INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team MAIA

Autonomous and Intelligent MAchine

Nancy - Grand Est

THEME COG

Activity Report

2008

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MAIA is a common project to INRIA, CNRS, INPL, Henri Poincaré University and Nancy 2 University through the LORIA laboratory (UMR 7503). For more details, we invite the reader to consult the team web site at http://maia.loria.fr/.

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2. Overall Objectives

2.1. Introduction

MAIA[1] research belongs to the field of *artificial intelligence*: our goal is to model, design and simulate computer based entities (agents) that are able to sense their environment, interpret it, and act on it with autonomy. We mainly work on two research themes: 1) stochastic models and 2) self-organization.

[1] MAIA stands for “MAchine Intelligente et Autonome”, that is “Autonomous and Intelligent MAchine”

2.2. Highlights of the year

François Klein with Vincent Zgueb, Loïc Fejoz, Jacques Henry et Guillaume Reny won awards prize of 9th national competition for aid in innovative technology company creation in the Emerging category for AIMA project : intelligent and communicating domestic assistant.

The AIMA project (Artificial Intelligence and Multi-Agents) stems from work conducted by a multidisciplinary work group in the LORIA computer science research laboratory in Nancy. By associating the "promise of intelligence" - now deemed credible ? and artificial intelligence with the latest scientific advances in systems organisation and communication (multi-agents), we have invented a concept for an intelligent domestic assistant, instructed through collective (or supervised) learning on the Internet. The machine, like man, becomes perfectible through progress made throughout its existence. Artificial intelligence in the service of mankind is the mission statement at AIMA.

MAIA participated to the Second Annual Reinforcement Learning Competition, that happened throughout the academic year 2007-2008. This event is a forum for reinforcement learning researchers to rigorously compare the performance of their methods on a suite of challenging domains. Our team (Bruno Scherrer, Christophe Thiery and Amine Boumaza) participated and won the competition in the most popular domain (Tetris) i.e. the domain where the biggest number of teams were involved.

3. Scientific Foundations

3.1. Introduction

MAIA research covers two research themes: 1) stochastic models and 2) self-organization. This section presents the scientific foundations of these themes.

3.2. Stochastic models

3.2.1. Objectives

We develop algorithms for stochastic models applied to machine learning and decision. On the one hand, we consider standard stochastic models (Markov chains, Hidden Markov Models, Bayesian networks) and study the computational problems that arise, such as inference of hidden variables and parameter learning. On the other hand, we consider the parameterized version of these models (the parameter can be seen as a control/decision of an agent); in these models (Markov decision processes, partially observable Markov decision processes, decentralized Markov decision processes, stochastic games), we consider the problem of a) planning and b) reinforcement learning (estimating the parameters *and* planning) for one agent and for many agents. For all these problems, our aim is to develop algorithmic solutions that are efficient, and apply them to complex problems.

In the following, we concentrate our presentation on parameterized stochastic models, known as (partially observable) Markov decision processes, as they trivially generalize the non-parameterized models (Markov chain, Hidden Markov Models). We also outline how these models can be extended to multi-agent settings.

3.2.2. A general framework

An agent is anything that can be viewed as sensing its environment through sensors and acting upon that environment through actuators. This view makes Markov decision processes (**MDPs**) a good candidate for formulating agents. It is probably why MDPs have received considerable attention in recent years by the artificial intelligence (AI) community. They have been adopted as a general framework for planning under uncertainty and reinforcement learning.

Formally, a Markov decision process is a four-tuple $\langle S, A, P, r \rangle$, where :

- S is the state space,
- A is the action space,
- P is the state-transition probability function that models the dynamics of the system. $P(s, a, s')$ is the probability of transitioning from s to s' given that action a is chosen.
- r is the reward function. $r(s, a, s')$ stands for the reward obtained from taking action a in state s, and transitioning to state s'.

With this framework, we can model the interaction between an agent and an environment. The environment can be considered as a Markov decision process which is controlled by an agent. When, in a given state s, an action a is chosen by the agent, the probability for the system to get to state s' is given by $P(s, a, s')$. After each transition, the environment generates a numerical reward $r(s, a, s')$. The behaviour of the agent can be represented by a mapping $\pi : S \rightarrow A$ between states and actions. Such a mapping is called a policy.

In such a framework, we consider the following problems:

1. Given the explicit knowledge of the problem (that is P and r), find an optimal behaviour, *i.e.*, the policy π which maximizes a given performance criteria for the agent. There are three popular performance criteria to evaluate a policy:
   - expected reward to target,
   - discounted cumulative reward,
   - the average expected reward per stage.
2. Given the ability to interact with the environment (that is, samples of P and r obtained by simulation or real-world interaction), find an optimal behaviour. This amounts to learning what to do in each state of the environment by a trial and error process and such a problem is usually called *reinforcement learning*. It is, as stated by Sutton and Barto [56], an approach for understanding and automating goal-directed learning and decision-making that is quite different from supervised learning. Indeed, it is in most cases impossible to get examples of good behaviors for all situations in which an agent has to act. A trade-off between exploration and exploitation is one of the major issues to address.
3. Furthermore, a general problem, which is useful for the two previous problems, consists in finding good representations of the environment so that an agent can achieve the above objectives.

In a more general setting, an agent may not perceive the state in which he stands. The information that an agent can acquire on the environment is generally restricted to *observations* which only give partial information about the state of the system. These observations can be obtained for example using sensors that return some estimate of the state of the environment. Thus, the decision process has hidden state, and the issue of finding an optimal policy is no more a Markov problem. A model that describes such an hidden-state and observation structure is the **POMDP** (partially observable MDP). Formally, a POMDP is a tuple $\langle S, A, P, r, \Omega, O \rangle$ where

- S, A, P and r are defined as in an MDP.
- Ω is a finite set of observations.
- O is a table of observation probabilities. $O(s, a, s', o)$ is the probability of transitioning from s to s' on taking action a in s while observing o. Here s, $s' \in S$, $a \in A$, $o \in \Omega$.

Hidden Markov Models are a particular case of POMDP in which there is no action and no reward. Based on the mathematical framework, several learning algorithms can be used in dealing with diagnosis and prognosis tasks. Given a proper description of the *state* of a system, it is possible to model it as a Markov chain. The dynamics of the systems is modeled as *transition probabilities* between states. The information that an external observer of the system can acquire about it can be modeled using *observations* which only give partial information on the state of the system. The problem of *diagnosis* is then to find the most likely state given a sequence of observations. *Prognosis* is akin to predicting the future state of the system given a sequence of observation and, thus, is strongly linked to diagnosis in the case of Hidden Markov Model. Given a proper corpus of diagnosis examples, AI algorithms enable the automated learning of an appropriate Hidden Markov Model that can be used for both diagnosis and prognosis. Rabiner [54] gives an excellent introduction to HMM and describes the most frequently used algorithms.

While substantial progress has been made in planning and control of single agents, a similar formal treatment of multi-agent systems is still missing. Some preliminary work has been reported, but it generally avoids the central issue in multi-agent systems: agents typically have different information and different knowledge about the overall system and they cannot share all this information all the time. To address the problem of coordination and control of collaborative multi-agent systems, we are conducting both analytical and experimental research aimed at understanding the computational complexity of the problem and at developing effective algorithms for solving it. The main objectives of the project are:

- To develop a formal foundation for analysis, algorithm development, and evaluation of different approaches to the control of collaborative multi-agent systems that explicitly captures the notion of communication cost.
- To identify the complexity of the planning and control problem under various constraints on information observability and communication costs.
- To gain a better understanding of what makes decentralized planning and control a hard problem and how to simplify it without compromising the efficiency of the model.
- To develop new general-purpose algorithms for solving different classes of the decentralized planning and control problem.
- To demonstrate the applicability of new techniques to realistic applications and develop evaluation metrics suitable for decentralized planning and control.

In formalizing coordination, we take an approach based on distributed optimization, in part because we feel that this is the richest of such frameworks: it handles coordination problems in which there are multiple and concurrent goals of varying worth, hard and soft deadlines for goal achievement, alternative ways of achieving goals that offer a trade off between the quality of the solution and the resources required. Equally important is the fact that this decision-theoretic approach allows us to model explicitly the effects of environmental uncertainty, incomplete and uncertain information and action outcome uncertainty. Coping with these uncertainties is one of the key challenges in designing sophisticated coordination protocols. Finally, a decision-theoretic framework is the most natural one for quantifying the performance of coordination protocols from a statistical perspective.

3.2.3. *Contemporary similar or related work in national and international laboratories*

As far as stochastic planning is concerned, since the mid-1990s, models based on Markov decision processes have been increasingly used by the AI research community, and more and more researchers in this domain are now using MDPs. In association with the *ARC INRIA LIRE* and with P. Chassaing of the OMEGA project, our research group has contributed to the development of this field of research, notably in co-organizing workshops for the AAAI, IJCAI and ECAI conferences. We also maintain vivid collaborations with S. Zilberstein (on two NSF-INRIA projects) and with NASA (on a project entitled "Self-directed cooperative planetary rovers") in association with S. Zilberstein and V. Lesser of the University of Massachusetts, E. Hansen of the Mississippi State University, R. Washington now at Google and A.-I. Mouaddib of CRIL, Lens.

