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CNRS
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Activity Report 2014

Project-Team MAIA

Autonomous intelligent machine

IN COLLABORATION WITH: Laboratoire lorrain de recherche en informatique et ses applications (LORIA)

RESEARCH CENTER
Nancy - Grand Est

THEME
Data and Knowledge Representation and Processing

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Project-Team MAIA

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Creation of the Project-Team: 2002 September 01, end of the Project-Team: 2014 December 31.

1. Members

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2. Overall Objectives

2.1. Overall Objectives

The objective of the MAIA [1] team is to address foundational and engineering aspects of artificial intelligence. Within this general framework, the team investigates the design and understanding of intelligent agents [2] which autonomously perceive and act upon an environment so as to achieve one or several goals. The MAIA group addresses the design of a single agent, a team of agents or a large number of agents. This common objective is considered from two perspectives organized around two lines of research:

- The first research activity is about **sequential decision making**. It has been influenced by Stuart Russell [53] who considers that an agent is rational. According to them: ■`For each possible percept sequence, an ideal rational agent should do whatever action is expected to maximize its performance measure`■ [52]. This view makes Markov decision processes (MDPs) and more generally sequential decision making a good candidate for building the behavior of an agent. It probably explains why MDPs have received considerable attention in recent years by the artificial intelligence (AI) community.
- The second activity is about **understanding and engineering reactive multi-agent systems**. It is influenced by research results from the field of behavioral biology which provides key insights for understanding how intelligent and adaptive behaviors appear in natural swarm systems. This encourages us to study principles of emergent behaviors in natural systems and apply them to the design of artificial intelligent systems. Reactive multi-agent systems are good candidates for building such autonomous and adaptive systems and our work mainly focuses on better understanding how we can soundly build such systems.

[1] MAIA stands for “MAchine Intelligente et Autonome”, that is “Autonomous and Intelligent MAchine”.
[2] In the field of artificial intelligence, an “agent” refers to an entity.

3. Research Program

3.1. Sequential Decision Making

3.1.1. Synopsis and Research Activities

Sequential decision making consists, in a nutshell, in controlling the actions of an agent facing a problem whose solution requires not one but a whole sequence of decisions. This kind of problem occurs in a multitude of forms. For example, important applications addressed in our work include: Robotics, where the agent is a physical entity moving in the real world; Medicine, where the agent can be an analytic device recommending tests and/or treatments; Computer Security, where the agent can be a virtual attacker trying to identify security holes in a given network; and Business Process Management, where the agent can provide an auto-completion facility helping to decide which steps to include into a new or revised process. Our work on such problems is characterized by three main lines of research:

- (A) *Understanding how, and to what extent, to best model the problems.*
- (B) *Developing algorithms solving the problems and understanding their behavior.*
- (C) *Applying our results to complex applications.*

Before we describe some details of our work, it is instructive to understand the basic forms of problems we are addressing. We characterize problems along the following main dimensions:

- (1) Extent of the model: full vs. partial vs. none. This dimension concerns how complete we require the model of the problem – if any – to be. If the model is incomplete, then learning techniques are needed along with the decision making process.
- (2) Form of the model: factored vs. enumerative. Enumerative models explicitly list all possible world states and the associated actions etc. Factored models can be exponentially more compact, describing states and actions in terms of their behavior with respect to a set of higher-level variables.
- (3) World dynamics: deterministic vs. stochastic. This concerns our initial knowledge of the world the agent is acting in, as well as the dynamics of actions: is the outcome known a priori or are several outcomes possible?
- (4) Observability: full vs. partial. This concerns our ability to observe what our actions actually do to the world, i.e., to observe properties of the new world state. Obviously, this is an issue only if the world dynamics are stochastic.

These dimensions are wide-spread in the AI literature and are not exhaustive, in particular the MAIA team is also interested by discrete/continuous or centralized/decentralized problems. The complexity of solving a problem – both in theory and in practice – depends heavily on where it resides in this categorization. A common practice is to address simplified problems, leading to perhaps *sub-optimal* solutions while trying to characterize how far from the *optimal* solution we stand.

In what follows, we outline the main formal frameworks on which our work is based; while doing so, we highlight in a little more detail our core research questions. We then give a brief summary of how our work fits into the global research context.

3.1.2. Formal Frameworks

3.1.2.1. Deterministic Sequential Decision Making

Sequential decision making with deterministic world dynamics is most commonly known as *planning*, or *classical planning* [49]. Obviously, in such a setting every world state needs to be considered at most once, and thus enumerative models do not make sense (the problem description would have the same size as the space of possibilities to be explored). Planning approaches support factored description languages in which complex problems can be modeled in a compact way. Approaches to automatically learn such factored models do exist, however most works – and also most of our works on this form of sequential decision making – assume that the model is provided by the user of the planning technology. Formally, a problem instance, commonly referred to as a *planning task*, is a four-tuple $\langle V, A, I, G\rangle$. Here, V is a set of variables; a value assignment to the variables is a world state. A is a set of actions described in terms of two formulas over V: their preconditions and effects. I is the initial state, and G is a goal condition (again a formula over V). A solution, commonly referred to as a *plan*, is a schedule of actions that is applicable to I and achieves G.

Planning is *PSPACE-complete* even under strong restrictions on the formulas allowed in the planning task description. Research thus revolves around the development and understanding of search methods, which explore, in a variety of different ways, the space of possible action schedules. A particularly successful approach is *heuristic search*, where search is guided by information obtained in an automatically designed *relaxation* (simplified version) of the task. We investigate the design of relaxations, the connections between such design and the search space topology, and the construction of effective *planning systems* that exhibit good practical performance across a wide range of different inputs. Other important research lines concern the application of ideas successful in planning to stochastic sequential decision making (see next), and the development of technology supporting the user in model design.

