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Identifying Roles in Multi-Agent Systems

by overhearing

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Abstract

In our daily life we are confronted with people in our society who act in different roles. To communicate and to understand each other it is important to recognize these roles. If you understand the implications of a role, you can better understand what this person tries to tell to you.

It is not always clear what role a person enacts. Often we match certain properties of persons to roles we already know by resembling common verbal and nonverbal expressions. In this thesis we focus on verbal communicative expressions, in particular the communicative acts supported as a standard by the Foundation for Intelligent Physical Agents (FIPA). These expressions follow social rules. These rules are collected in a protocol. Therefore we assume that a role is defined by typical expressions.

In a society of software agents we are testing two methods to recognize roles. These methods we define as deductive and inductive reasoning processes. In the deductive method a dialog between two software agents is validated according to a Document Type Definition (DTD), where dialogs are formatted in an extendible mark-up language (XML) document. In the inductive method a Naive Bayes Classifier determines the role from a dialog between two software agents.

In this thesis it is assumed that two different organizations contain in essence similar roles, but the way these roles express themselves can be different. These variations we call “dialects”. We assume that the essence of a similar role in different societies remains the same, which means in this thesis that every similar role tries to achieve a similar objective.

The objective a role-enacting agent has to achieve is an internal property of a role and in this thesis it is assumed that internal properties cannot be observed. The expressions the role-enacting agents use to communicate with each other, however, can be observed. These sets of communicative expressions appear in a dialog.

In this thesis we test the deductive and inductive reasoning process to provide a recommendation in order to recognize roles in a multi-agent system by overhearing. Both methods used contain a learning and a testing phase. In the learning phase an observer learns in one organization to recognize roles by overhearing conversations between two role-enacting agents. In the testing phase this observer applies this learned material to recognize the roles of two role-enacting agents in another organization.

To test both methods, we started with one original dialog as a control dialog and created five other dialogs, dialects, by varying the verbal communicative expressions. To pass the test means a role has been recognized from the observed dialog. To fail the test no role has been

classified. The results are that the deductive method is too inflexible; only the control dialog passed the test. The dialects for this method were not recognized at all. The inductive method considers all six dialogs passed the test.

At this point the inductive method is recommended for recognizing roles. Future research has to be made to calculate the quality of the outcome of the classification.

Using a role recognition method in multi-agent systems can be used as a tool to expand social relations (semi-)autonomously beyond the borders of an organization. This can give an agent the ability to increase their working domain where they can have dialogs with role-enacting agents from other organizations where prior relationships did not exist.

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“Something that has always puzzled me all my life is why, when I am in special need of help, the good deed is usually done by somebody on whom I have no claim.”

-William Feather

Virgina was my main supervisor. She motivated me with her enthusiasm about the contribution subject of the thesis would deliver to the scientific agent community. Her lectures about knowledge management were my initial drive to make a contribution in this field.

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Preface

Information Science started in the year 2000 as a new study at the Utrecht University in the Netherlands, and is part of the faculty Mathematics and Computer Science. This thesis is a graduate assignment and forms the termination of more than four years of study. It resulted in much acquired knowledge, although it is in fact a base for the future.

The idea for this research came from my involvement in theatre and at the same time attending to lectures about knowledge management. At the lectures I learned about distributed software agents who communicate with each other to share knowledge. When involved in theatre I was wondering about the fact how the theatre audience was able to understand what roles the actors play. And whether this understanding of roles could help distributed software agents to find each other to share their knowledge even better without human involvement.

List of terms and abbreviations

Blackboard	A webpage where all agents use to communicate. This is one central page where dialogs appear like on a chat channel.
Dialect	A variation on an official language.
DTD	Document Type Definition. This defines the structure an XML document should follow. This is used to validate the structure of XML documents.
FIPA	Foundation of Intelligent Physical Agents. This foundation has created a standard that describes an architecture for multi-agent systems how software agents should be organized and communicate.
HTML	Hyper Text Mark-up Language, A tag-based language to layout web pages.
KM	“Knowledge Management (KM) refers to the process of creating, codifying and disseminating knowledge within complex organizations, such as large companies, universities, and organizations for social and civil services.” [Bonifacio, 2002]
Multi-agent system	<p>A computer system or a network of computer systems where agents can communicate with each other. This communication is based on certain architecture. In this thesis we mainly use the OperA model. This is a theoretic model of an organization that describes how agents communicate based on the FIPA architecture.</p> <p>The implementation can be in for example the JAVA programming language.</p>
Naïve Bayesian	A classification method based on the Bayes theorem. In Naive Bayesian classification variables are considered to be

