Roles, an Interdisciplinary Perspective

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1. Introduction

The notion of *role* is ubiquitous in many fields of computer science, like programming languages, software engineering, coordination languages, databases, multiagent systems, knowledge representation, formal ontology, computational linguistics, security, and conceptual modelling, and also outside computer science, like in cognitive science, organizational science and linguistics.

In computer science, the discussion about roles started in the '70s with Bachman and Daya (1977), and, with a recurring trend, it comes back to the attention of the research community. Recently, roles have been used in many areas to handle interaction, for example, role based access control in security with the RBAC model (Sandhu et al. (1996)), collaboration roles in UML to describe the interaction among classes (Rumbaugh et al. (2004)), channels connecting components in coordination languages (Arbab (2003)), the separation of concerns to describe the interaction properties of objects in new contexts in programming languages, etc. With the rise of the internet, new communication possibilities and interactive computing created a new demand of research about roles, for example, in organizations in open multiagent systems, in role based programming languages, in using roles for the composition of web services, and in defining roles in standards for interoperability.

Notwithstanding this revival of the research about the notion of role, little agreement seems possible among the proposals in the different fields. This lack of agreement leads to the impossibility of transferring the results from one area to the other, and even inside a single area, a consequence which is quite unpleasant in a moment where the sharing of knowledge and standardization represent an added value in many fields. For example, in ontology, the lack of a common definition of role constitutes a problem for the interconnection of different knowledge bases: the result is that a widely used ontology language like OWL does not consider roles as a primitive. In multiagent systems, the openness of systems highlights the need of commonly accepted definitions, but again without a common notion of role it is not possible for a new agent to become part of an organization to interact with other agents; and in programming languages, software reuse can be improved only by a more developed theory of how objects interact with each other basing on the roles they play.

The likely reasons of these divergences are that many papers on the notion of role fail to have an interdisciplinary character, that much work proposes new definitions of roles to deal with particular practical problems, and that role seems an intuitive notion which can be grasped in its prototypical characters, but it is instead a deceptive one when details must be clarified. Few proposals, like Steimann (2000) or Masolo et al. (2004), have a more general attitude, and try to find a problem independent definition of role and to formalize it.

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2. The contributions collected in this issue

The recognition of the need of a wider agreement on roles lead us to organize with James Odell the first *Roles* event: "Roles, an Interdisciplinary Perspective - Roles'05" (Boella et al. (2005)), an American Association for Artificial Intelligence (AAAI) Fall Symposium, held on November 3-6, 2005 at Hyatt Crystal City in Arlington, Virginia (see the website `http://normas.di.unito.it/zope/roles05`). Despite the event was organized in the area of artificial intelligence, there was a good response also from the community of programming languages and even from sociology. No previous event focussed on roles, even if some other workshops offered the environment for discussing roles, like CorOrg, NorMas, AOSE, COIN, VAR. However, they either don't have an interdisciplinary character, or they discuss roles from a specific perspective, for example, NorMas is focused on normative systems (Boella et al. (2006, 2007)).

The call for papers of Roles'05 produced 30 submissions of which 22 presented at the workshop. The peculiar environment of the AAAI Symposia offered the opportunity for a lively discussion among researchers from different fields. From the presented papers five were selected for this special issue, representing the different areas involved in the workshop: ontology, programming languages and multiagent systems. Moreover, the article of Friedrich Steimann, the invited speaker of the workshop, complements the other ones by presenting an historical perspective on the subject, analysing the seminal work of Bachman and Daya (1977) on the Role data model for databases.

Roles'05 is followed after two years by the Roles'07 workshop which will be held on July 30-31, 2007 at Berlin inside the 21th European Conference on Object-Oriented Programming (ECOOP'07) on the topic "Roles and Relationships in Object Oriented Programming, Multiagent Systems, and Ontologies", in cooperation with Friedrich Steimann, Steffen Göbel and Steffen Zschaler (see the website `http://normas.di.unito.it/zope/roles07`).