We have been using the strengths of the basic theoretical properties of the two major approaches for learning and planning that we follow, to design exact algorithms that are able to deal with practical problems of high complexity. Instances of these algorithms include the JLO algorithm for Bayesian networks, the Q-learning, TD(λ) and Witness algorithms for problems based on the Markov decision process formalism, etc. While it is true that the majority of this work has been done in the United States, the French research community is catching up quickly by developing further this domain on its own. MAIA has been involved directly in making substantial contributions to this development, notably through our active participation in the (informally formed) group of French researchers working on MDPs. Thus, today there is a growing number of research labs in France with teams working on MDPs. To name a few, Toulouse-based labs such as IRIT, CERT, INRA, LAAS, etc., the GREYC at Caen, and certain Paris-based researchers such as R. Munos (Polytechnique) and O. Sigaud (Paris VI).

Most of the current work is focused on finding approximate algorithms. Besides applying these algorithms to a multi-agent system (MAS) framework, we have also been focusing on reducing the complexity of implementing these algorithms by making use of the meta-knowledge available in the system being modeled. Thus in implementing the algorithms, we seek temporal, spatial and structural dynamics or functions of the given problem. This is time-effective in finding approximate solutions of the problem. Moreover, we are seeking ways to combine rigorously these two forms of learning, and then to use them for applications involving planning or learning for agents located in an environment.

3.3. Self-organization

3.3.1. Objectives

One of the research themes of the MAIA project is that of collective intelligence. Collective intelligence concerns the design of reactive multi-agent systems to collectively solve a problem. Reactive systems made up of simple-behavior agents with decentralized control that despite their individual simplicity are able to collectively solve problems whose complexity is beyond the scope of individuals: "intelligence" of the system can be envisaged as a collective property.

One of the difficulties in the design of reactive multi-agent systems is to specify simple interactions between agents and between them and their environment so as to make the society be able to fulfill its requirements with a reasonable efficiency. This difficulty is proportional to the distance between the simplicity of individuals and the complexity of the collective property.

We are interested in the design of such systems by the transposition of natural self-organized systems.

3.3.2. Approach

Reactive multi-agent systems are characterized by decentralized control (no agent has a knowledge of the whole system) and simple agents that have limited (possibly no) representation of themselves, of the others, and of the environment. Agent behaviors are based upon stimulus-response rules, decision-making is based on limited information about the environment and on limited internal states, and they do not refer to explicit deliberation.

Thus the collective complexity that is observed comes out of the individual simplicity and is the consequence of successive actions and interactions of agents through the environment. Such systems involve two levels of description: one for individual behavior (with no reference to the global phenomena) and one to express collective phenomena.

The design problem can be summarized as the two following questions:

1. Considering a global desired property or behavior, how to build individual behaviors and system dynamics in order to obtain it?
2. Considering a set of individual behaviors and a system dynamics, how to predict (or guarantee) the global property?

Such a methodology is still missing and we contribute to this goal. We organize our research in three parts:

1. understanding collective intelligence by studying examples of such (natural) systems,
2. transposing principles found in example systems to solve problems, and
3. providing a framework to help analyze and formalize such systems.

- The first part is to model existing self-organized phenomena and thus have a better understanding of the underlying mechanisms. For instance, social phenomena in biology provide many examples in which a collection of simple, situated entities (such as ants) can collectively exhibit complex properties which can be interpreted as a collective response to an environmental problem. We have worked with biologists and provided several models of self organized activities in case of spiders and rats.
- Since individual models and system dynamics are established, the second part consists in transposing them in order to solve a given problem. The transposition corresponds to encode the problem such as to be an input for the swarm mechanism ; to adapt the swarm mechanism to the specificities of the problem, and if necessary to improve it for efficiency purpose ; and then to interpret the collective result of the swarm mechanism as a solution of the problem.
- The third part aims at providing a framework to face the following issues:
  1. Is it possible to describe such mechanisms in order to easily adapt and reuse them for several different instances of the problem (*generic or formal description*)?
  2. If such a generic description of a system is available, is it possible to assess the behaviour of the system in order to derive properties that will be conserved in its instantiations (*analyze and assessment of system*)?

3.3.3. Related work in the national / international research community

Among the two principal approaches to the study of multi-agent systems (MAS), we have chosen the line of "collective" systems which emphasizes the notions of interactions and organization. This choice is reflected in the numerous collaborations that we have undertaken with researchers of this field as well as in the kinds of research groups we associate and work with:

- the AgentLink community in Europe, especially the members interested in self-organization, and
- the research group "Colline" (under the aegis of GDR I3 and the AFIA) since 1997.

The approach that we have adopted for the design of multi-agent systems is based on the notion of self-organization, and it notably also includes the study of their emerging properties. If the research community working in this specific sub-domain is even smaller, it is growing interestingly, especially through the work being done at IREMIA (at the University of Réunion), at IRIT (Toulouse), at LIRIS (Lyon), at LIRMM (Montpellier) and in certain other laboratories of USA (D. Van Parunak, R. Brooks for example) and Europe F. Zambonelli (University of Modena, Italy), P. Marrow (British Telecom ICT Research Centre, UK), G. Di Marzo Serugendo (University of Geneva, Switzerland), etc.

Some of these researchers have taken inspiration from biological models to envisage the emerging properties. Principally, this current work is inspired by ant-colony models (such as at LIP6 and LIRMM in France or at the IRIDIA of Brussels in Belgium). We consider the use of the models such as the spider colonies or the groups of rats as an original contribution from us toward this study, it having never been utilized before. It must be mentioned that this field has been influenced to a considerable extent by the work of J.-L. Deneubourg of CENOLI (Brussels) which concerns phenomena involving self-organization in such colonies and the mechanisms of interaction by pheromones in ant-colonies.

4. Application Domains

4.1. Application Domains

In order to carry on its basic research program, the MAIA team has developed and is developing a strong known-how in sequential or distributed decision making. In particular, mathematical tools such as Markov decision processes, hidden Markov models or Bayesian Networks are appropriate and are used by the team for the development of real applications such as:

- monitoring the hydration state of patients suffering from kidney disease.

Through “Dialhemo” (see Sec. 5.1.2), the Maia team helps physicians to monitor patients by using stochastic models.

- elderly fall prevention.
  The PréDICA project (see Sec. 8.1.2) illustrates the use of particle filtering to detect loss of autonomy for elderly people.
- Coordination of intelligent vehicles and swarms of AUV (flying drones), see Sec. [ref:] and 8.1.1).

5. Software

5.1. Software

5.1.1. Bayabox

Bayabox is a toolbox for developping Bayesian networks applications in java. It supports algorithms for exact inference and parameter learning in directed graphicals models with discrete or continuous Gaussian variables. Bayabox is used in the Transplantelic project (see Sec. 7.1).

- *Availability*: Not distributed.
- *Contributors*: Cherif Smaili, Cédric Rose and François Charpillet.
- *Contact*: francois.charpillet@loria.fr

5.1.2. Dialhemo

The Dialhemo project has the objective to develop a remote surveillance and telediagnosis system adapted to renal insufficiency patients treated by hemodialysis. The main objective is to insure people who are treated either at home, or in self-dialysis centers, the same level of security as in hospital. A first software developed in cooperation with Diatelic SA, Gambro and ALTIR is currently experimented in several sites. About 150 patients currently benefit of this first system.

- *Availability*: distributed by Diatelic SA
- *Contributors*: Cédric Rose, François Charpillet
- *Contact*: francois.charpillet@loria.fr

5.1.3. FiatLux

FiatLux is a cellular automata simulator that allows the user to experiment with various models and to perturb them. These perturbations can be of two types. On the one hand, perturbations of dynamics change the type of updating, for example from a deterministic parallel updating to an asynchronous random updating. On the other hand, the user may perturb the topology of the grid by removing links between cells randomly.

FiatLux may be run in an interactive mode with a Graphical User Interface or in a batch mode for longer experiments. The interactive mode is suited for small size universes whereas the batch may be used for experiments involving several thousands of cells. The software uses two external libraries for the random generator and the real-time observations of variables ; it is also fitted with output procedures that writes in Gnuplot, Tex, HTML formats. The software is currently evolving towards the simulation of models of multi-agent systems.

- *Availability*: Download it at http://webloria.loria.fr/~fates/fiatlux.html
- *Contributors*: Nazim Fatès
- *Contact*: Nazim.Fates@loria.fr

5.1.4. FPG

FPG is a probabilistic planner addressing its problem as a reinforcement learning one. Its principle is to optimise a controller's parameters (such as a neural network whose input is a state and whose output is a decision) using a domain simulator. It relies on the libPG library (see below).

Although the first version was meant to deal with concurrent temporal probabilistic planning, current development effort is focusing on FPG-ipc, the version used for the international planning competition.

- *Availability*: http://fpg.loria.fr/
- *Contributors*: Olivier Buffet, Douglas Aberdeen
- *Contact*: olivier.buffet@loria.fr

5.1.5. LibPG

LibPG is a high-speed C++ and modular implementation of many popular RL algorithms for MDPs and POMDPs including: Baxter and Bartlett's GPOMDP/OLPOMDP, Jan Peter's Natural Actor-Critic, Various PSR code from Satinder Singh's papers, Online PSRs from McCracken and Bowling, HMM estimation of hidden state from observations, Finite history methods.

It requires the uBlas components of the Boost library. Having Lapack and Atlas will also open up more features.