3.1.2.2. Stochastic Sequential Decision Making

Markov Decision Processes (*MDP*) [51] are a natural framework for stochastic sequential decision making. An MDP is a four-tuple $\langle S, A, T, r\rangle$, where S is a set of states, A is a set of actions, $T(s, a, s') = P(s'|s, a)$ is the probability of transitioning to s' given that action a was chosen in state s, and $r(s, a, s')$ is the (possibly stochastic) reward obtained from taking action a in state s, and transitioning to state s'. In this framework, one looks for a *strategy*: a precise way for specifying the sequence of actions that induces, on average, an optimal sum of discounted rewards $\mathrm{E}\left[\sum_{t=0}^{\infty} \gamma^t r_t\right]$. Here, $(r_0, r_1, ...)$ is the infinitely-long (random) sequence of rewards induced by the strategy, and $\gamma \in (0, 1)$ is a discount factor putting more weight on rewards obtained earlier. Central to the MDP framework is the Bellman equation, which characterizes the *optimal value function* V^*:

$$\forall s \in S, \quad V^*(s) = \max_{a \in A} \sum_{s' \in S} T(s, a, s')[r(s, a, s') + \gamma V^*(s')].$$

Once the optimal value function is computed, it is straightforward to derive an optimal strategy, which is deterministic and memoryless, i.e., a simple mapping from states to actions. Such a strategy is usually called a *policy*. An *optimal policy* is any policy π^* that is *greedy* with respect to V^*, i.e., which satisfies:

$$\forall s \in S, \quad \pi(s) \in \arg\max_{a \in A} \sum_{s' \in S} T(s, a, s')[r(s, a, s') + \gamma V^*(s')].$$

An important extension of MDPs, known as Partially Observable MDPs (*POMDPs*) allows to account for the fact that the state may not be fully available to the decision maker. While the goal is the same as in an MDP (optimizing the expected sum of discounted rewards), the solution is more intricate. Any POMDP can be seen to be equivalent to an MDP defined on the space of probability distributions on states, called *belief states*. The Bellman-machinery then applies to the belief states. The specific structure of the resulting MDP makes it possible to iteratively approximate the optimal value function – which is convex in the *belief space* – by piecewise linear functions, and to deduce an optimal policy that maps belief states to actions. A further extension, known as a DEC-POMDP, considers $n \geq 2$ agents that need to control the state dynamics in a decentralized way without direct communication.

The MDP model described above is enumerative, and the complexity of computing the optimal value function is *polynomial* in the size of that input. However, in examples of practical size, that complexity is still too high so naïve approaches do not scale. We consider the following situations: (i) when the state space is large, we study approximation techniques from both a theoretical and practical point of view; (ii) when the model is unknown, we study how to learn an optimal policy from samples (this problem is also known as Reinforcement Learning [55]); (iii) in factored models, where MDP models are a strict generalization of classical planning – and are thus at least *PSPACE*-hard to solve – we consider using search heuristics adapted from such (classical) planning.

Solving a POMDP is *PSPACE*-hard even given an enumerative model. In this framework, we are mainly looking for assumptions that could be exploited to reduce the complexity of the problem at hand, for instance when some actions have no effect on the state dynamics (*active sensing*). The decentralized version, DEC-POMDP, induces a significant increase in complexity (*NEXP*-complete). We tackle the challenging – even for (very) small state spaces – exact computation of finite-horizon optimal solutions through alternative reformulations of the problem. We also aim at proposing advanced heuristics to efficiently address problems with more agents and a longer time horizon.

3.2. Understanding and mastering complex systems

3.2.1. General context

There exist numerous examples of natural and artificial systems where self-organization and emergence occur. Such systems are composed of a set of simple entities interacting in a shared environment and exhibit complex collective behaviors resulting from the interactions of the local (or individual) behaviors of these entities. The properties that they exhibit, for instance robustness, explain why their study has been growing, both in the academic and the industrial field. They are found in a wide panel of fields such as sociology (opinion dynamics in social networks), ecology (population dynamics), economy (financial markets, consumer behaviors), ethology (swarm intelligence, collective motion), cellular biology (cells/organ), computer networks (ad-hoc or P2P networks), etc.

More precisely, the systems we are interested in are characterized by:

- *locality*: Elementary components have only a partial perception of the system's state, similarly, a component can only modify its surrounding environment.
- *individual simplicity*: components have a simple behavior, in most cases it can be modeled by stimulus/response laws or by look-up tables. One way to estimate this simplicity is to count the number of stimulus/response rules for instance.
- *emergence*: It is generally difficult to predict the global behavior of the system from the local individual behaviors. This difficulty of prediction is often observed empirically and in some cases (e.g., cellular automata) one can show that the prediction of the global properties of a system is an undecidable problem. However, observations coming from simulations of the system may help us to find the regularities that occur in the system's behavior (even in a probabilistic meaning). Our interest is to work on problems where a full mathematical analysis seems out of reach and where it is useful to observe the system with large simulations. In return, it is frequent that the properties observed empirically are then studied on an analytical basis. This approach should allow us to understand where lies the frontier between simulation and analysis.
- *levels of description and observation*: Describing a complex system involves at least two levels: the micro level that regards how a component behaves, and the macro level associated with the collective behavior. Usually, understanding a complex system requires to link the description of a component behavior with the observation of a collective phenomenon: establishing this link may require various levels, which can be obtained only with a careful analysis of the system.

We now describe the type of models that are studied in our group.

3.2.2. Multi-agent models

We represent these complex systems with reactive multi-agent systems (RMAS). Multi-agent systems are defined by a set of reactive agents, an environment, a set of interactions between agents and a resulting organization. They are characterized by a decentralized control shared among agents: each agent has an internal state, has access to local observations and influences the system through stimulus response rules. Thus, the collective behavior results from individual simplicity and successive actions and interactions of agents through the environment.

Reactive multi-agent systems present several advantages for modeling complex systems

- agents are explicitly represented in the system and have the properties of local action, interaction and observation;
- each agent can be described regardless of the description of the other agents, multi-agent systems allow explicit heterogeneity among agents which is often at the root of collective emergent phenomena;
- multi-agent systems can be executed through simulation and provide good models to investigate the complex link between global and local phenomena for which analytic studies are hard to perform.

By proposing two different levels of description, the local level of the agents and the global level of the phenomenon, and several execution models, multi-agent systems constitute an interesting tool to study the link between local and global properties.

Despite a widespread use of multi-agent systems, their framework still needs many improvements to be fully accessible to computer scientists from various backgrounds. For instance, there is no generic model to mathematically define a reactive multi-agent system and to describe its interactions. This situation is in contrast with the field of cellular automata, for instance, and underlines that a unification of multi-agent systems under a general framework is a question that still remains to be tackled. We now list the different challenges that, in part, contribute to such an objective.

3.2.3. Current challenges

Our work is structured around the following challenges that combine both theoretical and experimental approaches.

3.2.3.1. Providing formal frameworks

A widespread and consensual formal definition of a multi-agent system is lacking. Our research aims at translating the concepts from the field of complex systems into the multi-agent systems framework.

One objective of this research is to remove the potential ambiguities that can appear if one describes a system without explicitly formulating each aspect of the simulation framework. As a benefit, the reproduction of experiments is facilitated. Moreover, this approach is intended to gain a better insight of the self-organization properties of the systems.

Another important question consists in monitoring the evolution of complex systems. Our objective is to provide some quantitative characteristics of the system such as local or global stability, robustness, complexity, etc. Describing our models as dynamical systems leads us to use specific tools of this mathematical theory as well as statistical tools.