classification	independent, not interdependent. More about this in section 2.5.2.
Role-enacting agent	A software agent who performs a role in a multi-agent system
Software agent	<p>A software agent is a piece of software that simulates specific tasks a real person could do. Also referred as intelligent agent. This agent can make decisions autonomously.</p> <p>In a setting where more then one agent is operating cooperatively or competitively we speak of a multi-agent system. In a multi-agent system where agents act in different roles this is referred to as a multi-agent society or multi-agent organization.</p>
Stereotyping	<p>Stereotypes are considered to be a group concept, held by one social group about another. Stereotyping is based on: Simplification, Exaggeration or distortion, Generalization, Presentation of cultural attributes as being ‘natural’.</p> <p>In computing, a stereotype is a concept in the Unified Modelling Language (UML), where it is used to encapsulate method behaviour such as <code><<constructor>></code> and <code><<getter>></code>. [wikipedia.org]</p> <p>In the thesis also the term social profiling is used.</p>
XML	eXtensible Mark-up Language. A tag-based language in which content can be structured. This language is a standard for defining formal mark-up languages which can be readable for machines and humans. The naming and structure of the tags can be used freely or can be used as an international standard which requires the consensus of a community to create consensus.

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1 Introduction

Saturday at noon you walk around the busy canals of Utrecht in the shopping area, as you walk by, you pick up a part of a conversation:

...

A: I have a fourteen year old son.

B: Well that's all right.

A: I also have a dog.

B: Oh, I'm sorry.

...

[Levinson, 1983]

The above conversation seems bizarre in isolation, but when embedded in an actual situation -A is trying to hire a room from landlord B- it seems natural and quite understandable. This demonstrates that role *recognition* may substantially improve the understanding of conversational contributions. The role appears to provide valuable *contextual information* to determine the meaning of the utterances.

Let's take another example. You walk into the classroom; it is the beginning of the semester and you have some questions for the teacher about the schedule. You don't know what he or she looks like. How do you know who the teacher is? Are you going to look for external appearance, such as grey hair? Are you going to look for certain behavioral aspects, such as a person who stands up and commands the other people to open their books at page one? Or are you going to disturb every single person by asking each of them if he or she is the teacher? We use our senses to observe expressions from other people and resemble these to expectations we have of the behavior of a role. In fact we match the observed behavior to the behavior one expects.

Recognizing the role someone enacts is usually a matter of stereotyping that is vital in daily life to get around and to get things done to meet your objective. In both examples to recognize stereotype roles we look for features that enable us to recognize an individual. An individual who enacts a role sends out *characteristic information* about the role he or she occupies. This can be accomplished by looking at the various verbal and nonverbal channels that provide this characteristic information. For example verbally on the auditive channel when you hear someone say: "Sir, you are under arrest" - the only role in society who can

legally say such a thing is a police officer, or nonverbally on the visual channel that provides information that a person is likely to be a police officer if he or she is wearing a police uniform, hand cuffs, a pistol and a badge.

1.1 Software agents

Clearly, being aware of the roles in society and organizations makes understanding each other easy. We know where to get information, we know who can do a particular job (like arresting people) and, as the first example shows us, it enables us to understand the meaning of a conversation.

In the electronic world individuals are represented by software agents and, to some extent, these agents show the same behavior as the individuals in our physical world. They show autonomous behavior, can communicate and since most of them are specialized, they play roles in a virtual sense.

1.2 Problem description

Like individuals in the physical world, electronic agents must be able to recognize roles. Software agents that cannot recognize a role will be constantly talking to the wrong agent, and will not be able to proactively engage a conversation to pursue its objective. (See Illustration 1)

To stress the importance of role recognition we use the field of knowledge management to provide an example.

“Knowledge Management (KM) refers to the process of creating, codifying and disseminating knowledge within complex organizations, such as large companies, universities, and organizations for social and civil services.” [Bonifacio, 2002] The tradition in KM projects is to create large, homogeneous knowledge repositories. In this repository the knowledge is represented according to a single conceptual schema¹. Using a single schema for the whole organization is incompatible with the nature of knowledge. This incompatibility lies in the mismatch between social form and technological architecture. “The social form is that each community uses its own conceptual schema to describe the world of phenomena in that specific domain. (See Illustration 1)” [Bonifacio, 2002]

¹ Conceptual schemas: schema's that represent shared conceptualisations of corporate knowledge, and enables communication and knowledge sharing across the entire organisation.