- *Availability*: http://code.google.com/p/libpgrl/
- *Contributors*: Olivier Buffet, Douglas Aberdeen
- *Contact*: olivier.buffet@loria.fr

5.1.6. Smaart simulator

In the framework of the 'Smaart' PEA-DGA project (8.1.1) we developped in collaboration with ENST Brest and CRIL Technology a simulator to study collective intelligence. This tool focuses on the simulation of autonomous AUV (flying robots), sensor networks and digital pheromones processes. This simulator extends the TurtleKit-Madkit Plateform developped in Montpellier 2 University, by introducing multi-layer environments and time control functionalities. We also introduced the OpenGL interface to enhance the graphical capabilities. We plan to generalize this tool to the simulation of any kind of robots and swarm systems.

- *Availability*: http://www.loria.fr/~simoniol/smaart.html
- *Contributors*: Olivier Simonin, Arnaud Glad, François Charpillet
- *Contact*: Olivier.Simonin@loria.fr

5.1.7. Cristal simulator

In the CRISTAL project (from Pole de competitivité Véhicule du Futur), we explore new models for safe platooning of autonomous vehicules, see (8.1.3). Studying platooning models and identifying global complex behaviors (e.g. non-linear behaviors such as oscillations and amplification of perturbations) can be addressed through the individual-based simulation approach. As no such tool exists for Platooning, we proposed an original real-time and multi-agent simulator mixing the event-based approach and the influence-reaction model. This later ensuring the simulation of simultaneous actions from several autonomous entities. Finally we developped 1D and 2D graphical viewers, and connexions to 3D world viewers.

- *Contributors*: Arnaud Glad, Olivier Simonin, François Charpillet, Alexis Scheuer
- *Contact*: Olivier.Simonin@loria.fr, Arnaud.Glad@loria.fr

5.1.8. wifibotlib

`wifibotlib` is a low/mid level library for controling WifiBot robots. This library allow interaction with the Wifibot either on the hardware level (setting motor speed, reading sensors) or on a slighlty more abstract level (advance, turn, stop). This software is available on the INRIA gforge at http://gforge.inria.fr/projects/wifibotlib.

- *Availability*: Download at http://gforge.inria.fr/projects/wifibotlib
- *Contributors*: Nicolas Beaufort, Jérôme Béchu, Alain Dutech, Julien Le Guen, François Rispal, Olivier Rochel
- *Contact*: Alain.Dutech@loria.fr

5.1.9. mdptetris

`mdptetris` is a project that gathers our C software related to our works on the game of Tetris. It contains a highly optimized Tetris game simulator and several modules for computing good controllers: exact dynamic programming for a small version of the game, approximate dynamic programming, cross-entropy optimization, CMAES (Covariance Matrix Adaptation Evolution Strategy), UCT (Upper Confidence Tree).

- *Availability*: Download at http://gforge.inria.fr/projects/mdptetris
- *Contributors*: Bruno Scherrer, Christophe Thiery, Amine Boumaza, Olivier Teytaud (from TAO, INRIA)
- *Contacts*: Bruno.Scherrer@loria.fr, Christophe.Thiery@loria.fr

6. New Results

6.1. Stochastic models

The keyword for our recent work on stochastic models is “distributed”. In terms of decentralized control, we have developed exact and approximate methods for the Decentralized Partially Observable Markov Decision Processes framework (DEC-POMDP) and investigated the use of game theory inspired concepts for learning to coordinate. We have also unveiled strong links between optimal and harmonic control and discussed some implications of these links for the distributed computation of optimal trajectories.

6.1.1. Decentralized Stochastic Models

There is a wide range of application domains in which decision-making must be performed by a number of distributed agents that try to achieve a common goal. This includes information-gathering agents, distributed sensing, coordination of multiple distributed robots, decentralized control of a power grid, autonomous space exploration systems, network traffic routing, decentralized supply chains, as well as the operation of complex human organizations. These domains require the development of a strategy for each decision maker assuming that decision makers will have limited ability to communicate when they execute their strategies, and therefore will have different knowledge about the global situation.

Our research team is focusing on the development of a decision-theoretic framework for such collaborative multi-agent systems. The overall goal is to develop sophisticated coordination strategies that stand on a formal footing. This enabled us to better understand the strengths and limitations of existing heuristic approaches to coordination and, more importantly, to develop new approaches based on these more formal underpinnings. One important result is that we are showing that the theory of Markov Decision Processes is particularly powerful in this context. In particular, we are extending the MDP framework to problems of decentralized control.

By relying on concepts coming from the Decision Theory and Game Theory, we have proposed some algorithms for decentralized stochastic models. These new results are related to both planing and learning. This work is supported partly by the INRIA associated team Umass with S. Zilberstein.

6.1.1.1. Building multi-agent systems by the use interactions and RL techniques
Participants: Vincent Thomas, Christine Bourjot, Vincent Chevrier.

This part of our work deals with formal approaches to build multi-agent systems. The DEC-POMDP model, proposed in 2000, was one of the first models to formally describe distributed decision problems, but works have proven that building the optimal policies of agents in this context is in practice intractable (NEXP complexity).

New approaches must then be proposed to tackle this issue differently. Our work is based on the constatation that the interactions among agents which can structure the problem are not explicitely represented. We assume that this can be one of the reasons why solving DECPOMDP is a difficult issue and that representing interactions can open new perspectives in collective reinforcement learning.

Guided by these hypotheses, our contributions consist in

- introducing a new formalism, the Interac-DEC-POMDP, in which interactions are explicitely represented so that agents can reason about the use of interactions and their relationships with others.
- and proposing a new general-purpose decentralized learning algorithm based on heuristic distribution of rewards among agents during interactions to build their policies.

We are currently developping this approach through the concept of social actions as a way to represent actions and interactions in a similar manner. The techniques we propose could constitute a first step to build systems with rational auto-organization property, that is to say, systems whose agent have the ability to organize themselves through interaction depending on the problem they have to solve.

6.1.1.2. Investigation in Game Theory inspired Decentralized Reinforcement Learning
Participants: Raghav Aras, François Charpillet, Alain Dutech.

Studying Decentralized Reinforcement Learning, so as to allow Multi-Agent Systems to learn to coordinate, from the point of view of Game Theory lead us to formulate a new approach for solving Dec-POMDP. This new formulation can also be applied for POMDP.

More specifically, we address the problem of finding exact solutions for finite-horizon decentralized decision processes for n-agents where n is greater than two. Our new approach is based on two ideas:

- we represent each agent's policy in the sequence-form and not in the tree-form, thereby obtaining a very compact representation of the set of joint-policies.
- using this compact representation, we solve this problem as an instance of combinatorial optimization for which we formulate a mixed integer linear program (MILP).

Our new algorithm has been experimentally validated on several classical problems often used in the Dec-POMDP community.

The impact of our new approach is still to be evaluated. If our algorithm is quicker than other exact algorithms, the improvement is not very large. A valid question is to know if our new approach can inspire new algorithms for either infinite-horizon problem or for finding approximate solutions to finite-horizon problems.

6.1.1.3. Convergence and rate of convergence of a simple ant model
Participants: Amine Boumaza, Bruno Scherrer.

It has been known for decades that optimal control can be solved through parallel and distributed algorithms. Such a fact allows one to understand some AI distributed approaches such as ant algorithms. In [9] we built a simple ant model that solves a discrete foraging problem. We described simulations and provided a complete convergence analysis: we showed that the ant population computes the solution of some optimal control problem and converges in some well defined sense. We discussed the rate of convergence with respect to the number of ants: we gave experimental and theoretical arguments that suggest that this convergence rate is superlinear with respect to the number of agents. Such strong analytical results are rare in the multi-agent literature.

6.1.2. Active Sensing

Participants: Vincent Thomas, Olivier Buffet, François Charpillet.

A large class of sequential decision making problems –namely active sensing– is concerned with acting so as to maximize the acquired information. Such problems can be cast as a special form of Partially Observable Markov Decision Processes where 1) the reward signal is linked to the information gathered and 2) there may be no actions with effects on the system.

Preliminary experiments with heuristic approaches have been conducted on a “hide and seek” problem where a predator wants to locate a prey in a complex environment. Using a probabilistic occupancy map, a good heuristic is to keep on moving towards the point of highest occupancy probability.

Active sensing involves dealing with large state spaces, especially when numerous sensors (which can be seen as agents) have to collaborate. This research will be further developped in the context of a project concerned with the low cost identification of defaults in aeronautics parts made of composite materials by selecting the observations to perform (which sensor, where, at which resolution).

6.1.3. Addressing large optimal control problems

6.1.3.1. Improving Approximate Dynamic Programming Solutions

Participant: Bruno Scherrer.

M. Petrik (University of Massachusetts) is an external collaborator.

Most algorithms for solving Markov decision processes rely on a discount factor, which ensures their convergence. It is generally assumed that using an artificially low discount factor will improve the convergence rate, while sacrificing the solution quality. In [25] we demonstrate that using an artificially low discount factor may in fact significantly improve the solution quality, when used in approximate dynamic programming. We propose two theoretical explanations of this phenomenon. The former justification follows directly from the standard approximation error bounds: using a lower discount factor may decrease the approximation error bounds. However, as these bounds are loose, their decrease does not entirely justify the improved solution quality. We thus propose another justification which applies when the rewards are received only sporadically: in such a case we can derive tighter bounds, which support a significant improvement in the solution quality with a decreased discount factor.

6.1.3.2. Parallel implementation of harmonic control

Participants: Amine Boumaza, Bruno Scherrer.