Roles, like objects, classes and relationships, pervade the vocabulary of all sciences that deal with the nature of things and how these things relate to each other. Ontology is at the core of sciences analysing the nature of things. Given their widespread presence in all fields, it is possible to argue that roles are so fundamental a notion that they must be granted the status of an ontological primitive, besides objects, classes, and relationships. We choose the Applied Ontology Journal for publishing the best papers of Roles'05 also because we believe that, on the one hand, the area of ontology constitutes the right area for finding an agreement between the different positions on roles: it provides a formal setting which can be neutral with respect to different applications. On the other hand, ontologies can benefit from looking at other formalisms, in particular for what concerns behavioral aspects of roles, as discussed in the article of Stephan Herrmann in this issue (Herrmann (2007)).

This special issue includes five articles: an historical perspective from the field of databases, a contribution from multiagent systems which propose an organization centered view of roles, an ontological classification of roles, a description of a tool for building ontologies which include roles, and a discussion on the properties of roles in object oriented programming languages.

– In "The Role Data Model Revisited" Friedrich Steimann shows how roles have been reinvented many times in computer science. This effort would have been avoided if the work of Charles Bachman in 1977 on the introduction of roles in database models (Bachman and Daya (1977)) were not ignored due to the success of the alternative of relational data base management systems and of the entity-relationship model. As a further negative effect, the success of these solutions lead with them the limiting idea that roles are just names used to distinguish places of a relationship (or columns of a table) that happen to have the same type – and, thus, could not be distinguished by their type names. Bachman's innovation starts from the recognition that most conventional records in databases are defined on roles: e.g., employees, customers, patients, or students. Roles like employers and employees are connected by (1:n) relationships. These roles can be played by different kinds of entities, e.g., persons and organizations, which in turn can play more than one role at the same time. Thus, Bachman separated the existence of an entity from its appearance in a relationship, where it exhibits role-specific behavior: roles can be acquired and released dynamically. The properties which Steimann

recognizes in Bachman's model are quite general and can be found also in other disciplines. Thus, if object, class, and relationship are ontological primitives, the notion of role deserves the same status. Bachman seems to anticipate also recent works in the ontology field, like Guarino and Welty (2002), where roles are defined as founded, since roles are defined in the context of relationships, and as not semantically rigid, since entities can assume and drop roles without losing identity. The most evident limitation of Bachman's model is that the same entity cannot play the same role more than once at the same time. This limitation has been solved in subsequent approaches by considering roles as adjunct instances associated (without an identity) to their players. Instead, the only solution coherent with the original role data model, according to Steimann, would have been to use the relationship as the place where to add the properties assigned to roles.

– "Roles, Players and Adaptable Organizations" by Alan W. Colman and Jun Han represents a contribution from the area of multiagent systems. The article focuses on building software systems on the basis of social contexts which are intentionally designed and structured in the systems. The social contexts give to the systems an organizational structure composed of a network of relationships among roles, and of the processes that maintain the viability of these relationships in response to changing goals and changing environments. The possibility to restructure itself distinguishes an organization from a mere structure. The restructuring processes can be regulated by some of the roles of the organization by means of interaction protocols and authority relationships (powers, expectations and obligations) which regulate the interaction among roles. Complex organizational structures are built by allowing organizations to play roles in other organizations.

In an open system it is difficult to make assumptions on the possible players of roles. Different kind of players, with different reasoning and acting capabilities, may require different degrees of autonomy. In this regard, the article discusses the shifting boundary between role and role-player: for example, a role for an inexperienced player can give to it more details about the procedures to achieve the role's goals with respect to a role for an experienced player.

