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# Interactive Collaborative Information Systems

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# Preface

The increasing complexity of our world demands new perspectives on the role of technology in decision making. Human decision making has its limitations in terms of information-processing capacity. We need new technology to cope with the increasingly complex and information-rich nature of our modern society. This is particularly true for critical environments such as crisis management and traffic management, where humans need to engage in close collaborations with artificial systems to observe and understand the situation and respond in a sensible way. We believe that close collaborations between humans and artificial systems will become essential and that the importance of research into Interactive Collaborative Information Systems (ICIS) is self-evident.

Developments in information and communication technology have radically changed our working environments. The vast amount of information available nowadays and the wirelessly networked nature of our modern society open up new opportunities to handle difficult decision-making situations such as computer-supported situation assessment and distributed decision making. To make good use of these new possibilities, we need to update our traditional views on the role and capabilities of information systems.

The aim of the *Interactive Collaborative Information Systems* project is to develop techniques that support humans in complex information environments and that facilitate distributed decision-making capabilities. ICIS emphasizes the importance of building actor-agent communities: close collaborations between human and artificial actors that highlight their complementary capabilities, and in which task distribution is flexible and adaptive. To fulfill such a prospect, we need intelligent systems that observe their environment, interpret and fuse information, have learning and decision-making capabilities, and have the ability to work in teams. It also means that we need to study the interaction of humans with their artificial counterparts in such settings and how their information needs can be met. Research within the ICIS projects helps create such views. ICIS combines research from information technology, artificial intelligence and human sciences to obtain a

multidisciplinary foundation from which innovative actor-agent systems for critical environments can emerge.

This book focuses on the employment of innovative agent technology, advanced machine learning techniques, and cognition-based interface technology for the use in collaborative decision support systems. It consists of five parts: *Reinforcement learning*, *Collaborative decision making*, *Computer-human interaction modeling*, *Architectures for distributed agent-actor communities*, and *Case studies and applications*.

**Reinforcement Learning** is the main subject of the first part of the book. This type of learning plays an important role in developing intelligent systems. As the systems (agents) have to realize a common goal, the question is which actions an agent should take in its environment to contribute to that common goal. Reinforcement learning is an established way to implement this process. The core research questions within this subject are the representation of the environment's state, the representation of the actions that an agent can take in a given state, and the long-term reward representing the common goal. Finding the optimal sequence of actions often becomes intractable, especially when the number of agents increases. As a result, approximate solutions are needed. These are discussed in the chapter "*Approximate dynamic programming and reinforcement learning*." This chapter focuses on an approximate solution for reinforcement learning given a representation with continuous states. The next chapter "*Learning with whom to communicate using relational reinforcement learning*" exploits relational structures to come up with strategies for multi-agent systems. The last chapter "*Switching between representations in reinforcement learning*" investigates when to switch online between feature sets representing the states.

The second part of the book addresses **Collaborative Decision Making**. Decision-theoretic models are given to describe cooperation between multiple agents under uncertainty. In these cases the state of the environment given the agent's observations is uncertain and can be described by, for instance, a probability distribution over the states. Approximate solution methods for these cases are presented in the chapter "*A decision-theoretic approach to collaboration: principal description methods and efficient heuristic approximations*". The next chapter "Efficient Methods for Near-Optimal Sequential Decision Making Under Uncertainty" discusses both Bayesian and distribution-free algorithms for sequential decision making when costs are known. A completely different approach is presented in the chapter on "*Ant colony learning algorithm for optimal control*". In this case an optimization heuristic is used and a novel algorithm is introduced in which the artificial agents (ants) work together to collectively learn optimal control policies. The chapter on "*Map-based support for effective collaboration in micro-mobile virtual teams*" presents collaboration in geo-spatial support systems where the maps aid the distributed decision-making process.

The topic of the third part of the book is **Computer-Human Interaction Modeling**. The first chapter of this part "*Affective dialogue management using factored POMDPs*" shows that partially observable Markov decision processes (POMDPs) are appropriate for this purpose and presents a novel approach to develop an affective dialogue model. The next chapter, "*Context-aware multimodal human computer interaction*," presents multimodal interaction techniques including speech, lip movement, facial expression, and text and visual communication. The chapter "*Design issues for pen-centric interactive maps*" focuses on pen-input recognition systems, in particular on new features for classifying iconic gestures. The response of users to intelligent systems showing adaptive behavior is studied in the chapter "*Interacting with adaptive systems*". Human poses are important for both interaction and situational awareness in human-inhabited environments. The last chapter, "*Example-based human pose recovery under predicted partial occlusions*," deals with that topic also in the case when partial occlusion occurs.

The architecture of intelligent decision-making system is an important glue that lets all the parts work together. This is the topic of the fourth part of the book, **Architectures for Distributed Agent-Actor Communities**. Chapter "*Agility and adaptive autonomy in networked organizations*" addresses the tradeoff in a multi-actor environment between global coordination of activities and respecting the autonomy of the actors involved. The underlying principles of multi-agents organizations that are not only hierarchical, but that can also adapt their structure are the topic of the chapter "*Adaptive hierarchical multi-agent organizations*". In the chapter "*Method for designing networking adaptive interactive hybrid systems*" the various architectures for this type of systems are given and a top-down design methodology is introduced. The tradeoff in a multi-actor environment between global coordination of activities and respecting the autonomy of the actors involved forms the topic studied in the chapter "*Agility and adaptive autonomy in networked organizations*".

**Case Studies and Applications** are discussed in the last part of the book. Crisis management is the topic of the first two chapters. In the first chapter, "*A call for sensemaking support systems in crisis management*", the information challenges in crisis management are explored and three case studies are investigated. In the next chapter, "*A distributed approach to gas detection and source localization using heterogeneous information*", a system for early detection of gaseous substances and coarse source estimation is presented by using heterogeneous sensor measurements and human reports. Mobility is the application discussed in the next two chapters. The chapter "*Traffic light control by multiagent reinforcement learning systems*" discusses extensions to improve a basic setting of multiple local controllers (agents), each responsible for the optimization of traffic lights around a single junction using reinforcement learning. The chapter "*Fusing heterogeneous and unreliable data from traffic sensors*" deals with traffic data fusion from a variety of traffic sensors using conservation laws and Poisson statistics. The last

chapter, "*Bayesian networks for expert systems, theory and practical applications*", shows the strength of Bayesian modeling approaches in three different applications: medical diagnosis support, petrochemical decision support and victim identification.

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Amsterdam, Delft,
November 2009

Frans C.A. Groen
Robert Babuška

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**Part II: Collaborative Decision Making**

**Part IV: Architectures for Distributed Agent-Actor Communities**

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