B. Girau (CORTEX Team, LORIA) is an external collaborator.

In [30], we have worked on the implementation of harmonic control (a specialized form of optimal control for robot navigation) on an embedded massively parallel hardware architecture: we solve the navigation problem that computes trajectories along a harmonic potential, using an FPGA implementation. This architecture includes the iterated estimation of the harmonic function. The goals and obstacles of the navigation problem may be changed during computation. The trajectory decision is also performed on-chip, by means of local computations of the preferred direction at each point of the discretized environment. The proposed architecture uses a massively distributed grid of identical nodes that interact with each other within mutually dependant serial streams of data to perform pipelined iterative updates of the local harmonic function values until global convergence. We have extended this architecture in [40] so that it be able to tackle larger environments while optimizing computation time. When the size of the environment exceeds the resource available on the circuits, it is split into several block. Then, iterated updates of the harmonic function are performed in a block-synchronous mode that takes advantage of large embedded SRAM memory resources.

6.1.3.3. New world records for the game of Tetris

Participants: Bruno Scherrer, Christophe Thiery.

The game of Tetris is a very large (and therefore challenging) optimal control problem. In [12], we consider the problem of designing a controller for this game. We explain there that comparing the performances of several controllers must be done with great care, as the game scores have a huge standard deviation, and as subtle implementation details can have a significant effect on the resulting performance. We also use the cross-entropy method to tune a rating-based one-piece controller based on several sets of features among which some original features. This approach leads to a controller that outperforms the previous known results. On the original game of Tetris, we show that with probability 0.95 it achieves at least $910,000 \pm 5\%$ lines per game on average. On a simplified version of Tetris considered by most research works, it achieves $35,000,000 \pm 20\%$ lines per game on average.

6.1.4. Probabilistic Planning

Participant: Olivier Buffet.

Douglas Aberdeen (Google Zürich) and Sylvie Thiébaux (The Australian National University) are external collaborators.

Classical automated planning differs from Markov Decision Processes in that 1) transitions are deterministic and 2) the system is modelled in a structured –hence compact– manner using state variables. Here, *Probabilistic Planning* represents the research field trying to solve problems involving both a structured representation and uncertainties in the system's dynamics.

6.1.4.1. The Factored Policy-Gradient (FPG) Planner

A key issue in probabilistic planning is to exploit the problem's structure to make large instances solvable. Most approaches are based on algorithms which explore –at least partially– the state space, so that their complexity is usually linked to the number of states. Our approach –a joint work with Douglas Aberdeen– is very different in that it is exploring a space of parameterized controllers. By chosing factored controllers (one sub-controller per action) with state variables as inputs, we strongly reduce the complexity problem.

In practice, the *Factored Policy-Gradient* (FPG) planner uses a policy-gradient reinforcement learning algorithm (coupled to a simulator) to optimize a controller based on a linear network (or a multi-layer perceptron). Although suboptimal, FPG proved to be very efficient by winning the probabilistic track of the international planning competition 2006. One of its strengths lies in generalization: an action known to be good in certain states will be prefered in similar states. This novel approach will be presented in full details in [3] (accepted for publication) and is part of a book chapter on operations planning [44] co-authored by Sylvie Thiébaux.

Recent work includes comparing FPG with a probabilistic planner (named FQL) based on a Q-learning algorithm. Although both algorithms use similar function approximators, FQL fails to provide good policies. Current research looks at using more appropriate policy-search algorithms based on population algorithms of actor-critic algorithms.

6.1.4.2. Defining New Benchmark Problems

As one of the two organizers of the uncertainty part of the international planning competition 2008, Olivier Buffet had to work on proposing new benchmark problems for probabilistic planning. This led to a research work studying the various types of difficulties that can be encountered, knowing that many are different from the difficulties in classical planning.

6.1.5. Reinforcement Learning in Robotics

Participant: Alain Dutech.

Nicolas Beaufort and Jérôme Bechu during their internship.

Applying Reinforcement Learning on a robot is a difficult task because of the following limitations:

- Learning must deal with continuous state and action spaces.
- Learning must able to take advantage of very few experiences as the cost to get new experiences can be high, especially when time is concerned.

Nevertheless, by taking inspiration from the work of W. Smart [55], we investigated the notion of *efficient* reinforcement learning. We designed a simple artificial experiment where a WifiBot has to detect and move to a given target before stopping in front of it. Provided the robot can detect and identify the target with its camera, showing the robot a path to the target 10 or 20 times is enough for it to *learn* to do it by itself. This was achieved by combining Peng's eligibility traces [53] with locally weighted approximation of the Q-Value of the MDP underlying the behavior of the robot.

As a side effect of this work is the creation of a low/mid level library for controling WifiBots (TM). This library allow interaction with the Wifibot either on the hardware level (setting motor speed, reading sensors) or on a slighlty more abstract level (advance, turn, stop). This software is available on the INRIA gforge at http://gforge.inria.fr/projects/wifibotlib.

6.1.6. Stochastic method application on Intelligent Transportation System

Participants: Maan El Badaoui El Najjar, François Charpillet, Cherif Smaili.

6.1.6.1. Introduction

In order to obtain an autonomous navigation system for intelligent transportation system or to develop Advance Driver Assistance Systems (ADAS), vehicles embedded systems have to complete several tasks: localization, obstacle detection, trajectory planning and tracking, lane departure detection. In our work, we study approaches based on the use of stochastic method for multi-sensors data fusion in taking into account especially the integrity of fusion results which can be defined as the confidence which one can be placed in the correctness of the estimation supplied by the whole system. In addition, real-time aspect of integrity for a multi-sensor fusion method is very challenging because it has to take into account the degradation of sensors measurements, [8]. There are several problems to tackle like the convergence robustness and divergence detection of multi-sensors fusion methods due to sensors measurements errors.
In these applications, our work tries also to study the utility of new information sources like geographical 3D model managed in real-time by 3D Geographical Information System (3D-GIS). In the last two years, we perform approaches for Mono and Multi-vehicles localisation, map matching and obstacle detection. Experimental results with real data are used to validate the developed approach and demonstrators are under development.

6.1.6.2. Geographical 3D model / 3D-GIS

A 3D-GIS was developed to manipulate the textured geographical 3D model (also called 3D city model or 3D virtual model in the literature). The 3D-GIS inputs are the 6 degrees of liberty of the virtual camera in the model. The developed outputs are: virtual image which is the view of the virtual camera, the corresponding depth image, a binary text file with the distance between the camera and each pixel of the virtual image, the 3D visible segments in a Bitmap image. This 3D-GIS was developed in partnership with the Tecnomade company. In the last year, we have developed also our self 3D-GIS adapted with two geographical 3D models of two experimental sites (INRIA Nancy, Grand Est site and Stanislas square in the down town of Nancy).

6.1.6.3. Geo-localisation with 3D-GIS

A key issue of many intelligent transportation applications is precise dynamic localisation in urban environment. The main sensor for outdoor localisation is GPS fused with odometer or INS using for example UKF (Unscented Kalman Filter) or Hybrid Bayesian Network (HBN). In order to overcome known GPS positioning problems (satellite mask, wave's multi-path), we developed a new pose observation which uses the geographical 3D model, managed by 3D-GIS. This observation is based on the 2D/3D matching between a real image captured by an on-board video camera and 3D information provided by the 3D-GIS [17].

6.1.6.4. Map matching and Mono/Multi-vehicles Geo-localisation

Map-matching is a technique that attempts to locate an estimated vehicle position on road network. Many map-matching algorithms have been developed and widely incorporated into GPS/DR vehicle navigation systems for both commercial and experimental ITS applications. However, simply combining GPS and DR cannot provide an accurate vehicle positioning system on a digital map. For this reason, we use the digital map as an observation to improve reliability of map-matching.

In our work, we propose to use Hybrid Bayesian network for map-matching and that for several reasons. Generally, to identify the correct road segment on which the vehicle is running and to determine the vehicle location on the segment is treated separately. In the proposed approach these two tasks are handled together in the framework of Dynamic Bayesian network (DBN).
In addition and in order to take into account the error of information sources (several sensors or database) used in this application, we introduce a new concept to manage probability and to model information sources uncertainty in the context of BN. Generally, map-matching methods founded in the literature use a several variant of Kalman filter or fuzzy logic for merging data and estimate the position of the vehicle. Kalman filter requires restricted topology and all conditional probability distribution (CPD) to be linear-Gaussian, whereas a BN allows more general graph structures with arbitrary CPDs (see thesis of Murphy). In the other hand, monitoring the positioning integrity is indeed crucial for many land vehicle applications. A way to ensure that the positioning information is valid is to have a multilayer series of checks. It is important to have integrity checking at the end-user level because this is the only place where all information used to form the position solution is present. The most robust way to validate the output of the positioning method is to manage all hypotheses while in integrating the history of the vehicle motion and all sensors uncertainty in real time.
Many researchers use heuristic methods to choose the most likely segment if several segments are candidates. In the BN framework, we are not obliged to select a most likely segment. We treat all probable segments like a multi-modal observation [8]. In this case, multi-estimation for the position is generated by the algorithm. Therefore, we are sure to do not neglect any hypothesis (probable segment).
Concerning the multi-vehicle localization method presented in this work, it can be seen like an extension of the Mono-vehicle method, in the sense that we have duplicated the BN used to fuse measurements sensors to localize one vehicle for several ones. Then, we have added vehicles inter-connection to represent finally the train of vehicles in the context of Bayesian network. The multi-sensor fusion of leader?s vehicle measurements with the Lidar range finder measurement in Bayesian network formalism can provide continuous and accurate geo-position of followers? vehicles. Thus this data fusion method allows computing an accurate follower?s position without using an expensive sensor on each follower?s vehicles.
The proposed method for multi-sensors fusion for multi-vehicle localization in train configuration permits to implement control law based on near-to-near approach, which can be seen as a first step in platoon control design. For both proposed approach, real data was used in this work to test and quantify the quality of results.