The authors contest approaches where roles are used in the modelling and to inform the design, but disappear as entities during implementation. They claim that roles should be first class entities also during the runtime phase of a system. Moreover, the authors contest the view of the dependence of roles from players, as deriving from an object-centric or player-centric perspective. In this perspective, the identity of the role is an adjunct to the identity of the object. Instead, the role should be seen as the stable entity (thanks to its link with the organization) to which transient players are attached. Their perspective looks at roles from an organization-centric viewpoint. From this perspective, a role's identity and existence derives from the organization that defines the roles and associations - not from the player itself. This view contrasts with ontological analyses where roles are founded mainly on players, or on other concepts, but not on the organizations offering the roles (Masolo et al. (2004)).

– In "Abstract vs. Social Roles - Towards a General Theoretical Account of Roles" of Frank Loebe, an ontology of roles is proposed. Roles are associated both with a player and a context, in an extension of the top-level ontology General Formal Ontology – GFO – (Herre et al. (2006)). The author classifies three kinds of roles according to the different kinds of contexts they belong to. Roles are parts of contexts (in some sense of the term) and the contexts emerge from the existence of the roles, in a mutual existential dependence. Three kinds of contexts are considered in the classification of role, which determine different playing relations:

* Relational role: corresponds to the way in which an argument participates in the context of some relationship; e.g., two as a factor of four refers to a relationship. Relational roles are special properties, and the "plays" relationship between entities and relational roles is thus subsumed by the "has-property" relation.
* Processual role: corresponds to the manner in which a player behaves in the context of some process (i.e., it participates in the process): e.g., John as the mover of some pen is categorized as a processual role. Processual roles are parts of processes, and, therefore, processes themselves.

  ∗ Social role: corresponds to the involvement of a social object within the context of some society; e.g., a student in a university. A genuine notion of playing a social role is required based on the notion of counts as (Searle (1995)), which is vaguely similar to inherence. However, inherence in the case of social roles is considered with respect to roles as "complex properties", since social roles are often defined with their own properties, relations and processes in which they (may) participate (confirming the view of roles as "patterns of behavior"). This means that social roles are considered as objects.

– "A Model of Roles in Ontology Development Tool: Hozo" by Riichiro Mizoguchi, Eiichi Sunagawa, Kouji Kozaki and Yoshinobu Kitamura merges an ontological analysis of roles with practical considerations about designing tools for building ontologies. The most novel element of their model is the notion of role holder, an abstraction of a composition of a role-playing entity with an instance of a role concept. In turn, the role concept instance can exist only in presence of an instance of the context the role is associated with. The introduction of the notion of role holder allows the authors to explain in which sense roles can play roles, and there can be instances of role concepts without a corresponding player. When we say that a citizen becomes a minister, in the Hozo model the situation is represented by making the role of minister played by the role holder of the citizen role, rather then by the instance of the role concept. In this way, it is possible also to express the requirement that to play a role it is necessary to be the player of another role.

As in Colman and Han (2007), roles (in the sense of role concept instances) can exist without a player, due to their relation with a context. Conversely, some contexts exist only in presence of the roles which compose the context. For example, a marriage exists only as far as both the roles of wife and husband exist. As Loebe (2007) does, the authors provide a classification of roles basing on the type of context they are related to. Besides relational roles, processual roles and social roles, Hozo distinguishes action related roles, attribute roles and composite roles. Composite roles allow to model a role like teacher, which includes both the role of staff member of a school and of agent of a teaching activity, and, thus, they depend on multiple contexts at a time.

– "A Precise Model for Contextual Roles: The Programming Language ObjectTeams/Java" by Stephan Herrmann describes the properties of roles in a modern approach which introduces roles in object oriented programming languages. According to a recent trend, witnessed also by Tamai (2002) and by Baldoni et al. (2007a), roles are considered as existing only in a context, where they explain new possibilities of interaction given to their players. This is another example of what Colman and Han (2007) in this issue call the organizational-centric view of roles. Contexts, called object teams, are defined at the universal level as classes which include other classes. These "inner" classes describe roles played by other objects, and they specify the properties and the behavior of the playing objects in the context of the team. When an object plays a role in a context, its behavior is changed according to what specified in the role: its methods, when they are invoked, can be substituted by the methods specified in the role, by means of aspect programming techniques (Kiczales et al. (1997)). Including roles in contexts promote coordination, as the roles, contrary to the usual encapsulation principle, can access the private state of each other and of the context, since they belong to the same namespace. Contexts partly correspond in multiagent systems to the concept of organization of Colman and Han (2007).

