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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team MAIA

Autonomous and Intelligent MAchine

Nancy - Grand Est

THEME COG

Activity Report

2007

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1. Team

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

Team Leader
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Alain Dutech [Research associate (CR) INRIA]
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Vincent Chevrier [Assistant professor, UHP, HdR]
Jean-Paul Haton [Professor, UHP, Institut Universitaire de France, HdR]
Alexis Scheuer [Assistant professor, UHP]
Olivier Simonin [Research associate (CR) "détachement" INRIA until August, then Assistant professor, UHP]
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Raghav Aras [Egide scholarship, UHP until August, ATER UHP starting September]
Cherif Smaili [scholarship, CNRS]
Cédric Rose [CIFRE, Diatelic SA]
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Sylvain Castagnos [scholarship, U. Nancy 2]
François Klein [MENRT scholarship, Nancy 2]
Hazem Nanaha [Egide scholarship, UHP, until october]
Rodolphe Charrier [Nancy 2]
Ilham Esslimani [Nancy 2]
Gabriel Corona [CORDI Scholarship, starting September]
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Julien Siebert [scholarship, Region Lorraine, starting October]
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Project Technical Staff
Guillaume Muller [Engineer, PAUSA Project]

Abdahllah Dibdib [Engineer starting October, CRISTAL Project]
Amine Boumaza [ATER, U. Nancy 2 until August, Engineer starting September, PAUSA Project]
Yoann Bertrand-Pierron [INRIA Engineer, until October]

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.

2.2. Highlights of the year

Anne Boyer and Sylvain Castagnos won awards prize of 9th national competition for aid in innovative technology company creation in the Development Creation category for her Project e-veille: personalization engine for rapid access to relevant information.

E-veille software offers personalized access to information sources (documentary intranet, product catalogue, portals, etc.) and high added-value services: creation of virtual communities, connections, target marketing, etc. The product facilitates rapid and relevant access to information by adapting to the user and anticipating his/her actions. It consists of a set of software models that implement artificial intelligence algorithms combining both social navigation (exploiting data on a user to deduce his/her preferences, habits and tastes) and collaborative filtering (electronic word-of-mouth based on modelling group behaviour and observing its activities in context to predict future ones). E-veille software deploys its services for hundreds of thousands of users in real-time. It is compliant with regulations in force at the CNIL with regards to personal privacy.

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.

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.

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

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 [53], 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 [52] 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 particular filtering to detect loss of autonomy for elderly people.
- Coordination of intelligent vehicles (flying drones (see Sec. 8.1.1))
- collaborative filtering.
  Strong industrial interest, has shown by the various collaborations with "Crédit Agricole" (see Sec. 7.1), e-veille (see Sec. 7.2)
- Analysis of medical signals.
  With Cardiabase (see Sec. 7.4), continuous stochastic models allow to classify ECG recordings.

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. 7.5).

- *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*: Cedric 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://nazim.fates.free.fr/Logiciel.htm
- *Contributors*: Nazim Fatès
- *Contact*: Nazim.Fates@loria.fr

5.1.4. 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 drones, 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*: not yet distributed
- *Contributors*: Olivier Simonin, François Charpillet
- *Contact*: Olivier.Simonin@loria.fr

5.1.5. SofoS

Anne Boyer and Sylvain Castagnos have developed a Peer-to-Peer document sharing platform called SofoS which is under the protection of an APP deposit[2]. This software includes a recommender system based on a distributed collaborative filtering algorithm. It has been specifically designed to be highly scalable and to provide relevant suggestions in real time.

- *Availability*: not yet distributed
- *Contributors*: Anne Boyer, Sylvain Castagnos
- *Contacts*: anne.boyer@loria.fr, sylvain.castagnos@loria.fr

[2] APP is the French Program Protection Agency. http://app.legalis.net/

6. New Results

6.1. Stochastic models

The keyword for our recent work on stochastic models is “distributed”. In term 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 unvailed strong links between optimal and harmonic control and discussed some implications of these links for the distributed computation of optimal trajectories. Several problems related to distributed knowledge have also been looked at, mainly through a combination of collaborative filtering and behavior modeling.