6.1.6.5. Obstacle detection approach

A method for detection and geo-localisation of obstacle using the 3D-GIS is also developed. The application principle is to extract obstacles by comparing two images: the image captured by the embedded camera where possible obstacles appear and the virtual image provided by 3D-GIS where real obstacles are not present. The depth information permits then to compute the distance between the detected obstacle and the vehicle and to geo-localise this obstacle [13]. The distance obtained with this method is validated with laser range finder measurements. A real-time demonstrator is in progress.

6.2. Self-organization

There are many situations which require us to deal with strongly interacting, massively parallel and decentralized systems. This is what brought us to work in the field of self-organized systems. These systems are described by various formal models such as reactive multi-agent systems or cellular automata. The work of the team mixes both theoretical and experimental approaches and seeks to provide applications in the field of image processing, localization and tracking, and bio-inspired problem solving.

6.2.1. Multi-agent modeling of the impact of user behavior in dynamical networks

Participants: Vincent Chevrier, Julien Siebert.

L. Ciarletta (Madynes team) is external collaborator for this action.

In distributed, dynamic networks and applications, such as Peer-to-Peer (P2P), users'behaviour and quality of service (or quality of experiment) are known to influence each other. In worst cases these mutual influences could lead the system to crash. We propose a novel approach to model relationships between users and QoS. It is based upon multi-agent systems in order to study the impact of situated behaviours on the global network and to integrate different levels of representation (users'behaviour, overlay protocols, network topology). We implemented this proposal by adapting an existing simulator (PeerfactSim) and undertook experiments to study the influence of the rate of cooperation of user and the rate of pollution of data on the functioning of the network. Results[27], [32], [35], [33] are the proposition of this multi-model approach and the basis of a simulation framework extending a public domain simulator.

6.2.2. *Using global patterns to control a reactive multi-agent system*

Participants: Christine Bourjot, Vincent Chevrier, François Klein.

Reactive multi-agent systems present global behaviours uneasily linked to their local dynamics. When it comes to control such a system, usual analytical tools are difficult to use and specific techniques have to be engineered. We proposed an experimental and dynamical approach to control the global behaviour of a reactive multi-agent system. We used reinforcement learning tools to link global information of the system to control actions. In [21], we proposed to use the behaviour of the system as this global information. The controllability is evaluated in terms of rate of convergence towards a target behaviour. We compare the results obtained on a toy example with the usual approach of parameter setting.

6.2.3. *Study of a deterministic nonlinear way for ant algorithms modeling*

Participants: Rodolphe Charrier, François Charpillet, Christine Bourjot.

This work is an attempt to formalize swarm intelligence under the angle of the science of complex systems. Its purpose is to design a generic model of situated reactive multi-agent systems capable of explaining collective behaviors resulting from auto- organization mechanisms such as those observed in natural systems like birds flocking or ants foraging.

The model we propose integrates decisional mechanisms inspired from coupled map lattice (CML) imagined in 1986 by the physicist Kuhiniko Kaneko for the study chaotic space-time phenomena. Roughly speeking CML can be seen as cellular automata in continuous space in which the transitions are controlled by chaotic nonlinear functions like the logistic function (the logistic map is a polynomial mapping, often cited as an archetypal example of how complex chaotic behaviour can arise from very simple non-linear dynamical equations).

This source of inspiration has several advantages: the mathematical framework is well suited to model dynamical systems such those we want to study and interesting mathematical results are available.

In this framework we have designed an original model, called Logistic Multi-agent system [cite:CHARRIER:2007:INRIA-00168313:1, CHARRIER:2007:INRIA-00168315:1, CHARRIER:2007:INRIA-00168317:1, CHARRIER:2007:INRIA-00170613:1]. This model combines a coupled map lattice and the influence- reaction model originally proposed by Jacques Ferber and Jean-Pierre Müller.

6.2.4. *Cellular Automata as a model of Complex Systems*

Participant: Nazim Fatès.

Cellular automata can be seen as the environment part of a multi-agent system. Formally, they are discrete dynamical systems and they are widely used to model natural systems. Classically they are run with perfect synchrony; *i.e.*, the local rule is applied to each cell at each time step. A possible modification of the updating scheme consists in applying the rule with a fixed probability, called the synchrony rate.

6.2.4.1. Phase transitions

It has been shown in a previous work that varying the synchrony rate continuously could produce a discontinuity in the behaviour of the cellular automaton. In [5], we investigated the nature of this change of behaviour using intensive numerical simulations. We showed that the phenomenon is a phase transition whose critical exponents are in good agreement with the predicted values of directed percolation.

6.2.4.2. A bio-inspired model of aggregation

These phase transitions were also observed in the context of bio-inspired computing. We examined how to model cellular societies such as the *Dictyostelium Discoideum amoebae*. We proposed a simple model of their behaviour, which allows to group a great number of agents at the same localisation without any need for a centralised control [51].

6.2.4.3. A Mathematical analysis of asynchronous two-dimensional systems

This is a joint work with L. Gerin from the IECN mathematics institute of Nancy ; it aims at exploring the behaviour of asynchronous two-dimensional cellular automata with two states and simple transition rules. Using the theory of stochastic process, we analysed the convergence properties of various rules and showed that different types of behaviours were observed. The maximum convergence time was estimated and it was shown that these systems display quick convergence (polynomial) or very long convergence (metastability) [50].

6.2.5. The influence-reaction method for modelling multi-agent systems

Participants: Vincent Chevrier, Nazim Fatès, Olivier Simonin.

It is a well-known problem that there exists no agreement in the scientific community on how multi-agent systems should be defined formally. The practise so far has been either to use an *ad hoc* formalism to describe a model, or, to present a model informally and to analyse the simulations obtained with a particular simulation platform. As a result, two major drawbacks appear : (a) reproducing the experiments on another platform is difficult, if not impossible, since one needs to have all the implicit parameters of a simulation in hand (e.g., the order of updating of the agents), (b) it is not clear whether the behaviour observed is due to the rules defining the agents and the environment or due to the "simulation scheme" that governs the interaction between the components of a multi-agent system.

To tackle this problem, we focused our efforts on two directions:

- We examine what is the relationship between cellular automata and multi-agent systems. A first method to automatically translate a reactive multi-agent model into a cellular automaton was proposed in [29].
- We propose a framework for describing multi-agent systems as discrete dynamical systems. As a starting point, we are restricted this study to very simple agents where the cells of environement are binary and where the agent's actions are restricted to turning left/or right, moving forward and changing the state of the cells on which they are located.

6.2.6. Intelligent Environments and Pheromone-based Algorithms

Swarm intelligence emerges from the interactions performed by a large number of simple agents. In this context, we are interested by algorithms relying on the marking of the environment, which is used as a common memory (a well-known example is pheromone droped by ants to perform indirect communication). Such an approach is now called digital pheromones, as marks are values that can be read and written by agents in cells of a discrete environment. In this framework we address the following challenge: understanding and designing self-organized systems, deploying physically these models and enable their interaction with real robots.

6.2.6.1. Theoretical study of Ant-based algorihms for the Patrolling problem

Participants: Arnaud Glad, Olivier Simonin, François Charpillet, Olivier Buffet.

We proposed in 2007 an original algorithm, called EVAP, to deal with multi-agent patrolling, which is based only on the pheromone evaporation process (cf. ICTAI'07, JFSMA'07). During the simulations carried out to measure the performances of EVAP, we identified that the system can self-organizes towards an optimal behavior. In particular we observed that agents tends to follow stable cycles corresponding to a hamiltonian covering of the environment. We then established the mathematical proof that the system can stabilize only to a set of cycles, one per agent, having the same lenght, cf. publication in ECAI'2008 [19]. Moreover, we recently introduced new heuristics in the agent behavior that improves dramaticaly the time for convergence. This work is in line with the PhD thesis of Arnaud Glad (since dec. 2007) which concerns the understanding and the optimization of self-organization resulting from such algorithms.

6.2.6.2. Intelligent Tiles

Participants: Olivier Simonin, François Charpillet.

Swarm intelligence, relying on digital pheromones and more generally on active environments, remains until now theoretical models studied in simulation. We aim at addressing the scientific and technological challenge of putting such multi-agent models in the real world. For this purpose we propose to pave the floor with “communicating” and autonomous *t*iles. Each tile is defined to ensure communication with its neighbours, and to allow a possible supported agent to read and write information. As a consequence tiles can be exploited to extend agents’ perceptions and communications, and to physically implement bio-inspired algorithms. A first Tile model has been defined and evaluated through the rewriting of the Satisfaction-Altruism model (Simonin & Ferber 2001). We developped a multi-thread architecture to emulate the tiles functionning. These first results are presented in a paper which is accepted for publication in the International Conference ICAART’09 [24]. In 2009, we plan to perform some experiments involving real mobiles robots that will perceive and communicate through the emulated tiles.

6.2.6.3. Collective construction of artificial potential fields (APF)

Participants: Olivier Simonin, François Charpillet.

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In the context of path-planning, we rewrited the classical Artificial Potential Field (APF) computation proposed by Barraquand & Latombe in an asynchronous and collective construction by reactive agents. We proved this model builds an optimal APF while dealing with the collective forraging problem (research and transport of resources by a set of autonomous agents/robots). In 2008, we extended simulations and measures by introducing dynamic environments (moving obstacles). Then we shown that our approach is more efficient in static environments than the classical ant algorithm, and need to be extended with a behavioral heuristics to compare with it in dynamic environments. These results are submitted to TAAS Journal. We done this work in collaboration with Eric Thierry from LIP, ENS Lyon. (see RR INRIA 2007).