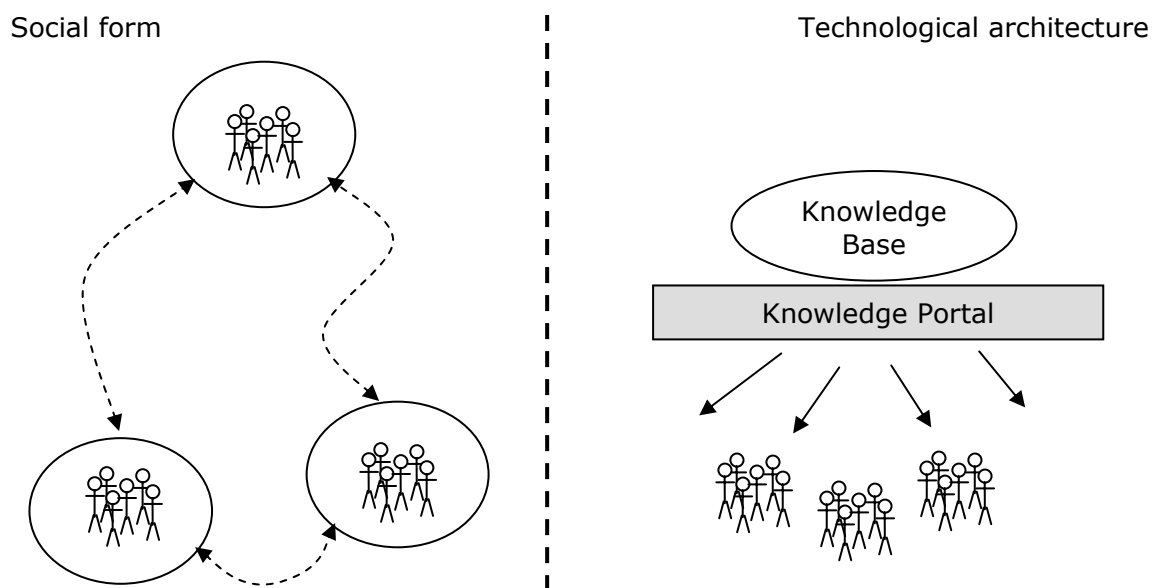


Illustration 1: Traditional knowledge management is lead through technology but creates a mismatch between the social form people normally communicate and share knowledge. [Bonifacio, 2002]

Bonifacio et al. describes an architecture that is more compatible with the social form. “The first idea is that knowledge should be autonomously managed where it is created and used, namely within each community. Autonomy means, for example, that each community should be allowed to build its own local conceptual schema.

The second idea is that each community has to create a link from its own conceptual schema to the schema of another community. These mappings can be defined by hand, but a KM system should support the creation of automatic (or semiautomatic) mappings. This requires the ability to compare, in a semantically relevant way, autonomously generated contexts.

The third idea points out that context matching is not enough. For human beings, knowledge sharing is often the result of a social process, in which many different cooperative strategies are used. The third idea underlying the proposed architecture is that the system should aim at to reproducing this social process.” [Bonifacio, 2002] See also: [Davies, 1998]; [Elst, 2003]; [Bonifacio, 2003]; [Mathieu, 2002]

In this thesis our aim contributes to the second and third idea; comparing autonomously generated contexts by matching social processes (conversations) by finding agents that are socially compatible to one another. In a social community a software agent enacts a social role. To find agents with a matching social process, we look at similarities in conversation strategies of role-enacting agents from other domains.

Flexibility and scalability

Let's assume that social interaction between software agents appears distributed on the World Wide Web. Let's also assume that on the World Wide Web software agents can autonomously find social compatible parties. Then these properties, distribution and recognition, creates the flexibility and scalability to share knowledge that lies beyond the specific domain of a software agent in a corporate multi-agent system. [Davies, 1998]; [Elst, 2003]; [Bonifacio, 2003]; [Mathieu, 2002]

Providing an autonomous coordination mechanism for each agent, organization boundaries could disappear, and a group of agents can create a self-organizing virtual community of agents with expert abilities. In this virtual community, specialized agents can pursue either their own or other agents' objectives. The advantage will be that the objective of an agent can much faster be achieved when connected to this virtual community, than restricted to the boundaries of an organization. Being inside this community the pool of agents is much bigger then limited to the agents inside an organization. For example we can see this community as a web-forum where people come together to help each other.

The problem is when an agent in the community is called "BR2992" there is no way to tell that this agent is a real estate broker. Agents who perform a role are recognized for what they do or say, not for what their names are. Therefore we have to create a universal mechanism that can determine what role an agent performs. As stated before we will look at the compatibility of conversation strategies of a role-enacting agent.

1.3 Research question

This thesis has an explorative character; the following question will be investigated:

"How can a software agent recognize roles in a multi-agent system?"

The thesis statement is: Software agents are able to recognize the roles that other agents enact by overhearing the conversations between the other agents.

To answer this research question we setup several research tasks involving role recognition as social profiling²:

1. Investigate the definition of a role.

² Social profiling: Making a profile of social behaviour.

2. Investigate the definition of a multi-agent system that uses role-enacting agents.
3. Investigate the definition of communication as an expression for recognizing roles.
4. Investigate recognition methods.
5. Investigate the implementation of the recognition methods.
6. Create a method to compare the recognition methods.
 - a. Create a specification that formally describes each method
 - b. Create an implementation for testing each method.

Solutions for these research tasks will be appear throughout the following sections of the thesis.

1.4 Thesis Scenario

To create a mechanism that can determine the role an agent performs, we created an example we called the “thesis scenario”. This scenario describes the scope of the problem that has been investigated. This is used to test our recognition methods described in section 3.

The thesis scenario is about an agent who has a question, but cannot get the answer inside his own organization. Therefore this agent is going to look for another agent in other organizations that can answer his question. In the other organizations he can only see what agents are saying to each other (like on a web-forum).

Illustration 2 shows an agent observing the dialogs of other agents, which we will call the observer agent. The agent that makes the observation is going to look for the side of dialogs the observing agent is interested in. Our assumption is that in a dialog each agent shows typical behavior in language. This typical behavior exposes the role that an agent performs. Also we assume that placing a role to an agent will help to create better understanding of a dialog.

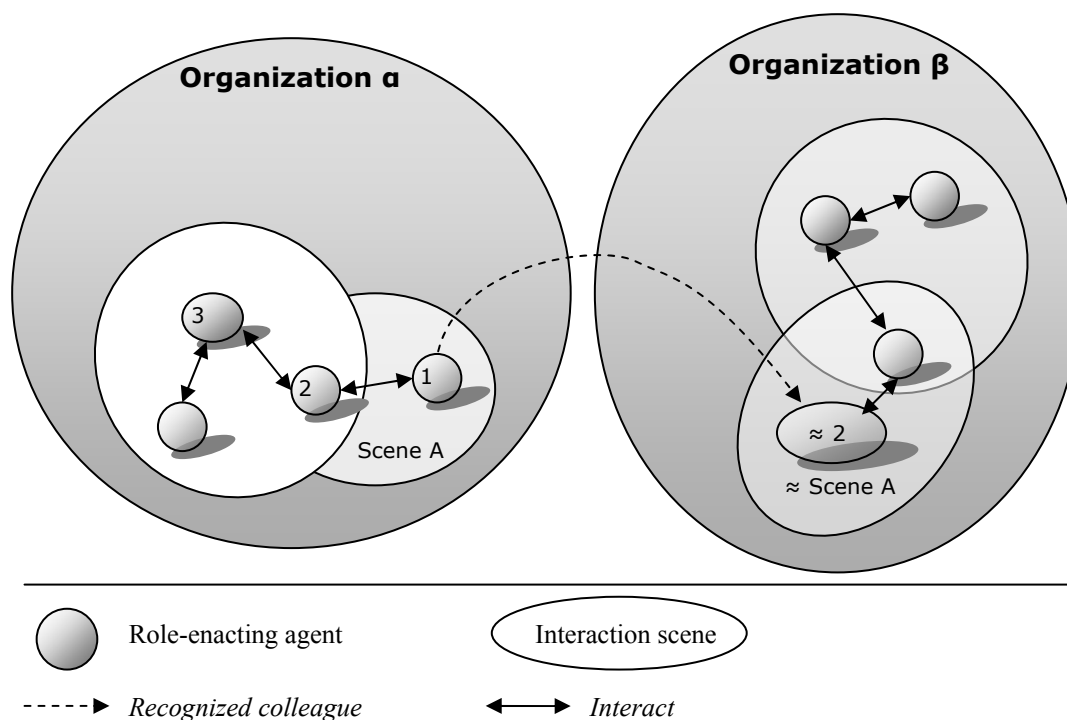


Illustration 2: Colleagues, that are role-enacting agents with similarities from different organizations, are able to meet their objective.

Illustration 2 shows how the *multi-agent system* for this scenario looks like. In this case the architecture of this system is based upon *the OperA model* from [Dignum, 2004]. We see two organizations. In these organizations communication between two or more role-enacting agents takes place within *interactions scenes*. A role-enacting agent is an agent who is currently occupying a role in an organization. An interaction scene is a place where two or more agents interact with each other to work on a goal set by the creators of the organization.

Role-enacting agent 1 from organization α regularly communicates with role-enacting agent 2 in interaction scene A. Agent 1 is not able to meet the objective that is set for his role. He is increasing his scope by looking for a colleague in organization β who resembles role-enacting agent 2.

To find a role, the observer agent 1 first learns to recognize role-enacting agent 2 from the conversations in scene A. Then the observer agent looks at the conversations between the role-enacting agents in organization β . From these observed conversations, agent 1 tries to find out which role-enacting agents show similarities in the conversations he has with role-enacting agent 2.

In the perspective of role recognition we find similarities with a drama play; most of the time when the play starts one does not know the objectives, or the name of the actor playing a role.