3.2.3.2. Controlling complex dynamical system

Since there is no central control of our systems, one question of interest is to know under which conditions it is possible to guarantee a given property when the system is subject to perturbations. We tackle this issue by designing exogenous control architectures where control actions are envisaged as perturbations in the system. As a consequence, we seek to develop control mechanisms that can change the global behavior of a system without modifying the agent behavior (and not violating the autonomy property).

3.2.3.3. Designing systems

The aim is to design individual behaviors and interactions in order to produce a desired collective output. This output can be a collective pattern to reproduce in case of simulation of natural systems. In that case, from individual behaviors and interactions we study if (and how) the collective pattern is produced. We also tackle "inverse problems" (decentralized gathering problem, density classification problem, etc.) which consist in finding individual behaviors in order to solve a given problem.

4. Application Domains

4.1. Decision Making

Our group is involved in several applications of its more fundamental work on autonomous decision making and complex systems. Applications addressed include:

- Robotics, where the decision maker or agent is supported by a physical entity moving in the real world;
- Medicine or Personally Assisted Living, where the agent can be an analytic device recommending tests and/or treatments, or able to gather different sources of information (sensors for example) in order to help a final user, detecting for example anormal situation needing the rescue of a person (fall detection of elderly people, risk of hospitalization of a person suffering from chronic disease;
- Active Sensing, where decisions have to be taken in order to gather information on a system. This can be applied to many fields, like for example monitoring the integrity of airplanes wings or the behavior of people in public areas.

4.2. Ambient intelligence

As the Nancy – Grand Est Research Center scientific strategy pushes the development of plateforms on Robotics and Smart Living Apartments, some members of the team have recentered their research toward “ambient intelligence and AI” . This choice is backed up by the Inria Large-scale initiative project termed PAL (Personal assistant Living) in which we are strongly involved. The regional council of Lorraine also supports this new research line through the CPER, (project "situated computing" or "INFOSITU" http://infositu.loria.fr) whose coordinator is a member of MAIA Team. Within this new domain of research in MAIA, we explore how intelligent decentralized complex systems can help designing intelligent environments dedicated to elderly people with loss of autonomy. This domain of research is currently very active, taking up a societal challenge that developed countries have to address.

5. New Software and Platforms

5.1. AA4MM Suite

Participants: Vincent Chevrier [correspondant], Christine Bourjot, Benjamin Camus, Julien Vaubourg, Victorien Elvinger.

Laurent Ciarletta (Madynes team, LORIA) is a collaborator and correspondant for this software. Yannick Presse and Benjamin Segault (Madynes team, LORIA) are collaborator for this software.

AA4MM (Agents and Artefacts for Multi-modeling and Multi-simulation) is a framework for coupling existing and heterogeneous models and simulators in order to model and simulate complex systems. The first implementation of the AA4MM meta-model was proposed in Julien Siebert’s PhD [54] and written in Java, and a renewed JAVA version was submitted to the APP (Agence pour la protection des programmes) the previous year.

The 2014 year was dedicated to improve existing software and to develop new components thanks to new scientific contributions.

Currently, two new software are submitted to the APP:

1. a modelling environment software that enables the graphical definition of multi-models from preexisting elements.
2. AA4MM-Visu, a plug in dedicated to the collection and visualization of information during simulation.

We plan to submit an enhanced version of the JAVA software and of the AA4MM-Visu.

5.2. MASDYNE

Participants: Vincent Chevrier [correspondant], Tomas Navarrete [CRP Henri Tudor].

This work was undertaken in the PhD Thesis of Julien Siebert, a joint thesis between the MAIA and MADYNES teams. It has been enhanced during the PhD of Tomas Navarrete.

MASDYNE (Multi-Agent Simulator of DYnamic Networks usErs) is a multi-agent simulator for modeling and simulating users behaviors in mobile ad hoc network. This software is part of joint work with MADYNES team, on modeling and simulation of ubiquitous networks.

5.3. FiatLux

Participant: Nazim Fatès.

FiatLux is a discrete dynamical systems simulator that allows the user to experiment with various models and to perturb them. It includes 1D and 2D cellular automata, moving agents, interacting particle systems, etc. Its main feature is to allow users to change the type of updating, for example from a deterministic parallel updating to an asynchronous random updating. FiatLux has a Graphical User Interface and can also be launched in a batch mode for the experiments that require statistics.

FiatLux is registered by the Agence pour la protection des programmes (APP). It is available under the CeCILL licence on the FiatLux website : fiatlux.loria.fr

In 2014, FiatLux was internally re-shaped in order to facilitate the reproducibility of experiments. In particular, attention was given to the generation of pseudo-random sequences for the stochastic models.

5.4. Platforms

Inria Research Center in Nancy has supported since 2010 the design and the construction of an innovative platform for favoring research in assistance for elderly people at home. This platform has been mainly funded by the CPER MISN (region of Lorraine , project Info-Situ (2010-2013). It consists of a standard apartment type F2, with a certain number of "smart and connected devices" such as sensor networks. This platform has been designed to make easy technical experimentation in an environment which is as close as possible to reality. Many technical developments have been done during the IPL PAL. In particular concerning MAIA Team, we have been working both (1) on the development of new algorithms to exploit the equipments, and (2) on the effective deployment of different kind of connected devices :

1. a network of depth cameras. These depth cameras are either fixed on the wall or are placed onboard wheeled mobile robots. One important achievement has been to connect these cameras to the ethernet network, each camera being considered as a Ros node with computation capabilities(using a NUC for each node). An other achievement has concerned the calibration of theses cameras. Today 7 cameras covers to whose HIS Platform.
2. Pressure sensing tiles which has been designed by Maia team (in cooperation which Hikob (http://www.hikob.com/applications/recherche/ and the Inria SED of Grenoble (Roger Pissard-Gibollet)) during the Pal evaluation period. Ninety tiles cover the floor of our experimental platform (HIS), which permit to sense activity through the natural interaction of people or robots with the floor when they are acting;
3. Mobile robots whose mobility allows a better coverage in term of perception of the environment.
4. recently we got a Qualisys motion capture system 5funded by Satelor Project).

These devices are all interconnected within the Robotic Operating System (ROS).

6. New Results

6.1. Highlights of the Year

- Two Research Fellow have been recruited with a focus on Service Robotics: Serena Ivaldi (CR2) and Francis Colas (CR1).
- The paper entitled : Exploiting Separability in Multiagent Planning with Continuous-State MDPs Jilles Dibangoye, Christopher Amato, Olivier Buffet, François Charpillet won the best paper award at AAMAS'2014, the international conference on autonomous agents and multi-agents.
- Jilles Dibangoye got an Assistant Professor position at INSA Lyon.