6.2.7. Safe decentralised control of intelligent vehicles (the platooning task)

Participants: Alexis Scheuer, Olivier Simonin, François Charpillet, Arnaud Glad.

We consider decentralised control methods to operate autonomous vehicles at close spacings to form a platoon. We use bio-inspired models, based on the flocking techniques, allowing each vehicle to compute its control from its local perceptions. Such decentralised approaches provide robust and scalable solutions.

However, collision avoidance has never been studied for these approaches. Stability is also an open problem for platoon of more than four vehicles: do oscillations appear when the motion of some vehicles are disrupted?

6.2.7.1. Formal specification and verification of situated multi-agent systems

This action is related to the ANR project TACOS (see Sec. 8.1.4), which started in January 2007. It is a collaboration with the DEDALE project of LORIA Lab. We are interested in specifying and studying situated multi-agent systems. This is an open problem, which is particularly interesting when designing critical decentralised systems. Our approach relies on the formal specification – in B language – of the influence-reaction model, which is a generic formulation of multi-agent systems proposed by Ferber & Muller in 1996.

This specification can be instantiated to prove properties for specific multi-agent systems. We considered as example the platooning task: we proved that the Daviet and Parent constant coefficient controller [52] ensures collision avoidance with a simple longitudinal platooning model (perceptions and actions are synchronous and without error). This work is submitted to International Journal Jaamas and we are extending the approach to deal with lateral platooning and noise/errors in models.

6.2.7.2. Safe decentralised control reducing inter-vehicle distances

We studied a more realistic model of the platooning task, introducing a delay between perceptions and actions and noise/errors in perceptions and actions. Within this modelling, Daviet and Parent controllers [52] show their limitations. We thus proposed a high-level controller, which transforms any controller into a safe controller, i.e. avoiding collision, and we proved this property. This work is presented in an article submitted to the 2009 IEEE International Conference on Robotics and Automation (ICRA'09). An extended version of this article, with detailed proof, is available as INRIA research report [48].

6.2.7.3. Coupling lateral and longitudinal controls

The work presented in the two previous paragraphs focuses on longitudinal control: all the vehicles are moving along a fixed path. When vehicles move in a two dimension space, a lateral controller is needed to steer the vehicles. While lateral and longitudinal controls can be considered separately, the longitudinal control should be done after the lateral control: while turning, a higher inter-vehicle distance is needed to avoid collision. A lateral control only based on individual sensors will be studied and the current longitudinal control adapted to curvilinear distances. First steps of this work already began, in particular through the cooperation with the team of Pr. D. Matko from Ljubljana University (PHC Egide 8.2.2) where an approach based on reference-path control was explored, see [23].

7. Contracts and Grants with Industry

7.1. Collaboration with Nephrolor: Transplantelic

Participants: François Charpillet, Cédric Rose.

We continue to develop telemedicine solutions for End Stage Renal Chronic patients. Transplantelic is a telemedicine project which aims at improving the follow up for patients with kidney graft. A new system is being developed and a clinical trial in a three year project is scheduled. Transplantelic just started in the beginning of 2006 and it is funded both by Region Lorraine and ARH. We have developed a new expert system using Bayabox (see Sec. 5.1.1) for the surveillance of patients with graft kidney.

7.2. Multi-agent simulation of public transportation

Participant: Vincent Chevrier.

The CUGN (communauté urbaine du grand nancy) possesses a huge amount of data collected from its public transportation network. These data are used to monitor and regulate in real time the trafic of buses and tramways.

In this collaboration, we studied the possibility to integrate these data in a multi-agent simulator in order to reproduce in differed time the functioning of a part of the network and to propose indicators that help to analyse the functioning of the system. A first part of the work was dedicated on the extraction of relevant data from raw ones and on their integration in the simulator. This year, we studied different views to provide and accurate and meaningfull understanding of the transportation system.

7.3. PAUSA

Participants: Amine Boumaza, François Charpillet, Vincent Chevrier, Guillaume Muller.

PAUSA (Partage d'autorité dans le système aéronautique) Partners: Eurisco, Airbus, DSNA/SDER, Dassault Aviation, Thales Avionics, LAMIH, ONERA, OKTAL, LORIA. This project aims at investigating the rôle of human factors in Air trafic Management in the context of a consequent increase of trafic as foreseen for the next 20 years. MAIA is concerned by the multi-agent modeling of the air trafic system from an organizational point of view.

8. Other Grants and Activities

8.1. National initiatives Actions

8.1.1. PEA-DGA SMAART

Participants: Olivier Simonin, François Charpillet, Arnaud Glad.

The aim of this project is twofold: (i) designing bio-inspired coordination mechanisms for swarms of Unmanned Aerial Vehicles (UAV), (ii) studying sharing authority between operators and swarms of robots/UAVs. After designing a swarm control for UAVs, i.e. adapting the EVAP algorithm 6.2.6, we conduced statistical analyses showing that the proposed model is robust to perturbations and provides a very good average performance to the multi-agent patrolling problem (see 2007 publications). Concerning sharing authority, we proposed original interface to manipulate pheromones fields and groups of UAVs. The whole system was experimented with operators at ENST Brest. Statistics and interviews show that operators do not reach to improve the whole system when dealing with the patrolling task. We identified a set of key points to improve human understanding and control of swarm of robots, see [22], [31]. The SMAART project ended successfully in July 2008, providing in particular a generic UAVs simulator (see 5.1.6). We currently applying to a new project with ENST Brest to define new way of interaction between humans and swarm systems.

8.1.2. RNTS PROJECT PréDICA

Participant: Jamal Saboune.

The program PréDICA is related to the theme of falls in the elderly, with aspects related to both prediction and detection included. The program is a continuation of the exploratory project PARAChute, which was financed by the RNTS in 2003, which included only those aspects related to fall prediction:

- Definition of the characteristic parameters of a static balance “signature” using the stabilogram analysis produced by a personal scale.
- Analysis of typical gait using a camera without images.

Given that the end result of an exploratory project is to demonstrate the feasibility of a method and/or a technology, the PARAChute project attained its aims quite well:

- Realization of a prototype to analyst static balance.
- Development of an algorithm to track movement during gait.

The results arising from this exploratory project enable a change into a pre-competitive stage for the technologies developed, as well as to incorporate a multi-center evaluation in order to validate the parameters extracted from the balance and gait signatures. It seems that the transformation into a pre-competitive project is the “raison d’être” of a completed exploratory project.

The underlying rationale for the PARAChute research project remains the same as when the initial project was proposed. In addition, the heat wave of summer 2003 in France provided further evidence were any needed of the severity of the problem, in particular the need for innovative approaches in terms of non-intrusive observation of the elderly in their daily environment.

8.1.3. CRISTAL

Participants: Olivier Simonin, Alexis Scheuer, Arnaud Glad, Cherif Smaili, François Charpillet.

Partners: Lohr Transitec, GEA, VULog, UTBM, MaIA, TRIO, DEDALE, IMARA, Lasmea.

This project is one of the major projects of the Alsace Franche-Comté competitiveness cluster on automotive systems. This Cristal project is leaded by Lohr Industry whose has conceived the tram chosen for the city of Clermont-Ferrand(Translohr). Lohr is convinced that this kind of system conceived for transportation of huge number of people can be completed by an individual transportation system made up of small electric vehicles for short downtown movements. One key issue of such a system is platooning (convoy of automatic vehicles) and certification. This project has been funded by FCE (1Meuros). During the year 2008, we studied the Daviet & Parent approach for platooning, showing the limit of the model when the number of vehicles grows. For this purpose we developped a multi-agent simulator 5.1.7 allowing the study of models' parameters and robustness (via simulation of noise on sensors and actuators). We presented these results in the first annual report of the Cristal Project and submitted a publication to ICRA'09 Conference.

8.1.4. ANR TACOS Trustworthy Assembling of Components: frOm requirements to Specification

Participants: Olivier Simonin, Alexis Scheuer, François Charpillet.

TACOS is an ANR-SETIN project started in january 2007 and managed by the DEDALE-Loria team (Pr. J. Souquieres). Other partners are LACL LAS (Paris 12), LAMIH ROI-SID (U. Valenciennes) and LIFC TFC (U. Franche-Comté).

This project proposes a components based approach for the specification of trustworthy systems. It consists in requirement expression to formal specification, by using or adapting existing tools. The applicative domain is the transport, by focusing on distributed and embedded systems that have functional and non functionnal properties relating to time and availability contraints. Maia is involved in the definition of the case-study, which consists in a platoon of autonomous vehicules. In order to study such systems we defined in collaboration with DEDALE a generic B expression of the Influence/Reaction model, that was proposed by Ferber & Muller in 1996. The I/R model allows to clearly represent dynamics in situated multi-agent systems. Our proposition extends the approach to its formal writting and the ability to prove some properties by using B provers. We illustrated this framework by studying the bio-inspired platooning model proposed by Maia (cf. Sec. 6.2.7). This work is currently submited to JAAMAS journal and more detailled in the internal report INRIA-00173876. We now work on improving the framework, involving simulation and study of the properties of the system.

8.1.5. ANR project MAPS

Participant: Alain Dutech.