In this article, on the one hand, it is possible to find many of the properties associated in ontological analysis of roles, among which Loebe (2007) in this issue: roles are acquired and relinquished dynamically; roles do not exist independently of their players and contexts, even if they have instances to represent context dependent attributes and behavior; and an object can play several roles simultaneously, also of the same type, if the role instances belong to different instances of the same context. On the other hand, providing a programming language approach allows to clarify some issues which are less easy to detail in a more static approach like ontology. In particular, roles are often associated with behaviors, but the relation between the behavior of the role and the behavior of the player is not clear if the technical details of method invocation are not analysed.

3. What is a role?

This special issue does not propose an overall definition of roles. In this editorial, however, we want to highlight some features of roles acknowledged by the articles collected here, which are often disregarded in the literature. Undisputed distinguishing features of roles seem to be their dependence on some other entities and their dynamic character. These properties contrast roles with the notion of natural type. Its natural type is essential to an entity: if an entity changes its natural type, it loses its identity; instead, in Guarino and Welty (2002)'s terms, roles lack the rigidity which natural types possess.

The first conclusion we can draw from the articles of this special issue is that roles have a relational nature, and, for this reason, they are linked with the notion of interaction. Already Masolo et al. (2005) elaborate on the relational nature of roles, highlighting their definitional dependence on relationships, but this nature is not always accepted. The connection between roles and relationships has been disregarded since relationship itself is a notion whose importance is not fully recognized yet, for example, in programming languages. With the advent of the object orientation paradigm relationships have moved out of the focus of attention at some levels of representation, like programming languages, giving way to the more restricted concept of attributes or, more technically, references to other objects. A reference is tied to the object holding it and as such is asymmetric – at most the target of the reference can be associated with a role. This is in contrast with the intuition that every role should have at least one counter-role (e.g., student and professor, buyer and seller, initiator and bidder, etc.). The existence of a counter role, in turn, highlights the function of roles in describing the interaction of objects in the scope of a relationship (e.g., a negotiation process in the case of the pair of roles like initiator and bidder): each role is associated with another role, namely the one it interacts with. In other disciplines, like ontology and multiagent systems this connection with interaction already emerged. In the ontology of Loebe (2007), social roles participate in processes, to model the interactions among roles, and play roles in relationships associating them to their counter roles. The relational and interactional nature of roles emerge clearly in the area of multi-agent systems (see Colman and Han (2007)), since roles specify the interaction among agents and the communication protocols.

The second conclusion is strictly related to the first one. As Loebe (2007) recognizes, often, relational roles, at a deeper analysis, can turn into social roles. Thus, roles are associated to a social context they belong to. This view is directly inspired by the organizational metaphor, where roles are a way to structure an organization and to distribute responsibilities. The relationships connecting roles and counter-roles span across an organization. This metaphor is particularly effective in the field of multiagent systems, where organizational structures are used to coordinate agents in open systems by assigning them roles specifying their responsibilities. The organizational-centric point of view theorized by Colman and Han (2007) in this issue sharply contrasts with past work on roles, which still constitutes the prototypical view in many communities (see, e.g., Bäumer et al. (1997)): roles as extensions of the behavior of objects or agents, disregarding the context the roles belong to and the interactions they allow.

The third conclusion is that behavior should not be disregarded as a main feature of roles. In sociology, often, roles have been defined as "patterns of behavior". In computer science, on the one hand, programming languages associate methods to roles, and, sometimes, like in Herrmann (2007), the methods of the roles even substitute the methods of their players. On the other hand, in multiagent systems (like in Colman and Han (2007) and Boella and van der Torre (2007)), the behavior associated with roles has a different nature with respect to the behavior associated with the agents playing them. While the players can perform physical actions, roles exercise powers. The notion of power is derived from the organizational (or institutional) metaphor: an action of the player of a role counts as an institutional action which affects the obligations, permissions, responsibilities and powers of the organizations and of the other roles involved. These two kinds of actions seem to have a different ontological status which is partly unexplored.

4. Open questions

Even if this special issue clarifies some problems about the notion of role, many questions remain open. Among them, we identify the following ones:

1. How the notion of role in computer science can benefit from the analyses made in other disciplines? For example, organizational theory and the construction of social reality proposed in philosophy by Searle (1995) and Tuomela (1995) have been recently considered to model roles in ontologies (Bottazzi and Ferrario (2005)). Notions like sociotechnical systems developed in sociology are introduced by Jahnke et al. (2005).

2. The notion of role emerges as a likely candidate to be added besides the other ontological primitives, like object, class and relationship. Often, ontologies have a cognitive bias, like DOLCE has (Gangemi et al. (2002)). Thus, the question becomes: is the notion of role also a cognitive primitive or can it be related to other primitives? For example, recent work (Baldoni et al. (2006)) suggests that the notion of role is related to the notion of *affordance* developed in cognitive science by Gibson (1979). Affordances are the interaction possibilities offered by an environment to an animal living in it. Roles can be explained as sets of affordances (niches in Gibson (1979)'s terminology) and can be played by different entities according to their capabilities. the connection between the notion of role and the cognitive notion of affordance, thus, explains also the interactional character of roles discussed above.

3. Roles and relationships seem to be two sides of the same coin and, thus, are strictly interconnected. Recent work on relationships in object oriented languages witnesses the existing interest for relationships (Balzer et al. (2007)). However, roles are rarely connected with relationships. Thus, the following one remains an open question: when relationships are introduced in object oriented languages, how can roles be added too? The solution supported by Steimann (2007) is to overload the notion of relationship with the properties and behaviors which are associated to the roles a relationship identifies. Baldoni et al. (2007b) propose the opposite solution: relations should be reduced to roles, rather than to attributes or references, and the roles should be overloaded with the properties specific of the relationship. Can the two views be merged or are they incompatible?

4. Is a single definition of role possible? And, if it is not useful to have one or, if it does not exist, how many different notions of role exist? Loebe (2007) in this issue distinguishes between relational, processual and social roles on the basis of the context a role belongs to, and Mizoguchi et al. (2007) introduce further distinctions. A new challenge is to define a metalevel framework to cover different definitions of roles by specifying it by means of different parameterizations, to understand which are all the variables at issue. A preliminary tentative is given by Genovese (2007) where a metamodel is defined and different models of roles, like RBAC, are described with it.

5. Which are the criteria for evaluating role models? Which are the benchmark examples to be covered? Most works on roles use the student-course example, but it is rather simple and it is not clear whether it is general enough to cover most features attributed to the different types of roles. Steimann (2007) proposes as a criterion the possibility to use a model of roles as a metamodel of itself. Herrmann (2007) shows how Object Teams can provide a metamodel of itself: which other proposals can pass this test?

6. Mizoguchi et al. (2007) propose a first tentative to model roles in OWL. However, a general agreement must still be found. How can the notion of role be introduced as an ontological primitive in the standards for the semantic web? How and in which setting is it possible to formulate a proposal and find the necessary political agreement on it?

We hope that the discussion at the next edition of *Roles* at ECOOP'07, which aims at proposing a "Role Manifesto", will be able to answer these questions and to identify the general properties of roles which can be accepted in different research communities.

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