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. Optimal and approximate solutions for decentralized control

Participants: Daniel Szer, François Charpillet.

The subject of this work, detailed in [54], is the optimal resolution of decentralized Markov decision processes (DEC-POMDPs). The DEC-POMDP model was introduced in 2000 and constitutes a formal framework for describing cooperative distributed decision problems under uncertainty. Publication about this work has been completed this year by a journal paper on an entirely new way of applying heuristic search techniques, such as A*, to decentralized decision problems ([13]).

6.1.1.2. Building multi-agent systems by the use interactions and RL techniques

Participants: Vincent Thomas, Christine Bourjot, Vincent Chevrier.

This part of our works 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 works [14] is based on the constatation that the interactions among agents which can structure the problem are not explicitely represented. Our works 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.

Experiments have validated the ability of our algorithm to organize interactions among agents and to build interesting collective behaviours, even if they are not optimal. The techniques we propose could then 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.

6.1.1.3. 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.

6.1.1.4. Multi-agent Reinforcement Learning

Participants: Olivier Buffet, François Charpillet, Alain Dutech.

Previous work done in collaboration with O. Buffet[3] on using Reinforcement Learning to build reactive multi-agent systems has been finalized by the paper publication of one article.

This journal article presents with more details earlier work which lead to an original Reinforcement Learning (RL) methodology for the design of multi-agent systems([3]). In the realistic setting of situated agents with local perception, the task of automatically building a coordinated system is of crucial importance. To that end, we design simple reactive agents in a decentralized way as independent learners. But to cope with the difficulties inherent to RL used in that framework, we have developed an incremental learning algorithm where agents face a sequence of progressively more complex tasks. We illustrate this general framework by computer experiments where agents have to coordinate to reach a global goal.

6.1.2. The optimal control point of view on AI

Participants: Amine Boumaza, Bruno Scherrer, Christophe Thiery.

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

[3] who did his PhD in the MAIA team in 2001-2004 and did some post-doctoral studies for the National ICT Australia

Artificial intelligence (AI) is a domain that deals with intelligent behavior, learning, and adaptation in machines. AI is currently made of many sub-disciplines that focus on specific problems: planning, multi-agent systems, neural networks, vision and so on. The following works are related to the belief that AI is fundamentally a control problem, and that the optimal control framework may play a more and more central role in AI. As we describe in more details below, we have showed this year that the optimal control framework allows to have a deeper understanding of some distributed AI approaches (like ant algorithms) and of a planning technique known as harmonic control.

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 [2], [18], [17] 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.

Optimal control and harmonic control have traditionally been considered as unrelated alternatives for trajectory planning and control. We have shown that they are in fact deeply related. We provided in [19] formal evidence, in continuous domain and in a standard discretization, that harmonic control is the limit case of some optimal control problem in which we make the noise level tend to infinity. In other words we have shown that optimal control subsumes harmonic control. This gives more insight into what harmonic control is. Also, we believe that this might be of interest to the many practitioners of harmonic control in the robotics community. In [34], we have begun to work on the implementation of harmonic control 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. In the future we will investigate how its more general form, optimal control, may be implemented on similar architectures.

Eventually, during the Master Thesis of Christophe Thiery [49], we worked on a general algorithm for solving Markov Decision Processes, λ Policy Iteration, which generalizes standard algorithms of the literature like Value Iteration and Policy Iteration. We reimplemented an application of an approximate version of λ Policy Iteration to the game of Tetris and found much better results than what was originally observed by Ioffe and Bertsekas [51] and believe that there was a small bug in their original implementation. We also studied an alternative approach, a direct policy search approach based on cross entropy, and used it to derive a Tetris controller that significantly outperforms the publicly known previous record: our best controller achieves an average of 35 millions of lines per game while previous best controllers were performing around 1 million lines.

6.1.3. Stochastic method application on Intelligent Transportation System

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

In order to obtain an autonomous navigation system or to develop Advance Driver Assistance Systems (ADAS), intelligent vehicles have to complete several tasks: localisation, 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. Our work tries also to study the utility of new sources of information like geographical 3D model managed in real-time by 3D Geographical Information System (3D-GIS). In the last two years, we perform approaches for vehicle localisation, map matching and obstacle detection. Experimental results with real data are used to validate the developed approach and demonstrator is under development.

6.1.3.1. 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.

6.1.3.2. 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, 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 (using interpretation trees) between a real image captured by an on-board video camera and a virtual image provided by the 3D-GIS [25].

6.1.3.3. Geo-localisation with 2D-GIS and Map matching

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. In that case, we use the digital map as an observation to improve the reliability of map-matching. In many cases, when a vehicle is in front ambiguous situations (parallel road and junction of roads), we try to identify the most likely segment. Inevitably, this identification is closely related to the accuracy of sensors and therefore the identification of the most likely segment remains a real problem. To resolve these ambiguous situations, we have develop a method for multi-sensor fusion to obtain multi-modal estimation realized using (HBN). Bayesian network manages all hypotheses until the elimination of the ambiguity [42].

6.1.3.4. 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 obstacles don't. The depth information permits then to compute the distance between the detected obstacle and the vehicle and to geo-localise this obstacle [24]. The distance obtained with this method is validated with laser range finder measurements. A real-time demonstrator is in progress.

6.1.4. Recommender systems

Participants: Anne Boyer, Sylvain Castagnos, Ilham Esslimani, Geoffray Bonnin.

J.-C. Lamirel and R. Kassab (CORTEX team, LORIA), A. Brun (PAROLE team, LORIA) are collaborators for this action.

The amount of data exponentially increases on the Internet and it is becoming more and more difficult to extract the most relevant information within a very short time. Recommender systems support decision processes for identifying pertinent and reliable items among a huge collection of available resources. The interest in such systems has dramatically increased due to the demand of personalization technologies by for example e-commerce applications or information retrieval services. Approaches to solving recommendation problems can be classified as content based, knowledge based, demographic, utility based or collaborative, etc. Our work mainly relies on collaborative filtering processes even though we also investigate other approaches such as combining it with content based analysis. In this case, recommender systems help users to find interesting items by modeling their preferences and by comparing them with users having the same tastes. Nevertheless, there are a lot of aspects to consider when implementing such a recommender system such as scaling problems, privacy, sparsity of data, quality of prediction or security and trust.

6.1.4.1. A Distributed Information Filtering

Participants: Anne Boyer, Sylvain Castagnos, Ilham Esslimani.

The term “collaborative filtering” denotes techniques using the known tastes of a group of users to predict the unknown preference of a new user. The aim of such algorithms is to predict the interest of a resource for a given user, given his past consultations. In practical terms, it amounts to identifying the active user to a set of people having the same tastes, based on his past actions and his known preferences. This starts from the principle that people who liked the same items have the same topics of interests. Thus it is possible to predict the relevancy of data of the active user by taking advantage of experiences of a similar population. A lot of collaborative filtering processes are centralized. The scientific problems we address have consisted in finding a way to distribute the computations, in order to be suitable for hundred thousands of people, and to preserve anonymity of users (personal data remain on client side). Because of the industrial contexts (collaboration with a company called ASTRA specialized in satellite website broadcasting, collaboration with Credit Agricole S.A.), we consider the situation where the set of users is relatively stable, whereas the set of items may vary considerably from an execution to another. We proposed new generic models both based on a client/server and a peer-to-peer architectures which rely on a user-based collaborative filtering algorithm and a behavior modeling process [26] [22]. Our solutions are particularly designed to address the issues of privacy [4], novelty [28], data sparsity [27], and scalability.

We are investigating the combination of our models which demographic data processing to maximize the function of utility and satisfaction of users (collaboration with Credit Agricole S.A.).

6.1.4.2. Towards a statistical grammar of usage

Participants: Anne Boyer, Geoffray Bonnin.

A. Brun (PAROLE Team, LORIA) is an external collaborator.

For several months we have been investigating how to build a statistical grammar of usage based on the analogy with statistical language modeling. Statistical language models have proved their efficiency in domains such as automatic speech recognition, optical character recognition, natural language processing, etc. We explore the use of the most well-known statistical language models such as n-grams, triggers, etc. to improve the quality of predictions by introducing the notion of sequentiality in resource consultations [21] [20] [23].

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. Incremental process for the assessment of a multi-agent model in ethology

Participants: Vincent Thomas, Christine Bourjot, Vincent Chevrier.

D. Desor (Université Henri Poincaré, Nancy 1, URAFPA) is an external collaborator for this action.

This work deals with the modeling of biological self-organized systems, precisely, the specialisation observed among rats groups. We have built a multi-agent model of this phenomenon that does not require sophisticated reasoning, nor mental representation and that relies on a self-organized process. This model enables to reproduce the core aspects of the phenomenon.

This article [43] proposes an incremental process to assess this model. This way of proceeding enables us to have a detailled picture of what the model can reproduce or not. Furthermore, such an incremental process on the model leads to new questions about the biological phenomenon.

6.2.2. Multi-agent modeling of the impact of user behavior in peer to peer systems

Participants: Vincent Chevrier, Julien Siebert.

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

Peer to peer (P2P) systems are open, distributed and heterogeneous systems where the behavior of the users can impact the global functioning of the network. We showed a real need to integrate into a single coherent model both a model of the user together with a model of the P2P systems in order to accuratly study the mutual influences of the user behavior and of the features of P2P system (protocol used, transfer delays, type of data exchanged, ...). We proposed a multi-model perspective to deal with this issue: we integrate and make interact several models, one of the user behavior as a reactive agent model, one of the overlay network (as the agent environment) and one of the protocol used (as the interaction model between agents). 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[46] are the proposition of this multi-model approach and the basis of a simulation framework extending a public domain simulator.

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 [31], [30], [32], [33]. This model combines a coupled map lattice and the influence- reaction model originally proposed by Jacques Ferber and Jean-Pierre Müller.

6.2.4. Study of phase transitions in massively parallel 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. 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 [45] we investigate the nature of this change of behaviour using intensive numerical simulations. We applied a two-step protocol to show that the phenomenon is a phase transition whose critical exponents are in good agreement with the predicted values of directed percolation.

Our research is currently evolving towards the study of this phase transition phenomenon in the context of bio-inspired computing. Indeed, we wish to examine to which extent the phase transition phenomenon could be applied for describing the brutal change of behaviour in cellular societies such as the *Dictyostelium Discoidum amoebae* [50].

6.2.5. Environment-based models for Distributed Problem Solving

Participants: Olivier Simonin, François Charpillet.

One of the main approach to deal with Swarm Intelligence is to mark the environment in order to use it as a common memory (pheromones deposit by ants is a well-known example of such an indirect way of communication). Digital marks are values that can be read and written by agents in cells of discrete environments. We focus on two approaches:

- Digital pheromones simulate real pheromones in discrete environments. Evaporation and diffusion processes are computed by the environment. We re-examined these processes to address other problems than path-planning. In particular we proposed the EVAP model, based only on evaporation, to deal with multi-agent patrolling. Performances of the model have been compared to existing solutions, showing its efficiency and to be optimal on certain environments. This model has been published in [37] (ICTAI'07) and [35] (JFSMA'07), and used to define the drones coordination model implemented in the SMAART project (see 8.1.1). This work was also supported by the Internship INRIA program, through the master fellowship of Hoang Nam Chu from Hanoï (Vietnam). We now go into details of these collective processes in order to control their complexity. We also plan to deploy such algorithms on sensor networks in real environments.

- Collective construction of artificial potential fields (APF). We transformed the classical APF computation proposed by Barraquand & Latombe in an asynchronous and collective construction by reactive agents. We proved this model build an optimal APF while dealing with the collective forraging problem (research and transport of resources by a set of autonomous agents/robots). This solution is more efficient than the pheromone-based approach (results are submited to ACM TAAS Journal). This work is made in collaboration with E. Thierry from LIP, ENS Lyon. [47]

6.2.6. Decentralized control of intelligent vehicles (the platooning task)

Participants: Alexis Scheuer, Olivier Simonin, François Charpillet.

DEDALE project is a LORIA collaborator for this action.

We study decentralized solutions to enable a system operating electrical vehicles under precise automatic control at close spacings to form a platoon. We address bio-inspired models, relying on the flocking techniques, that allow each vehicule to compute its control from its local perceptions. We are interested in such a decentralized approach because it can provide robust and scalable solutions. However we try to develop new tools to manage their global complexity, for instance to avoid oscillations in the convoy when some vehicules are perturbated. The control of a convoy composed of several autonomous vehicles (more than four) remains an open problem. To address this challenge we focused on two approaches:

- The formal specification and verification of situated multi-agent systems, that can be formulated within the influence-reaction model proposed by Ferber & Muller in 1996. Our objective is to prove the correctness of reactive multi-agent systems with respect to a certain formal specification or property, using formal methods. This work is related to the ANR project TACOS (see 8.1.3), carried out with DEDALE project and using the B language.

- Multiagent simulation allows to experiment these decentralized models and to focus on time constraints. We developped such a tool as a direct implementation of the B expression of the influence-reaction model proposed above.

A first version of this bio-inspired platooning model has been presented in an article which is under submission in JAAMAS Journal and also refered as an internal report [48].

7. Contracts and Grants with Industry

7.1. Collaboration with Crédit Agricole SA

Participants: Anne Boyer, Sylvain Castagnos, Ilham Esslimani.

In 2006, we began a collaboration with the team called "Veille technologique" of the company "Crédit Agricole SA". The aim of the collaboration is to investigate the benefits of collaborative filtering and social navigation in the framework of an intranet platform. First, we implement our client-server user-based collaborative algorithm within the information system of the company and therefore realize a proof of concept in an industrial context. We are now exploring new algorithms relying on the use of the tags let by users during the navigation process and demographic data.

7.2. The e-veille project

Participants: Anne Boyer, Sylvain Castagnos.

Anne Boyer and Sylvain Castagnos are creating a company in order to exploit in industrial contexts the various algorithms based on collaborative filtering they have designed. This project called *e-veille* has been the 2007 laureate of the national contest "creation of innovative companies" in the category "Creation-Developpement". This contest is organized by the French "ministère de la Recherche" with the help of OSEO ANVAR. They are also laureates of the "Master 2007 de la creation d'entreprise", and the regional contest "Entreprendre 2007". For the moment, this project is hosted by the "incubateur lorrain".

7.3. Collaboration with Technoscope

Participants: Anne Boyer, Geoffray Bonin, Armelle Brun.

In 2007, we have a one-year collaboration with a French press agency named Technoscope. The aim of the collaboration is to investigate the benefits of the sequential collaborative filtering in the context of information delivery.

7.4. Collaboration with CardiaBase

Participants: François Charpillet, Julien Thomas.

CardiaBase's core business is central reading of cardiac data (ECGs and holsters), in order to assess the cardiac consequences (side effects) of new drugs. The evolution of medical knowledge and the release of tighter regulatory guidelines demand more and more intensive controls of cardiac data to guarantee drugs safety, and notably :

- assessing the ECG evolution of patients when under a new drug,
- quickly receiving alerts in case of severe ECG abnormalities,
- storing all the ECGs of a patient and tracking (comparing) any changes over time.

CardiaBase provides interpretation which is based on reading methods performed by trained cardiologists. In order to improve the process, we have developed a new approach to automatic ECG segmentation based on hierarchic continuous density hidden Markov models[44]. We applied a wavelet transform to the signals in order to highlight the discontinuities in the modeled ECGs. A training base of standard 12-lead ECGs segmented by cardiologists was used to evaluate the performance of our method. We used a Bayesian HMM clustering algorithm to partition the training base, and we improved the method by using a multi-model approach. The developed software is on the verge of being integrated in the Cardiabase software.

7.5. 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.

7.6. 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. This year we mainly worked on the extraction of relevant data from raw ones and their integration in the simulator.

7.7. 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. DGA PEA SMAART

Participants: Olivier Simonin, François Charpillet.

The main objective of this project is to create coordination mechanisms for Unmanned Aerial Vehicles for surveillance. The focus is on designing individual behaviors for every drone in order for them to develop self-organization capabilities at the group level. During the year we proposed bio-inspired solutions to the decentralized control of swarms of drones. We focuses on algorithms relying on digital pheromones computation (see 6.2.5). Algorithms have been written in a project report and implemented as a software in collaboration with the CRIL compagny (see 5.1.4). This work shows that collective intelligence can be achieved from digital pheromones, networks sensors and ACO-based algorithms, as their combination defines a robust and adaptive solution to the patrolling task.

8.1.2. RNTS PROJECT PréDICA

Participants: Jamal Saboune, François Charpillet.

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. 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. 6.2.6). This work is currently submited to JAAMAS journal and more detailled in the internal report [48]. We now work on improving the framework, involving simulation and study of the properties of the system.

8.1.4. 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.

8.2. European initiatives

8.2.1. Technical Forum Group: “Self-Organization”

Participants: Christine Bourjot, Vincent Chevrier.

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.

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

Participant: Olivier Simonin.

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

A. Koukam (Pr.), F. Gechter and P. Gruer, from ICAP team in SeT Laboratory (University of Technologies of Belfort-Montbéliard), are other french participants. The cooperation concerns the Laboratory of Process Automation and Informatisation, from Faculty of Electrical Engineering, University of Ljubljana.

This project, entitled "Plate-forme de robots mobiles coopératifs fondée sur une approche multi-agents : recherche et applications", was elaborated in 2006 by Pr. D. Matko from University of Ljubjana and O. Simonin when he was in UTBM. Today, Maia is a collaborator and O. Simonin (Maia) remains the french leader of the project. A primary meeting was organized in Belfort in september to define the first actions of the project. The decentralized control of intelligent vehicules has been identified as a common problem. We plan to combine the automation model from slovenian team with the bio-inspired french team models. A new meeting is planned in November to visit the University of Ljubljana and to prepare some students exchanges.

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

Over the past years, a fruitful research collaboration has been established between MAIA and the RBR group at the University of Massachusetts, directed by S. Zilberstein. The collaboration was conceived at a meeting that took place in 1995 at the International Joint Conference on Artificial Intelligence in Montreal. During this meeting, we identified a high degree of overlap between our interests, research projects, and solution techniques. These common interests relate to the development of planning and monitoring techniques for autonomous systems that can operate in real-time and can cope with uncertainty and limited computational resources. At that time, the U.S. team investigated a solution technique based on "anytime algorithms" and our team investigated the "progressive processing" model.

Since then, we have worked together on both of these models and exploited the synergy to improve their applicability and effectiveness. This year this collaboration has been funded by INRIA as an associated team. 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. There is a wide range of application domains in which decision-making must be performed by a number of distributed agents that are trying 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, 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.

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). The first meeting took place at Hanoi in November.

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.

This year we studied different collective solutions to the patrolling multi-robot problem. We first proposed the EVAP model, based on the pheromone evaporation process, showing the interest of using numerous simple robots (see details in 6.2.5). In collaboration with IFI researchers, we published this work in [37] and [35], including a student from Hanoï supported by the Internship INRIA program. Then we focused on energy limitation for robots. This constraint produced two approaches exploiting environment-based model (i) collective construction of paths to energy sources (based on [47]) (ii) robots dedicated to the transport of energy that move using the self-organized model defined in [9]. Publications are in preparation. In July, O. Simonin visited LIAMA Laboratory (Beijing) to present Maia works to the 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

- Marek Petrik, Phd from University of Massachusetts, 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 is a reviewer for JMLR (Journal of Machine Learning Research) and JAAMAS (Journal of Autonomous and Multi-Agent Systems).
- Vincent Chevrier is a reviewer for AMSTA07 conference, of a special issue on multi-agent systems of RIA (2007)
- Olivier Simonin was a reviewer for the following Journal committees:
  - RIA Revue d'Intelligence Artificielle
  - MAGS Multiagent and Grid Systems Journal (IOS Press)
  - JESA Journal Européen des Systèmes Automatisés

  He was also a reviewer for the special volume on "Complex environments models for Multi-Agent Systems", LNCS post-proceedings of the Third International Workshop on Environments for Multi-agent Systems (fev. 2007)

- 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 IJCAI-2007 and JFPDA-2007.
- François Charpillet has been a reviewer journal for Engineering Applications of Artificial Intelligence, Journal of Artificial Intelligence Research.

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 at Grenoble as the second edition of the JFPDA conference (JFPDA'07) 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,
  - advisory board of EUMAS, the European Workshop on Multi-Agent Systems and of JFSMA (French speaking conference on multi-agent systems)
  - the program committee of MA4CS'07; of TAMC07, IICAI-07, CODS'2007, ARCO07, Intelligence Artificielle et Web Intelligence 07.
- 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:
  - Quatrièmes Journées Francophones MODÈLES FORMELS de l'INTERACTION, 30 Mai–1er Juin 2007, Paris.
  - 1st KES Symposium on Agent and Multi-Agent Systems ? Technologies and Applications. Wroclaw, Poland 31 May -1 June 2007.
  - 2e Journées Francophones Planification, Décision, Apprentissage pour la conduite de systèmes, 2 au 6 juillet 2007 à Grenoble.
  - to be in PC of ECAI 2008
- 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"
- Anne Boyer is a member of the editorial committee of the journal "TSI".
- Christine Bourjot is member of the program committee and organisation committee of ARCo'07 colloquium, Nancy, Novembre 2007
- Christine Bourjot is member of the administration council of ARCo "Association for cognitive research"

[6] http://interstices.info

9.2.3. Phd and HDR committees

- François Charpillet was a member of the following PhD committees:
  - Sana Moujahed, Approche Multi-agents auto-organisée pour la résolution de contraintes spatiales dans les problèmes de positionnement mono et multi-niveaux, Université de Technologie de Belfort-Montbéliard.
  - Aurelie Clodic, Supervision pour un robot interactif : Action et Interaction pour un robot autonome en environnement humain, Université Paul Sabatier, Toulouse III.
- François Charpillet was a member of the following HDR committee : Gilles Coppin, Aide à la décision et coopération homme-machine, Université Paris VI.
- Anne Boyer was a reviewer of the PhD committee of Vincent Schickel (EPFL, September 2007), and member of the PhD committee of Mohamed Khalgui (Nancy University, February 2007).
- Vincent Chevrier was a reviewer of the following PhD Committees:
  - Grégory Beurrier, Univ Montpellier
  - Nicolas Parisey, Univ Bordeaux
- Olivier Simonin was a member of the PhD committee of Jérome Chapelle (Université de Montpellier II, dec. 2006) and he will be a member of the PhD committee of
  - Sana Moujahed (University of Technologies of Belfort-Montbéliard)
  - Gregory Beurier (University of Montpellier II)

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.
- Anne Boyer is member of the “Specialist Committees” in Strasbourg.
- Olivier Simonin was a member of the “Specialist Committees” in Nancy 1 until april 2007 and in UTBM (Belfort) until sept. 2006.
- 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 TECSAN, is Member of scientifique concils of SET laboratory(UTBM) and GREYC Caen, Member of evaluation committees of INRA unité MIA Toulouse (2006) and LISC, CEMAGERF, Clermont Ferrant(2007).
- Anne Boyer is “chargée de mission auprès du Président de l’Université Nancy 2” about “new technologies of information and communication”.
- Olivier Simonin is a member of the extended LORIA Direction team, in charge of the scientific theme “Perception, Action, Cognition”.
- Olivier Simonin was a member of the Research Engineer (IR) examination committee of
  - INRIA Research Engineer for robotics at LORIA (july 2007)
  - IRD Research Engineer for Research Unity R079 GEODES (september 2007)

9.3. Popularization activity

9.3.1. Exploring cellular automata

Participant: Nazim Fatès.

We wrote a dissemination article explaining about cellular automata [6] for the Interstices dissemination website.

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[2] A. BOUMAZA, B. SCHERRER. *Convergence et taux de convergence d'un modèle fourmi pour le fourragement*, in "Revue d Intelligence Artificielle", 2007, http://hal.inria.fr/inria-00172200/en/.

[3] O. BUFFET, A. DUTECH, F. CHARPILLET. *Shaping Multi-Agent Systems with Gradient Reinforcement Learning*, in "Autonomous Agents and Multi-Agent Systems", vol. 15, n^o 2, 2007, p. 197–220, http://hal.inria.fr/inria-00118983/en/.

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