Rooted at the crossroad of neuroscience and computer neuroscience, this project aims at increasing our understanding of the brain. By studying, modeling and simulating the behavior of *orienting the gaze* from different points of view (neuroscience, behavior psychology and artificial intelligence), we plan to increase our understanding of the spatial and temporal dynamics of cortical maps. MAIA is more particularly involved in using reinforcement learning in a high level simulation to validate some functional concepts and then in trying to formulate biologically plausible low-level mecanism that could support the reinforcement learning paradigm.

8.1.6. The INRIA ARC AMYBIA

Participant: Nazim Fatès.

The project gathers researchers from the MAIA team (Nazim Fatès), the CORTEX team (Bernard Girau), the ALCHEMY team (Hugues Berry). The context of our collaboration is the definition of innovative schemes of decentralised and massively distributed computing. We aim at contributing to this at three levels:

- At the modelling level, we think that biology provides us with complex and efficient models of such massively distributed behaviours. We start our study by addressing the decentralised gathering problem with the help of an original model of aggregation based on the behaviour of social amoebae. learn more...

- At the simulation level, our research mainly relies on achieving large scale simulations and on obtaining large statistical samples. Mastering these simulations is a major scientific issue, especially considering the imposed constraints: distributed computations, parsimonious computing time and memory requirements. Furthermore its raises further problems, such as: how to handle asynchronism [Fat04], randomness and statistical analysis? learn more...
- At the hardware level, the challenge is to constantly confront our models with the actual constraints of a true practise of distributed computing. The main idea is to consider the hardware as a kind of sanity check. Hence, we intend to implement and validate our distributed models on massively parallel computing devices. In return, we expect that the analysis of the scientific issues raised by these implementations will influence the definition of the models themselves.

Details are available at: http://www.loria.fr/~fates/Amybia/project.html

8.1.7. COMAC

Participants: Vincent Thomas, Olivier Buffet, François Charpillet.

The COMAC[2] project, currently in its starting phase, is part of the MIPI[3] research effort. The main objective of the project is to develop diagnosis tools for the low cost identification of defaults in aeronautics parts made of composite materials.

Our work will focus more precisely on information gathering problems involving active sensors, i.e. an intelligent system which has to select the observations to perform (which sensor, where, at which resolution).

Related work has been conducted in the field of Active Sensing (Section 6.1.2). We are currently examining applications for a PhD position associated with the project.

8.1.8. PEPS - Vers une formalisation des théories des organisations

Participants: Christine Bourjot, Vincent Chevrier, Vincent Thomas.

The main challenge of this STI2 PEPS (Projets Exploratoires Pluridisciplinaires) is to gather researchers from several fields (sociologist, specialist of theory of organization and computer scientists) to collaborate on the understanding and the modelling of social organizations.

Whereas an important number of collaborations has been undertaken between computer scientists and ethologists to understand and model biological collective phenomena, few similar works have been conducted in sociology. The main objective of this STI2 PEPS (Projets Exploratoires Pluridisciplinaires) proposed by Pascal Roggéro (Université Toulouse 1) and Christophe Sibertin-Blanc (IRIT) is to gather multi-agent community and researchers from sociology (sociologists, specialists of theory of organization) to collaborate on the understanding and the modelling of social organizations.

As an exploratory project, this project is very prospective. It focuses on presenting organization theories and multi-agent models that could be suited for social systems multi-agent modelling. This project constitutes a first step to analyse the feasability of a research programm devoted to social organization modelling.

8.2. European initiatives

8.2.1. Technical Forum Group: "Self-Organization"

Participants: Christine Bourjot, Vincent Chevrier, Vincent Thomas.

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[2] COMAC = *contrôle optimisé multi-techniques des aérostructures composites* / optimised multi-technique control of composite aeronautic parts

[3] MIPI = *matériaux innovants et produits intelligents* / innovative materials and intelligent products

MAIA is member of AgentLink that is the European Commission's IST-funded Coordination Action for Agent-Based Computing[4]. Vincent Chevrier is promoter of the Technical Forum Group "Self Organization" in AgentLink [5]. The aim of the TFG is to work on self-organization in the complex distributed systems such as multi-agent systems. Currently, the group members are involved in the writing of a book entitled where MAIA team is responsible of two chapters.

8.2.2. PHC Slovénie Partenariat Hubert Curien (ex PAI Egide)

Participant: Olivier Simonin.

Plate-forme de robots mobiles coopératifs fondée sur une approche multi-agents: recherche et applications.

This project was elaborated in 2006 by Pr. D. Matko from University of Ljubjana and O. Simonin when he was a member of SeT Lab. from UTBM (University of Technologies of Belfort-Montbéliard). Pr. A. Koukam, F. Gechter and P. Gruer, from UTBM-SeT are other french participants. The cooperation concerns the Laboratory of Process Automation and Informatisation, from Faculty of Electrical Engineering, University of Ljubljana.

The decentralized control of intelligent vehicules and mobile robots has been identified as a common problem. Our work focuses on the platooning problem which has been presented in the previous section 6.2.7. We elaborated a reference-path control to provide a new near-to-near algorithm for platooning. We validated the approach with mobile robots and published the results in ICINCO International Conference [23]. A long version of this work is submitted to the Int. Journal Transactions on Control Systems Technology.

8.3. International initiatives

8.3.1. University of Massachusetts, Resource-Bounded Reasoning Lab, Associated Team program : Decision-theoretic framework for collaborative multi-agent systems

This association of the two research teams has focused on the development of a decision-theoretic framework for planning and control of collaborative multi-agent systems by formalizing the problem as decentralized control of a Markov process. The overall goal is to develop sophisticated coordination strategies that stand on a formal footing. This enables us to better understand the strengths and limitations of existing heuristic approaches to coordination and, more importantly, to develop new approaches based on these more formal underpinnings.

8.3.2. SCOUT project : Survey of Catastrophe and Observation in Urban Territories

Participants: Olivier Simonin, Alain Dutech, François Charpillet.

This project is funded by STIC-Asie Program for a duration of two years. The partners are from Vietnam (IFI, centre MICA, CARGIS), China (LIAMA), Cambodia (ITC) and France (IRD, LRI-Paris Sud, MAIA-LORIA, IGN). 2006-2008.

The project is in the context of a developing country and under its economical constraints. It aims at developing the technology supporting district-level decision-making in case of disasters using :

- Teams of simple, cheap, communicating, ground and aerial self-organized robots dedicated to the gathering of information, with a variety of sensors, on damaged sites.

- A data fusion system, to which the robots transmit their perceptions, which is specialized and trained for extracting relevant semantic information from them.

- A 3D GIS that supports a simulation of a district, used by local decision-makers to monitor the progress of the robots, the extent of the damages, and assign new targets to the robots.

[4] http://www.agentlink.org
[5] http://www.irit.fr/TFGSO/

We studied different collective solutions to the patrolling multi-robot problem. We explored solutions based on the EVAP algorithm, i.e. using the pheromone evaporation process (see 6.2.6.1). We conduced simulation statistics showing the interest of using a swarm approach. In collaboration with IFI researchers, we published this work to ICTAI'07 Int. Conference and French Conference JFSMA 2007. We are now preparing experiments with Kheperas robots which should involve a student from IFI Institute. In December 2007, A. Dutech visited IFI (Hanoï) and presented advances of Maia work to Scout partners.

8.3.3. CEDRE Project

Participants: Maan El-Badaoui-El-Najjar, François Charpillet.

This project is about localisation in urban environment using GPS and INS aided by monocular vision system and 3D geographical model. It is funded by the scientific CEDRE program between France and Lebanon . The lebanese partner is Université Libanaise, Faculté de Génie Branche 1 (ULFG1) at Tripoli.

Geo-localisation methods are explored, using GPS, INS, monovision camera and a new geo-information source, which is the 3D cartographical model. A 3D-GIS (Geographical Information System) has been developed to manipulate and navigate in a precise 3D cartographical model database (Stanislas Place).

9. Dissemination

9.1. Visiting scientists

- Alan Carlin, Phd from University of Massachusetts, Amherst, visited us for a month in June. This visit happened in the context of our INRIA associated team with INRIA.
- Akshat Kumar, Phd from University of Massachusetts, Amherst, visited us for a month in June. This visit happened in the context of our INRIA associated team with INRIA.

9.2. Conference, workshop, PhD and HDR committees, invited talks

9.2.1. Journal and Conference reviewing

- Amine Boumaza was a reviewer for the JAAMAS (Journal of Autonomous and Multi-Agent Systems) and for the IEEE-TRO (IEEE Transaction on robotics).
- Amine Boumaza is a member of the IEEE Technical Committee on safety Security and Rescue Robotics. The main goal of the TC is to help stimulate and coordinate research and development for civilian safety and rescue applications.
- Bruno Scherrer was a reviewer for JAAMAS, AAAI, ECML, ICML, EWRL and JFPDA.
- Vincent Chevrier is a reviewer for IBERAMIA08 conference and for the ACM Transaction on Adaptive and Autonomous Systems review and for a special issue on Artificial Intelligence and Web Intelligence of Revue d'Intelligence Artificielle.
- Olivier Simonin was a reviewer for IEEE Transactions on Industrial Informatics Journal and for CIRAS08, AT2AI (AAMAS Workshop), ACM SAC09, FIRA ICER09 & ICSR09 International Conferences. He was also a reviewer for JFSMA08 and HUMOUS08 French Conferences.
- Christine Bourjot was reviewer for MA4CS (MultiAgent for Complex Systems, a satellite conference of the European Conference on Complex Systems 2007) , for the journal NPSS (Nouvelles Perspectives en Sciences Sociales 2007), for the colloquium ARCo'07 (colloque de l'Association pour la Recherche Cognitive).
- Alain Dutech has been a reviewer for AAAI-2008, ICML-2008, RFIA-2008, JFPDA-2008, EWRL-2008 and for the following journals : RIA; IEEE Transactions on Systems, Man, and Cybernetics–Part C: Applications and Reviews; JESA.

- Olivier Buffet was a reviewer for the conferences: AAAI-08, AAMAS-08, ECAI-08, ECML-08, JFPDA-08 and NIPS-08; and for the journals: JAIR (Journal of Artificial Intelligence Research), CI (Computational Intelligence), JAAMAS (Journal on Autonomous Agents and Multi-Agent Systems) and TRO (Transactions on Robotics).

9.2.2. Conference organization, Program committees, Editorial boards

- MAIA is a leading force in the *PDMIA* group (Processus Decisionnels de Markov et Intelligence Artificielle) and played a great part in the annual meeting of the group. This year, the group annual meeting was held in Metz as the third edition of the JFPDA conference (JFPDA'08) where people from the *planing* community exchanged with people from *reinforcement learning*.
- Vincent Chevrier is a member of:
  - the editorial board of Interstices[6], a site to disseminate research work about computer science for French-speaking person,
  - the advisory board of JFSMA (Journées Francophones sur les Systèmes Multi-Agents)
  - the program committee of ECOSOA (Environment-Mediated Coordination in Self-Organizing and Self-Adaptive Systems) and Eumas (European workshop on multi-agent systems)
- Vincent Chevrier is the moderator of the mailing list of the French spoken community on multi-agent systems.
- François Charpillet was a member of the following conference committees:
  - Cinquièmes Journées Francophones MODÈLES FORMELS de l'INTERACTION, 2009.
  - ECAI 2008
  - Humans Operating Unmanned Systems (HUMOUS 2008)
- François Charpillet is member of the editorial committee of "revue d'intelligence Artificielle".
- Christine Bourjot and Vincent Chevrier are members of the working group "Colline" (AFIA, GDR I3).
- Christine Bourjot is member of the scientific council of CogniEst "Reseau Grand Est des Sciences Cognitives"
- Christine Bourjot is member of the administration council of ARCo "Association for cognitive research"
- Olivier Simonin was a member of the following conference program committee:
  - JFSMA'08 (Journées Francophones sur les Systèmes Multi-Agents)
  - HUMOUS 2008 (Humans Operating Unmanned Systems)
  - ICSR 09 Inter. Conference on Social Robotics (FIRA RoboWorld Congress)
  - ICER 09 Inter. Conference on Entertainment Robotics (FIRA RoboWorld Congress)
  - SIM track on Advances in computer Simulation at ACM Symp. on Applied Computing 2009 (SAC 09)
  - CIRAS 2008 Fifth Inter. Conf. on Computational Intelligence, Robotics and Autonomous Systems (IEEE Robotics and Automation Society - Singapore Chapter)
  - AT2AI-6 Sixth International Workshop "From Agent Theory to Agent Implementation" Held at the Seventh International Conference AAMAS 2008

[6] http://interstices.info

9.2.3. PhD and HDR committees

- François Charpillet was a member of the following PhD committees:
  - (as a reviewer) David Meignan,Une approche organisationnelle et Multi-agents pour la modélisation et l'implantation de Métaheuristiques Université de Franche-Comté et Université de Technologie de Belfort-Montbéliard
  - (as a reviewer) Anthony Fleury, Détection de motifs temporels dans les environnements multi-perceptifs. Application à la classification automatique des activités de la vie quotidienne d'une personne suivie à domicile par télémédecine, Université Joseph Fourier, Grenoble.
  - (as a reviewer) Johann Bourcier , Auto-Home : une plate-forme pour la gestion autonomique d'applications "pervasives", Université Joseph Fourier, Grenoble.
  - (as a commitee member) Cindy Cappelle, Localisation de véhicules et détection d'obstacles : Apport d'un modèle virtuel 3D urbain, Université des Sciences et Technologies de Lille.
  - (as a commitee member) Laetitia Matignon, Synthèse d'agents adaptatifs et coopératifs par apprentissage par renforcement, Université de Franche-Comté.
  - (as a commitee member) Grégory Beaumet, Planification continue pour la conduite d'un satellite d'observation agile autonome, Université de Toulouse.
  - (as a commitee member) Arnaud Campéa, Modélisation de l?hétérogénéité de croissance dans le système aquacole, Institut National Polytechnique de Lorraine.
  -
- François Charpillet was a member of the following HDR committees:
  - (as a reviewer)Jean-Charles Creput, Hybridation de Méta-heuristiques pour la résolution (distribuée) de problèmes d'optimisation spatialisés, Université de Bourgogne.
  - (as a committee member) Vincent Hilaire. Du semi-formel au formel: une Approche Organisationnelle pour l'Ingénierie de Systèmes Multi-Agents, Université de Bourgogne.
- Vincent Chevrier is member of the "comité de thèse" of Laurent Poligny (Univ. Evry) and was a member of the following PhD Committees:
  - (as a reviewer) Joris Deguet Univ J. Fourier Grenoble, May 2008.
  - (as a commitee member) Matthias Mailliard, Univ Toulouse, December 2008
  - (as a commitee member) Smail Kouider, Univ P. Verlaine, Metz, November 2008
- Olivier Simonin was a member of the PhD committee of Sana Moujahed (University of Technologies of Belfort-Montbéliard), dec. 2007.
- Alain Dutech was a member of the PhD committee of Raghav Aras (Université de Nancy I, oct. 2008).

9.2.4. Specialist Committees (commission de spécialistes)

- Vincent Chevrier is a member of the "Specialist Committees" in Nancy 1 (UHP)
- François Charpillet is a member of the "Specialist Committees" in Paris XI, and INPL Nancy.
- Olivier Simonin is a member of the "Specialist Committees" in INPL Nancy.
- Bruno Scherrer is a member of the "Specialist Committees" in Lille 3.
- Alain Dutech is a member of the "Specialist Committees" in Nancy 2.

9.2.5. Other responsibilities

- François Charpillet is member of evaluation committees of ANR program Emergence Bio Emergence Tec,
- François Charpillet is member of the AERES evaluation committee for "Laboratoire des Equipes Traitement des Images et du Signal (ETIS), unité de recherche commune à l'Ecole Nationale de l'Electronique et de ses Applications (ENSEA), l'Université de Cergy-Pontoise (UCP), et le CNRS (UMR 8051, rattachée au département "ST2I - Sciences et technologies de l'information et de l'ingéniérie")".
- François Charpillet was a member of the INRIA, Nancy Grand Est CR 2 examination committee
- Olivier Simonin is a member of the LORIA Direction team, in charge of the scientific theme “Perception, Action, Cognition”.
- Olivier Simonin is a member of the “operation committee” of MIS Project (Modélisation, Interaction, Simulation) of CPER MISN INRIA & Region Lorraine.
- Vincent Chevrier was a member of the “comipers”, the INRIA Lorraine LORIA examination comittee for scientific employees.

9.3. Popularization activity

9.3.1. Invited talks

Vincent Chevrier did the following invited talks:

- *Modélisation SMA de phénomènes collectifs : application au tissage collectif chez les araignées sociales* in the LPNHE (Laboratoire de Physique Nucléaire et Hautes Energies), Univ Paris 6, the 24 June 2008
- *Simulation of specialisation among a rat community* in the 1st Workshop on MAS in Biology at meso or macroscopic scales, Paris 02 July 2008.

Olivier Simonin did the following invited talks:

- *Approches multi-agents bio-inspirées pour des problématiques du transport : flotille de véhicules, placement de ressources, etc* in the XIIIème session du Forum: Systèmes Multi-Agents & Transports, 31 janvier 2008, Paris.
- *SMAART: une approche bio-inspirée pour la patrouille avec un essaim de drones* in Second Workshop of PEA Action, 22 oct. 2008, LAAS Toulouse.

9.3.2. Spring school

Vincent Chevrier did a 3 hours talk on MAS and collective phenomena in the Spring School held in conjunction with the Maghrebian Conference on Information Technologies), 26-27 April 2008, Oran, Algeria.

9.3.3. European city of sciences (Ville Européenne des Sciences)

Christine Bourjot, Vincent Chevrier and Vincent Thomas are participant to the European city of sciences, in Nef du Grand Palais Paris from 14 to 16 November, within the INRIA “digital city”. This manifestation gathers several research institutions and aims at providing an insight on current research developments to non specialists.

Didier Desor and Henri Schroeder from URAFPA, Nancy University are associated to this manifestation.

9.3.4. Scientific diffusion

Alain Dutech, Bruno Scherrer and Christophe Thiery wrote a large audience article [10] for the dissemination french site Interstices on the application of optimal control to the game of Tetris. Bruno Scherrer participated to the “Fête de la Science 2008” where people were invited to play in parallel with the optimal controller on a small version of Tetris.

9.3.5. Processus décisionnels de Markov en intelligence artificielle

Participants: Olivier Buffet, François Charpillet, Alain Dutech, Bruno Scherrer, Daniel Szer, Simon Le Gloannec.

In the last few years, a group of french-speaking researchers has written an introductory book on MDPs in Artificial Intelligence. It not only covers the principles of MDPs (including reinforcement learning and POMDPs) but also popular extensions (approximate algorithms, multi-agent approaches...) and selected applications. This book has been published in June 2008 [46], [45]. An english version is currently under preparation.

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