BEST PAPER AWARD :

[12] **Exploiting Separability in Multiagent Planning with Continuous-State MDPs in 13th International Conference on Autonomous Agents and Multiagent Systems**. J. S. DIBANGOYE, C. AMATO, O. BUFFET, F. CHARPILLET.

6.2. Decision Making

6.2.1. Complexity Analysis of Exact Dynamic Programming Algorithms for MDPs

Participant: Bruno Scherrer.

Eugene Feinberg and Jefferson Huang are external collaborators from Stony Brooks University.

Following last year's work on the strong polynomiality of Policy Iteration, we show that the number of arithmetic operations required by any member of a broad class of optimistic policy iteration algorithms to solve a deterministic discounted dynamic programming problem with three states and four actions may grow arbitrarily. Therefore any such algorithm is not strongly polynomial. In particular, the modified policy iteration and λ-policy iteration algorithms are not strongly polynomial. This work was published in the *Operations Research Letters* [4].

6.2.2. Analysis of Approximate Dynamic Programming Algorithms for MDPs

Participants: Bruno Scherrer, Manel Tagorti.

Matthieu Geist is an external collaborator from Supélec.

In [40], we consider LSTD(λ), the least-squares temporal-difference algorithm with eligibility traces algorithm proposed by Boyan (2002). It computes a linear approximation of the value function of a fixed policy in a large Markov Decision Process. Under a β-mixing assumption, we derive, for any value of $\lambda \in (0,1)$, a high-probability estimate of the rate of convergence of this algorithm to its limit. We deduce a high-probability bound on the error of this algorithm, that extends (and slightly improves) that derived by Lazaric et al. (2012) in the specific case where $\lambda = 0$. In particular, our analysis sheds some light on the choice of λ with respect to the quality of the chosen linear space and the number of samples, that complies with simulations. This work was presented at the National JFPDA conference [34].

In the context of infinite-horizon discounted optimal control problem formalized by Markov Decision Processes, we focus on several approximate variations of the Policy Iteration algorithm: Approximate Policy Iteration (API), Conservative Policy Iteration (CPI), a natural adaptation of the Policy Search by Dynamic Programming algorithm to the infinite-horizon case (PSDP), and the recently proposed Non-Stationary Policy Iteration (NSPI). For all algorithms, we describe performance bounds with respect the per-iteration error ϵ, and make a comparison by paying a particular attention to the concentrability constants involved, the number of iterations and the memory required. Our analysis highlights the following points: 1) The performance guarantee of CPI can be arbitrarily better than that of API, but this comes at the cost of a relative—exponential in $\frac{1}{\epsilon}$—increase of the number of iterations. 2) $PSDP_\infty$ enjoys the best of both worlds: its performance guarantee is similar to that of CPI, but within a number of iterations similar to that of API. 3) Contrary to API that requires a constant memory, the memory needed by CPI and PSDP is proportional to their number of iterations, which may be problematic when the discount factor γ is close to 1 or the approximation error ϵ is close to 0; we show that the NSPI algorithm allows to make an overall trade-off between memory and performance. Simulations with these schemes confirm our analysis. This work was presented at this year's international conference on Machine Learning (ICML) [28].

Finally, we consider Local Policy Search, that is a popular reinforcement learning approach for handling large state spaces. Formally, it searches locally in a parameterized policy space in order to maximize the associated value function averaged over some predefined distribution. The best one can hope in general from such an approach is to get a local optimum of this criterion. The first contribution of this article is the following surprising result: if the policy space is convex, *any* (approximate) *local optimum* enjoys a *global performance guarantee*. Unfortunately, the *convexity* assumption is strong: it is not satisfied by commonly used parameterizations and designing a parameterization that induces this property seems hard. A natural solution to alleviate this issue consists in deriving an algorithm that solves the local policy search problem using a boosting approach (constrained to the convex hull of the policy space). The resulting algorithm turns out to be a slight generalization of conservative policy iteration; thus, our second contribution is to highlight an original connection between local policy search and approximate dynamic programming. This work was presented at this year's European conference on Machine Learning (ECML) [27].

6.2.3. Adaptive Management with POMDPs

Participants: Olivier Buffet, Jilles Dibangoye.

Samuel Nicol and Iadine Chadès (CSIRO) are external collaborators.

In the field of conservation biology, adaptive management is about managing a system, e.g., performing actions so as to protect some endangered species, while learning how it behaves. This is a typical reinforcement learning task that could for example be addressed through Bayesian Reinforcement Learning.

During Samuel Nicol's visit, the main problem we have studied is how to manage company inspections to deter these companies from adopting dangerous behaviors. This was modeled as a particular Stackelberg game, where N companies benefit from acting badly as long as they are not caught by inspections, and where 1 government agency has to decide which companies to inspect given a limited budget. The expected result is a stochastic strategy (randomly deciding which companies to inspect, with probabilities that depend on the benefits/losses of both types of players). We are working on exploiting particular features of this computationally complex problem to make it more tractable.

6.2.4. Solving decentralized stochastic control problems as continuous-state MDPs

Participants: Jilles Dibangoye, Olivier Buffet, François Charpillet.

External collaborators: Christopher Amato (MIT).

Decentralized partially observable Markov decision processes (DEC-POMDPs) are rich models for cooperative decision-making under uncertainty, but are often intractable to solve optimally (NEXP-complete), even using efficient heuristic search algorithms.

State-of-the-art approaches relied on turning a Dec-POMDP into an equivalent deterministic MDP —whose actions at time t correspond to a vector containing one decision rules (/instantaneous policy) per agent— typically solved using a heuristic search algorithm inspired by A*. In recent work (IJCAI'13), we have identified a sufficient statistic of this MDP —an *occupancy state*, i.e., a probability distribution over possible states and joint histories of the agents— and demonstrated that the value function was piecewise-linear and convex with respect to this statistic. This brings us in the same situation as POMDPs, allowing to generalize the value function from one occupancy state to another and to propose much faster algorithms (also using efficient compression methods).

This year, we have further progressed on this line of research.

- A journal paper has been submitted that presents the "occupancy MDP" approach in details.

- In the case of Network-Distributed POMDPs, a particular setting where the relations between agents follow a fixed network topology, we have shown that the value function could be decomposed additively with one value function per neighborhood. This work has been presented at AAMAS'2014 [12], receiving the conference's best paper award.
- To further scale up the resolution of Dec-POMDPs, we have proposed multiple approximations techniques that can be combined and allow controlling error bounds. This work has been presented at ECML'2014 [13].

6.2.5. Learning Bad Actions

Participant: Olivier Buffet.

Jörg Hoffmann, former member of MAIA, Michal Krajňanský (Saarland University), and Alan Fern (Oregon State University) are external collaborators.

In classical planning, a key problem is to exploit heuristic knowledge to efficiently guide the search for a sequence of actions leading to a goal state.

In some settings, one may have the opportunity to solve multiple small instances of a problem before solving larger instances, e.g., trying to handle a logistics problem with small numbers of trucks, depots and items before moving to (much) larger numbers. Then, the small instances may allow to extract knowledge that could be reused when facing larger instances. Previous work shows that it is difficult to directly learn rules specifying which action to pick in a given situation. Instead, we look for rules telling which actions should not be considered, so as to reduce the search space. But this approach requires considering multiple questions: What are examples of bad (or non-bad) actions? How to obtain them? Which learning algorithm to use?

A first algorithm (with variants) has been proposed that learns rules for detecting (supposedly) bad actions. It has been empirically evaluated, providing encouraging results, but also showing that different variants will perform best in different settings. This algorithm has been presented at ECAI'2014 [24], and has participated in the learning track of the international planning competition in 2014 (http://ipc.icaps-conference.org/).

6.3. Ambiant Intelligence And Robotic Systems

6.3.1. Adaptation of autonomous vehicle traffic to perturbations

Participants: Mohamed Tlig, Olivier Buffet.

Olivier Simonin, a former member of the MAIA team, is an external collaborator from INSA-Lyon.

The aim of the European project InTraDE is to propose more efficient ways to handle containers in seaports through the use of IAVs (Intelligent Autonomous Vehicles).

In his PhD thesis, Mohamed Tlig considers the displacements of numerous such IAVs whose routes are a priori planned by a supervisor. However, in such a large and complex system, different unexpected events can arise and degrade the traffic: failure of a vehicle, human mistake while driving, obstacle on roads, local re-planning, and so on.

In 2013, we have started looking at improving vehicle flows in complete road networks. In particular, we have proposed an approach that allows multiple flows of vehicles to cross an intersection without stopping, allowing to reduce delays as well as energy consumption. This has led to a publication in ICALT-14 [30], with more details in a research report [41].

This year, we have made a further step by coordinating the controller agents located in each of the network's intersections. More precisely, they are constrained to let the vehicles alternate at the same frequency —at the expense of potentially reducing the maximum flow of some roads— and a distributed algorithm offsets these "signals" so as to optimize either the energy consumption, or the time spent in the network. This tends to induce "green waves" wherever possible, i.e., to prevent vehicles from having to slow down before a traffic light. This work has been presented at ECAI-14 [31].

6.3.2. Platooning: safe and precise virtual hooking mechanism or automated vehicles

Participants: Jano Yazbeck, Alexis Scheuer, François Charpillet.

Among the several goals that we were trying to achieve in InTraDE, we were interested in platooning too. In her PhD thesis, Jano Yazbeck considers Platooning as a technique that aims at steering , safely and precisely, a train of vehicles along a path generated by a leader which can be driven by a human. Thus the trajectory is unknown to the followers. Platooning is considered in this project in order to move containers efficiently from the discharge zones of ships to the storage areas.

To obtain a safe and precise platooning, we aim at controlling the longitudinal and lateral behaviors of each vehicle of the platooning. On the one hand, the longitudinal controller computes a longitudinal velocity (or acceleration) which avoids collisions between vehicles by maintaining a safe inter-distance between each couple of successive vehicles. On the other hand, the lateral controller computes an angular velocity or a steering angle so that the vehicle follows precisely the leader's path. These two controllers can be decoupled and computed separately when the convoy moves at a low velocity.

This year, we proposed a platooning algorithm based on a near-to-near decentralized approach which has been published at ICRA 2014 [32]. In this approach, each vehicle estimates and memorizes on-line the path of its predecessor as a set of points. After choosing a suitable position to aim for, the follower estimates on-line the predecessor's path curvature around the selected target. Then, based on a heuristic search, it computes an angular velocity using the estimated curvature. The optimization criteria used in this work allows the robot to follow its predecessor's path without oscillation while reducing the lateral and angular errors.

In october, Jano Yazbeck defended her Phd Thesis [2].

6.3.3. Map Matching

Participant: François Charpillet.

This work [8] has been realized during the Intrade Projet with Maan Badaoui from Lille University. It addresses an important issue for intelligent transportation system, namely the ability of vehicles to safely and reliably localize themselves within an a priori known road map network. For this purpose, we have proposed an approach based on hybrid dynamic bayesian networks enabling to implement in a unified framework two of the most successful families of probabilistic model commonly used for localization: linear Kalman filters and Hidden Markov Models. The combination of these two models enables to manage and manipulate multi-hypotheses and multi-modality of observations characterizing Map Matching problems and it improves integrity approach. Another contribution of the paper is a chained-form state space representation of vehicle evolution which permits to deal with non-linearity of the used odometry model. Experimental results, using data from encoders' sensors, a DGPS receiver and an accurate digital roadmap, illustrate the performance of this approach, especially in ambiguous situations.

6.3.4. Multi-Camera Tracking in Partially Observable Environment

Participants: Arsène Fansi Tchango, Olivier Buffet, Vincent Thomas, Alain Dutech.

Fabien Flacher (Thales ThereSIS) is an external collaborator.

In collaboration with Thales ThereSIS - SE&SIM Team (Synthetic Environment & Simulation), we focus on the problem of following the trajectories of several persons with the help of several controllable cameras. This problem is difficult since the set of cameras cannot simultaneously cover the whole environment, since some persons can be hidden by obstacles or by other persons, and since the behavior of each person is governed by internal variables which can only be inferred (such as his motivation or his hunger).

The approach we are working on is based on (1) the HMM (Hidden Markov Models) formalism to represent the state of the system (the persons and their internal states), (2) a simulator provided and developed by Thales ThereSIS, and (3) particle filtering approaches based on this simulator. Since activity and location depend on each other, we adopt a Simultaneous Tracking and Activity Recognition approach (STAR) as presented in current state-of-the-art approaches.

A first novelty lies in the use of a complex behavioral simulator. In a single-target setting, we demonstrated that it allows inferring the behavior of a complex individual, even in case of long periods of occlusions (when cameras do not cover the trajectory of the target). This idea led to publications in AAMAS-14 [16], STAIRS-14 [18], and ECAI-14 [17].

A remaining issue is to find tractable algorithms for efficiently tracking multiple targets simultaneously, which requires using a factored particle filter (with one distribution per target). To that end, we use a Joint Probabilistic Data Association Filter with two key ingredients. The first ingredient is a particular model of dynamics that largely decouples the evolution of several targets, and turns out to be very natural to apply (which has led already to a publication in Fusion-14 [19]). Then, the factorization *a priori* implies, for a given target, simulating each of its particles with each particle of each other target (which leads to a huge number of simulations). The second proposed ingredient is to simulate each particle of a given target only with a small number of "representatives" of each other target (and then, because more particles are produced than needed, a selection/resampling step is required).

6.3.5. Emergence et Developmental Learning

Participants: Alain Dutech, Matthieu Zimmer.

Yann Boniface (CORTEX, Loria) is an external collaborator

Following our ongoing work on using reinforcement learning for the control of redundant continous robotic systems, we explore how learning such complex tasks can benefit from a developmental approach, following some line of work already tested in robotics [50].

"Emergence", on of the key concepts grounding this work, has been presented – from an artificial intelligence perspective – and discussed with researchers from other fields. This lead to fruitful exchanges and a chapter in a bookdedicated to the dual aspects of (human gestures) : appearance and emergence [36]. "Developmental Learning" was also the main subject of a seminar in Lyon in which Alain Dutech has been invited [47].

More concretely, we have developed several algorithms which mix artificial neural networks (like Dynamic Self-Organizing Maps or Reservoir Computing Network) with reinforcement learning mechanisms in order to build simple artificial systems that are *autnomous* and that learn without any *exogeneous* intervention from an external being. This work, initiated through two master thesis, is now the central topic ot the PhD of Matthieu Zimmer, started in october 2014.

6.3.6. Online Evolutionary Learning

Participants: Amine Boumaza, François Charpillet, Iñaki Fernandèz.

Evolutionary Robotics (ER) deals with the design of agent behaviors using artificial evolution. Within this framework, the problem of learning optimal decision functions (or controllers) is treated as a policy search problem in the parameterized space of candidate policies. In this work we are interested in learning optimal behaviors for swarm of mobile agents online (while solving the task). We adopt an online onboard distributed view [56], [48] and consider the learning process as executed at the agents' level in a decentralized way. This kind of algorithms raises several questions concerning the usefulness of selection pressure (partial views of population, noisy fitness values, etc.).

We studied the impact of task-driven selection pressures in on-line distributed ER for swarm behavior learning. We proposed a variant of the mEDEA [45] algorithm in which we added a selection operator, in a task-driven scenario. We evaluated four selection methods that induce different intensity of selection pressure in a multi-robot navigation with obstacle avoidance task and a collective foraging task.

Experiments showed that a small intensity of selection pressure is sufficient to rapidly obtain good performances on the tasks at hand. We introduced different measures to compare the selection methods, and show that the higher the selection pressure, the better the performances obtained, especially for the more challenging food foraging task. This research was presented at the 13th International Conference on the Synthesis and Simulation of Living Systems [21].

6.3.7. Frailty evaluation and Fall detection

Participants: Amandine Dubois, François Charpillet, Thomas Moinel, Maxime Rio.

This work is related to the IPL PAL and Satelor project and is related to Personal Assistant Living (PAL) for elderly people with loss of autonomy.

- Clinical evaluation of frailty in the elderly is the first step to decide the degree of assistance that elderly people require. No standard tests exist to detect the level of frailty, each clinician chooses his protocol among existing tools. There are clinical tests as *Tinetti test*, *Timed Up and Go* test for evaluating the degree of dependance and the frailty of elderly people. These tests consist in asking a person to realize exercises simulating movements of daily life. The physician evaluates the quality of gait and the balance of the patient. These tests are often used but, the disadvantage is that the final verdict relies primarily on a subjective opinion. The aim of our work is to provide new objective criteria to refine the elderly frailty quantification. We base ourselves on the frailty definition of Fried *et al* as being a clinical syndrome in which three or more of the following criteria are present: unintentional weight loss, self reported exhaustion, weakness (with regards to grip strength), slow walking speed and low physical activity. From this definition, we have defined two axis of development to evaluate the frailty of a person: Sensor based Activity recognition with the aim to follow and report daily life activities in order to detect evolution that coud reveal increased frailty [1], gait analysis in order to assess gait pattern and their evolution over time [14].
- An other PAL research domain, which is related to activity recognition, has attracted our attention: fall detection. Falls in the elderly is a major public health problem because of their frequency and their medical and social consequences. One of our objectives is to design an automatic system to detect fall at home, which in its final version will be made up of a network of RGB-D sensors, some of them being mobile embedded a wheel mobile robot.

The main contribution of this work has been to design a simple but robust method based on the identification and tracking of the center of mass of people evolving in an indoor environment through a RGB-D camera. Using a simple Hidden Markov Model whose observations are the position of the center of mass, its velocity and the general shape of the body, we have shown that we can surprisingly monitor the activity of a person with high accuracy, detect falls with very good accuracy without false positives and also measure some interesting parameter such as speed of gait, length of steps, etc. An experimental study, that is reported in [46], has been driven in our smart apartment lab. 26 subjects were asked to perform a predefined scenario in which they realized a set of eight postures. 2 hours of video (216 000 frames) were recorded for the evaluation, half of it being used for the training of the model. The system detected the falls without false positives. This result encourages us to use this system in real situation for a better study of its efficiency. Therefore, we started this year an experimention in a room of a follow-up care and rehabilitation facility (OHS) in Nancy. "Office d'Hygiène Sociale" (OHS) is an association under the law of 1901. It supports nearly 800 people over 60 years and nearly 1,000 children and adults with disabilities. The association manages 26 facilities (40% health field, 40% medical-social field and 20% social field) and employs more than 1,500 professionals.

6.3.8. Posture recognition with a Depth camera

Participants: Abdallah Dib, François Charpillet, Xuan Nguyen, Alain Filbois [SED].

In this research line, we focus our contribution on improving model-based approaches that use a population-based stochastic framework for full human body tracking using monocular depth camera. One of the major challenges in human tracking is the high-dimensional state spaces. To address this problem, we propose a tracking algorithm based on APF and CMA-ES. While APF has been widely applied for human tracking in RGB and depth images, the application of CMA-ES to human tracking is still limited. Yet, CMA-ES shares many similar ideas with APF and can be exploited to improve the performance of APF. Our key idea is to update the covariance matrix for sampling particles at each layer of APF, using a subset of best particles, an idea inspired from CMA-ES. The resulting algorithm is shown to greatly reduce the number of particles required for successful tracking. In the absence of image features such as texture or color, existing likelihood models for human tracking in depth images are often built by computing distances between data points and model points sampled on the surface of the human body model. When human body parts are close or when severe self-occlusions are present, these models fail to capture good pose hypotheses. As a result, existing approaches are unable to track a broad range of human motions. To deal with this issue, we propose a likelihood model which is based on comparing observed depth images and rendered depth images obtained by classic rendering techniques. Combining with our tracking algorithm, the proposed likelihood model has been shown to be effective when tracking under severe self-occlusions. To the best of our knowledge, our approach is the first model-based one that uses a population-based stochastic framework able to track full human body with non-frontal and unusual poses, using monocular depth camera.

6.3.9. Pressure sensing floor

Participants: Mihai Andries, François Charpillet, Olivier Simonin.

The use of floor-sensors in ambient intelligence contexts began in the late 1990's, with projects like ORL active floor, the Magic carpet by Paradiso *et al.*, and the smart floor by Orr *et al.* These floors were, later on, integrated in smart environments, aimed at delivering assistance services like continuous diagnosis of users' health. According to the literature there are currently at least 6 main types of floor pressure sensing technologies: binary switches, piezoelectric, load cells, capacitive, polymer thick film (PTF), and photo interrupter sensors. Most of presented solutions extract a set of features for their tracking and identification task. Recently, sensing floors products like the SensFloor (a floor network of capacitive proximity sensors), Capfloor (a network of capacitive sensors), Elsi® smart floor (http://www.elsitechnologies.com) and FloorInMotion (Tarkett France) started being commercialized by companies, mainly for the senior care industry.

We have ourselves developed a sensing floor. This load-sensing floor is composed of square tiles, each equipped with two ARM processors (Cortex m3 and a8), 4 load cells, and a wired connection to the four neighboring cells. Each tile has 16 light-emitting diodes which provide visual feedback. The processing units were manufactured by Hikob [3]. This prototype was originally designed as a medium of interaction for robots with distributed control, in an ant-like fashion. The computing unit available on each tile can register a virtual pheromone trace, that can then be transmitted to other robots, using either wired or wireless communication. In a different perspective, the sensing-floor acts merely as a sensor for an ambient intelligence. Using the magnetometer embedded on the processing unit of the tile, each tile can detect disturbances in its surrounding magnetic field, that can be caused by the presence of robots. Each tile also has an embedded accelerometer, that allows it to detect shocks that can be caused by objects or humans falling on the ground.

Several functionalities have been implemented this year on this prototype floor, including weight measurement, fall detection, footstep tracking and activity recognition. We also implemented heuristic real-time multi-user localisation (without user identification) in an indoor setting using this prototype floor.

6.3.10. Living assistant Robot

Participants: François Charpillet, Nicolas Beaufort, Abdallah Dib.

With LAR (**living AssistanT Robot**), a PIA projet which started in March, Abdallah Dib joined our team for a PhD. His work is about the development of a low cost navigation system for a robot evolving in an indoor environment. The main issue of his work is to design a Simultaneous Localisation and Mapping algorithm working in a dynamic environment in which people are moving. This is very challenging if we restrict the sensing capabilities of the robot with low cost sensors such as RGB-D camera. An important service we expect the robot to achieve, is realizing similar services as the one we described below: fall detection, activity recognition. This year first result have been published [11]. A feature based visual SLAM method that uses chamfer distance to estimate the camera motion from RGB-D images has been presented. The method does not require any matching which is an expensive operation and always generates false matching that affects the estimated camera motion. Our approach registers the input image iteratively by minimizing the distance between the feature points and the occupancy grid using a distance map. We demonstrate with real experiments the capability of the method to build accurate 3D map of the environment with a hand-held camera. While the system was mainly developed to work with RGB-D camera, occupancy grid representation gives the method

[3] http://www.hikob.com/

the ability to work with various types of sensors, we show the capacity of the system to construct accurate 2D maps using telemeter data. We also discuss the similarities between the proposed approach and the traditional ICP algorithm.

6.3.11. Exploring an unknown environment with a team of mobile robots

Participants: François Charpillet, Olivier Simonin, Nassim Kaldé.

This work is the continuation of the work realized during the ANR Cart-O-matic (2010 to 2013). We address, here, the problem of efficient allocation of the navigational goals in the multi-robot exploration of unknown environment. Goal candidate locations are repeatedly determined during the exploration. Then, the assignment of the candidates to the robots is solved as the task-allocation problem. A more frequent decision-making may improve performance of the exploration, but in a practical deployment of the exploration strategies, the frequency depends on the computational complexity of the task-allocation algorithm and available computational resources. Therefore, this year, we have proposed an evaluation framework to study exploration strategies independently on the available computational resources. A comparison of the selected task-allocation algorithms deployed in multi-robot exploration has been done and published with Jan Faigl from Czech Technical University in Prague in the framework of the PHC project MACOREX.

An other point that is addressed by Nassim Kaldé is to consider the same problem but with dynamical environment in particular populated with human beings. First results of Nassim Kalde have been published in JFSMA'14 [33]. He published too the work done during his Master thesis [23].

6.4. Understanding and mastering complex systems

6.4.1. Adaptive control of a complex system based on its multi-agent model

Participant: Vincent Chevrier.

Laurent Ciarletta (Madynes team, LORIA) is an external collaborator.

Complex systems are present everywhere in our environment: internet, electricity distribution networks, transport networks. These systems have as characteristics: a large number of autonomous entities, dynamic structures, different time and space scales and emergent phenomena. This thesis work is centered on the problem of control of such systems. The problem is defined as the need to determine, based on a partial perception of the system state, which actions to execute in order to avoid or favor certain global states of the system. This problem comprises several difficult questions: how to evaluate the impact at the global level of actions applied at a global level, how to model the dynamics of an heterogeneous system (different behaviors issue of different levels of interactions), how to evaluate the quality of the estimations issue of the modeling of the system dynamics.

We propose a control architecture based on an "equation-free" approach. We use a multi-agent model to evaluate the global impact of local control actions before applying the most pertinent set of actions.

Associated to our architecture, an experimental platform has been developed to confront the basic ideas or the architecture within the context of simulated "free-riding" phenomenon in peer to peer file exchange networks. We have demonstrated that our approach allows to drive the system to a state where most peers share files, despite given initial conditions that are supposed to drive the system to a state where no peer shares. We have also executed experiments with different configurations of the architecture to identify the different means to improve the performance of the architecture.

This work helped us to better identify [26] the key questions that rise when using the multi-agent paradigm in the context of control of complex systems, concerning the relationship between the model entities and the target system entities.

6.4.2. Multi Modeling and multi-simulation

Participants: Vincent Chevrier, Christine Bourjot, Benjamin Camus, Julien Vaubourg.

Laurent Ciarletta and Yannick Presse (Madynes team, LORIA) are external collaborators.

Laurent Ciarletta is the co-advisor of the thesis of Julien Vaubourg.

Complex systems generally require to use different points of view (abstraction levels) at the same time on the system in order to capture and to understand all the dynamics and the complexity. Being made of different interacting parts, a model of a complex system also requires simultaneously modeling and simulation (M&S) tools from different scientific fields.

We proposed the AA4MM meta-model [54] that solves the core challenges of multimodelling and simulation coupling in an homogeneous perspective. In AA4MM, we chose a multi-agent point of view: a multi-model is a society of models; each model corresponds to an agent and coupling relationships correspond to interaction between agents.

This year we progress in the definition of multi-level modeling [42]. We identified several facets of multi-level modeling and implemented then as different kinds of interactions in AA4MM framework. We progressed on the specification of the meta-model which helped to define a modeling environment.

In the MS4SG projet which involves MAIA, Madynes and EDF R&D on smart-grid simulation, we developed a proof of concepts for a smart-appartment case [10].

6.4.3. Cellular automata as a foundation of complex systems

Participant: Nazim Fatès.

Our research on emergent collective behavior focuses on the analysis of the robustness of discrete models of complex systems. We ask to which extent systems may resist to various perturbations in their definitions. We progressed in the knowledge of how to tackle this issue in the case of cellular automata (CA) and multi-agent systems (MAS).

We proposed an extended version of our survey on asynchronous cellular automata [3].

In collaboration with colleagues from India, we proposed a complete characterisation of the reversibility of the set of the 256 Elementary Cellular Automata with asynchronous updating [29]. These rules are known to be diffcult to study in all generality and it is interesting to notice that here, asynchronism is an aid rather than an obstacle to analyse the behaviour of the systems.

With Henryk Fukś (Brock Univ., Canada), we proposed a mathematical analysis of the second-order phase transitions that are observed in the most simple asynchronous cellular automata [22].

Our work on the classification of cellular automata was presented in the AUTOMATA'14 conference and is now the topic of a collaboration with L. Gerin (École Polytechnique) [44], [20].

We are currently participating to the edition of the first book devoted to probabilistic cellular automata and to a special issue of the French-speaking journal *Technique et Science Informatique* (Lavoisier editors).

6.4.4. Revisiting wavefront construction with collective agents: an approach to foraging.

Participants: François Charpillet, Olivier Simonin.

We consider here [7], the problem of coordinating a team of agents that have to collect disseminated resources in an unknown environment. We are interested in approaches in which agents collectively explore the environment and build paths between home and resources. The originality of our approach is to simultaneously build an artificial potential field (APF) around the agents' home while foraging. We propose a multi-agent model defining a distributed and asynchronous version of Barraquand et al. Wavefront algorithm. Agents need only to mark and read integers locally on a grid, that is, their environment. We prove that the construction converges to the optimal APF. This allows the definition of a complete parameter-free foraging algorithm, called c-marking agents. The algorithm is evaluated by simulation, while varying the foraging settings. Then we compare our approach to a pheromone-based algorithm. Finally, we discuss requirements for implementation in robotics.

7. Bilateral Contracts and Grants with Industry

7.1. Inria-EDF Strategic action MS4SG

Participants: Vincent Chevrier, Julien Vaubourg, Victorien Elvinger.

Laurent Ciarletta, Yannick Presse and Benjamin Segault (Madynes team, LORIA) are external collaborators.

The MS4SG (multi-simulation for smart grids) project is granted as a strategic action between Inria and EDF. This project is joint between Madynes and MAIA team from Inria-NGE and EDF R&D.

Smart-grids are electric supply grids endowed with smart capabilities because of the use of information and communication technologies. This perspective of smart grids corresponds to new challenges and it is needed to re-think the way electricity is supplied to customers and the power supply network regulated.

The simulation approach can be taken to envisage the supervision and regulation of these systems. Such an approach implies to integrate simulators coming from different domains: electrical networks, communication networks and information systems. As these domains can influence each other, smart-grids can be considered as a kind of complex system and we are faced with multi-modeling and multi-simulation issues: models in these simulators (and therefore simulators softwares) are heterogeneous (at least equation based and event based models), the softwares used are existing ones, etc.

The aim of the project is to provide primitives based on AA4MM in order to enable the multi-modeling and the multi-simulation of smart-grids.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. AME Satelor SATELOR

Participants: François Charpillet, Maxime Rio, Nicolas Beaufort, Xuan Nguyen, Thomas Moinel, Mélanie Lelaure, Theo Biasutto-Lervat.

Economic mobilisation agency in Lorraine has launched a new project SATELOR providing it with 2.5 million Euros of funding over 3 years, out of an estimated total of 4.7 million. The leader of the project is Pharmagest-Diatelic. PHARMAGEST is the French leader in computer systems for pharmacies, with a 43.5 % share of the market, 9,800 clients and more than 700 employees. Pharmagest is in Nancy. Recently, PHARMAGEST Group expanded its activities into e-health and the development of telemedicine applications. The SATELOR project will accompany the partners of the project in developing new services for maintaining safely elderly people with loss of autonomy at home or people with a chronic illness. Maia team will play an important role for bringing some research results such as :

- developing a low cost environmental sensor for monitoring the daily activities of elderly people at home
- developing a low cost sensor for fall detection
- developing a low cost companion robot able to interact with people and monitoring their activities while detecting emergency situations.
- developing a general toolbox for data-fusion : bayesian approach.

8.1.2. CNRS / Université de Lorraine PEPS project "MAJESTIC" (2014)

Participants: Vincent Thomas, Amine Boumaza, Olivier Buffet, Alain Dutech.

Sylvain Castagnos (KIWI team, LORIA/UL), and several members of the Centre de recherche sur les médiations (CREM) of Université de Lorraine —in particular Sébastien Genvo— are external members.

This multidisciplinary project —which involves humanities, social sciences, computer science, and cognitive sciences— proposes to evaluate the playful elements of “expressive” games, which involve and express complex social or individual issues. It aims at elaborating and testing —through qualitative usage analyses— a set of hypotheses allowing to study the factors contributing to reinforce, on the one side, the commitment of the user in these often atypical products and, on the other side, the player’s knowledge-building.

This project led to the organisation of an international seminar “expressive game” and to the creation of two platforms for qualitative usage analysis: one in tcrm-Blida (Metz), and one in Artem (Nancy).

8.1.3. Université de Lorraine MSH project “PSYPHINE”

Participants: Amine Boumaza, Alain Dutech.

This multidisciplinary project – which involves philosophy, sociology, psychology and computer sciences – aims at exploring the concept of consciousness in an artificial being. Our main objective is to devise a new non-verbal ”Turing test” in order to think about various cognitive levels that are less linked to the capacity of using a language.

8.2. National Initiatives

8.2.1. Inria IPL PAL Personally Assisted Living

Participants: François Charpillet, Olivier Simonin, Mihai Andries.

The PAL project is a national Inria Large Scale Initiative involving several teams of the institute (Arobas, