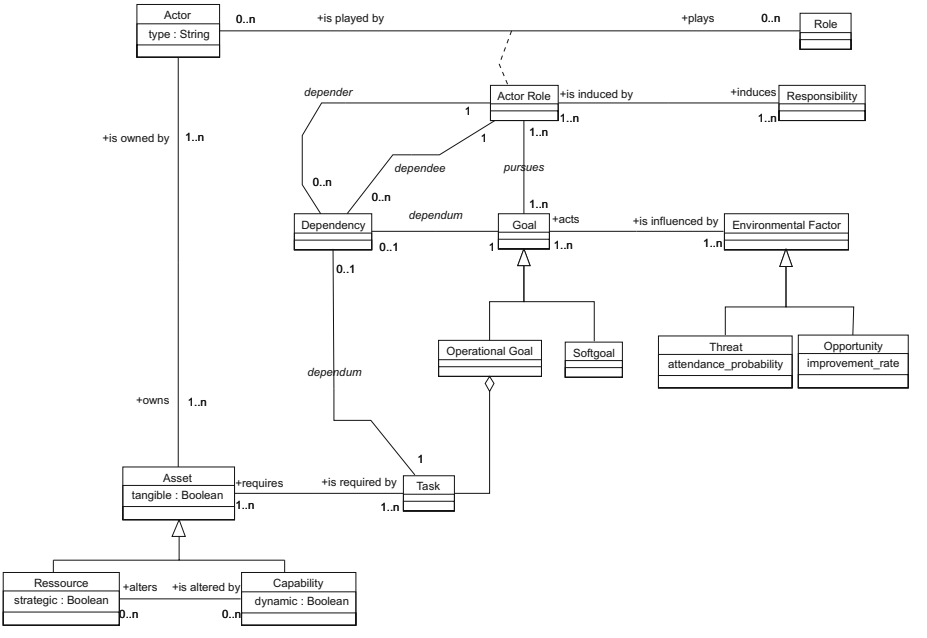

Fig. 1. The Market Ontology Class Diagram

operational aspects of the organizational context in which the actors relationship takes place. This class diagram is made of *concepts* (e.g., "Actor", "Roles", "Goals", etc.), *relationships* relating concepts (e.g., "Plays", "Owns", "Realizes", etc.), *attributes* of concepts or relationships (e.g., "Probability_of_happening", "Improvement_rate", etc.), and *constraints* on concepts and relationships (e.g., "An actor achieves a goal if and only if that actor possesses all the ressources required to achieve it").

3.1 Ontology's Entities and Relationships

The ontology we develop in this paper is aimed to study complex market relationships between economic actors as for example in the case of market intermediation. Studying such an issue nevertheless requires different complementary aspects, they are categorized here as intentional, operational and environmental dimensions. This section overviews the different ontology's concepts in the context of the dimensions they belong to. Figure 1 depicts a class diagram representing the concepts of a market ontology (in the form of *entities* i.e. *classes*) as well as their relationships (*associations* and *generalizations*); the aim of this section is to link each of the concepts and to bring them to further definition.

Intentional Dimension. The intentional dimension identifies and formalizes the actors involved in the market relationship, assigns them roles under which the

have responsibilities and pursue goals independently of the way to implement them. This dimension answers the question: *"Who is involved and what is he looking for?"*. *Actors* are intentional entities used to model organizations as private or public companies, governmental departments, etc. that are processor for some actions. The *Actor* owns a *Type* which documents his basic function on the market (for example *intermediary*, *seller*, *buyer*, etc.). They occupy *Roles* which are abstract characterizations of expected behaviour of an *Actor* within some specified context of the market. A defined *Actor* playing a defined *Role* is characterized as an *Actor Role*. The *Actor Role* has a *Responsibility* onto the market; indeed by playing a defined *Role*, the market expects the *Actor Role* to conform to particular guidelines. The later must be followed due to the professional nature of the *Actor Role*. An *Actor Role* pursues some *Goals* guiding his actions. *Goals* are sometimes involved in a *Dependency* relationship i.e. an *Actor Role* is dependent of an other *Actor Role* for the realization of the *Goal*. *Goals* are divided into two subcategories, *Operational Goals* (sometimes called hard goals, see [1]) which are functional goals the *Actor* has to fulfil in the context of a particular *Role*. Softgoals represent non-functional requirements i.e. global qualities of a software system such as security, flexibility, maintainability, usability, etc. They can hardly be the result of an operational decomposition but are more of the result of an adequately followed analysis and design.

Operational Dimension. The operational dimension realizes the operational goals identified by the intentional dimension in terms of tasks. Fulfilling tasks requires resources that can be human, devices, patents, etc. This dimension answers the question: *"How is each goal realized?"*. The *Operational Goals* can be achieved by the execution and satisfying realization of a series of *Tasks* (possibly in a particular sequence). *Tasks* execution and successful realization entails a series of tangible and intangible *Assets* that can be of different nature [13]. Indeed, *Assets* are divided into *Resources* and *Capabilities*. We consider here *Resources* as all the human and material *Assets* (employees, machines, software, money, furniture, etc.) that are required to fulfill the *Tasks*. The *Capabilities* can be viewed as more intangible *Assets*, like management skills, organizational processes, knowledge base, etc. that are controlled by the actor and contribute to the realization of the *Tasks*. *Resources* and *Capabilities* are closely interlinked. For instance, [14] argue that actors will exploit their dynamic *Capabilities* to alter their resource base and maintain their competitive advantage.

Environmental Dimension. The environmental dimension represents the factors that are external to the organization but has a variable (positive or negative) influence on the goal realization. This dimension answers the question: *"What must be watched out?"*. An *Environmental Factor* can be an external *Threat* for the adequate goal's fulfilment (in terms of adequate achievement) or an opportunity that can potentially contribute to the goal's achievement (in terms of time, quality of achievement, etc.). A goal achievement is indeed subject to multiple realization ways (alternative *Tasks* can be used) and paths (another sequence or some tasks can be avoided when some guard conditions are met). Moreover a

Probability of happening is associated to each *Threat* as well as an *Improvement rate* to each *Opportunity*. Those features will be useful for the *Threats* and *Opportunities* prioritization into strategic planning. The operational solutions and other strategies that the *Actor* (or *Actor Role*) can put into practice to deal with the threats or to operationalize an opportunity are not represented here as entities since they are outside the scope of this paper. Further developments onto the ontology could however incorporate them.

3.2 Ontology Formalization

In this section, we will bring the market ontology to further formalization.

Definition 1. *A tuple* $\langle\{(rol_i, q^a_{rol_i}), \ldots, (rol_{i+m}, q^a_{rol_{i+m}})\}, Act^a\rangle$ *is called an actor* a*, where* rol_i *is a role. The actor plays a series of roles to pursue goals at quality level and cost* $q^a_{rol_i}$*. Played roles are a vector of quality level and cost with values.* Act^a *is assumed to contain all additional properties of the actor necessary for its definition, the only relevant for the present discussion is its type (for example intermediary).*

Format and content of Act^a will depend on the structure of the market on which the framework is applied. For simplicity reasons an *actor role* is defined here over a single role. However, in practice, an actor mostly plays serveral roles.

Definition 2. $\langle a, rol_i, q^a_{rol_i}\rangle$ *associating a role* rol_i *to a quality level* $q^a_{rol_i}$ *achieved by the actor* a *is an actor role* a^{AR}_i*. The actor must be capable of playing the role:* $\forall a^{AR}_i = \langle a, rol_i, q^a_{rol_i}\rangle, (rol_i, q^a_{rol_i}) \in a$.

Any actor a that can play $m > 1$ roles can also be seen as a set of actor roles: $\{a^{AR}_i, \ldots, a^{AR}_{i+m}\}$. It is necessary to have a more precise idea of how tasks and goals are conceptualized.

Definition 3. *A task* tk_i *is* $\langle tk^{pre}_i, \tau_i, \{(asset_i), \ldots, (asset_{i+m})\}, tk^{post}_i\rangle$*, where* tk^{pre}_i *describes the task precondition,* τ_i *is a specification (in some natural or formal language) of how the task must be executed,* $asset_i$ *is a asset (ressource or capability) required to achieve the task and* tk^{post}_i *describes the conditions that must be met when the task can be stated executed. Tasks belong to the set* $\mathbb{TK}$*.*

Definition 4. $\langle g^\iota_j, g^N_j, g^E_j, goalState_j, goalTransit_j\rangle$ *is a goal* g_j*, where* g^ι_j *provides the details of the functional decopmosition of the goal,* (g^N_j, g^E_j) *defines a workflow. Nodes represent tasks, and edges transitions between tasks. The two functions label nodes and edges with tasks information:* $goalState_j : g^N_j \longmapsto \mathbb{TK}$ *is a partial function returning the task for a given node in the workflow, while* $goalTransit_j : g^E_j \longmapsto \{tk^{pre}_i\}_{tk_i \in \mathbb{TK}} \cup \{tk^{post}_i\}_{tk_i \in \mathbb{TK}}$ *maps each edge to a condition from the set of all task preconditions (i.e.,* $\{tk^{pre}_i\}_{tk_i \in \mathbb{TK}}$*) and postconditions (i.e.,* $\{tk^{post}_i\}_{tk_i \in \mathbb{TK}}$*). The task specified on a node must have the precondition and postcondition corresponding to conditions given, respectively, on its incoming and its outgoing edges.*

A goal can therefore be understood as a process, composed of a set of tasks ordered over the workflow representing the goal. The functional specification of the goal, i.e., g_j^t is not of interest here. Achieving a goal requires the specification of expected QoS, in addition to the maximal involvment of ressources, and explicit market responsibilities i.e. the Actor Role has a series of responsibilities to respect.

Definition 5. *A goal achievement* $\hat{g}_j$ *is* $\langle g_j, g_j^{QoS}, g_j^{ressources}, g_j^{respo} \rangle$*, where:*

- g_j *is the goal to achieve.*
- g_j^{QoS} *specifies expected qualities and their required level. Its definition follows a QoS ontology. Whatever the specific QoS ontology, expected qualities are likely to be specified as (at least)* $g_j^{QoS} = \langle (p_1, d_1, v_1, u_1), \ldots, (p_r, d_r, v_r, u_r) \rangle$*, where:*
  - p_k *is the name of the QoS parameter (e.g., connection delay, standards compliance, and so on).*
  - d_k *gives the type of the parameter (e.g., nominal, ordinal, interval, ratio).*
  - v_k *is the set of desired values of the parameter, or the constraint* $<, \leq, =, \geq, >$ *on the value of the parameter.*
  - u_k *is the unit of the property value.*
- $g_j^{ressources}$ *is the maximal level of ressources the actor role pursuing the goal is ready to involve for its fulfillment.*
- g_j^{respo} *is a set of responsibilities that constrain the actions the actor role may take when executing the tasks to achieve the goal.*

By conceptualizing the goal as suggested in Def.4, the goal is thus mapped onto a workflow WF where each node is a task i.e. a step in goal achievement and an edge in WF corresponds to the execution of a task tk_k. Each path from the starting node to the destination node corresponds to a sequence of tasks ensuring the achievement of the goal within the prescribed QoS. The model thus assumes that there are alternative ways for achieving the goal. The workflow is a graphical model of the different ways the goal can be achieved as a sequence of tasks.

4 Ontology Application to Market Intermediation

Besides traditional firms with productive activities, market intermediaries that centralize transactions without transforming goods represent a large portion of the economy. Market intermediaries appear on the market when they increase the net gains from the transactions relative to decentralized trade in which partners negotiate the terms of exchange directly [15]. In economic literature, a market intermediary is defined as *an economic agent that helps supply and demand meet, whether by purchasing from suppliers and reselling to buyers or by helping both to*

meet each other [16,15]. This definition supposes that two kinds of intermediaries exist: the merchant and the matchmaker [17]. Beyond this view restricted to buyers and sellers, one can extend the above definition to all pairs of potential partners sharing a common goal. For example, employment and matrimonial agencies can also be considered as intermediaries on their respective markets [18,19]. Specifically, theory on two-sided matching explores the role played by intermediaries in a centralized matching procedure.

During the last 20 years, changes in intermediation processes came up with the Internet and the related information and communication technologies (ICTs). Most of the studies about online market intermediation have emphasized the impacts of ICTs in terms of *search facilitation* [20], *transaction costs reduction* [21] and *transparency improvement* [22]. Among others, [23] *established potential impacts of ICTs on the different roles of market intermediaries*. Indeed, market intermediaries notably differ from other firms as they may play different roles in order to create value and improve the efficiency of an exchange process. Anticipating the further developments and orientations of online market intermediation involves a good knowledge of what the roles of those organizations are. In the literature, even if one can note a "lexical richness"[1] in writing about the roles of online intermediaries [24,23,25], the scientific community attributes always more than a single role to the market intermediary. As a whole, the concerned scholars seem to agree on four major roles for online market intermediaries: (1) a transactional role consisting in aggregating supply and demand; (2) an informational role consisting in collecting, organizing and evaluating dispersed information; (3) a logistical role consisting in providing the required infrastructure; and finally (4) an assurance role consisting in providing trust and security to the transaction process. This multi-role feature of online market intermediaries makes them a relevant frame for the study.

To apply our ontology-based framework to online market intermediation, we have taken the eBay company as an example of a Web-based market intermediary between buyers and sellers. Clearly, the eBay company is not isolated from the rest of the world since a lot of stakeholders represent other actors that take place in eBay's environment. These stakeholders include the buyers, the sellers, but also PayPal, postal service providers, and the community at large. As an actor, eBay (the "firm" rather than the platform itself) owns the type of "market intermediary" that specifies its function on the market. We also assume here that eBay plays the roles (at least one) that have been defined higher. At last, due to a lack of space we cannot go through all of the four roles; The interested reader can refer to [26] for an application to the *assurance role* (i.e. providing trust and security to the transaction process). Building trust is commonly referred in the literature as the key role of Web-based organizations [27]. A broader application of the ontology is available in [28].

[1] A large variety of terms -like roles, functions, activities,- are employed in the literature to describe similar concepts answering the fundamental question "what do intermediaries do?".

5 Conclusion

This paper has taken steps towards extending the modeling capabilities and abstraction potentials of traditional enterprise ontologies by integrating concepts dealing with the complexities inherent to organizations in a comercial relationship with others. Even though this stream of thought already disposes of plenty of studies notably in organizational modeling through i* [1,2], those approaches mostly focus on information systems development rather than on decision taking support. In this paper, we explicitly consider different dimensions leading to multiple levels of aggregation. We provide the contours of an updated framework that helps integrate the specificities of complex and inter-dependant organizations. The aim is here to put forward a formalized tool enabling management science researchers and practitioners to model complex organizations and their related market relationships. To that aim we have instantiated the model to the study of online market intermediation. Our ontology also extends existing works by including consideration of the fact that organizations pursuing several goals simultaneously largely depend on their environment (i.e. external threats and opportunities always impact the way goals are achieved). That is why we add an environmental dimension to the classic dyadic representation of decisional (or, to use our terms, "intentional") and operational dimensions. True to the ontological spirit, we hope to stimulate further research by reorienting enterprise modeling into strategic paths. The goal should be to reach unification in theoretical concepts for giving the scientific community a basis to build upon. Finally, there is the important challenge of crafting empirical research to strengthen the proposed ontology and to make further progress in modeling complex organizations as well as multi-role driven market relationships.

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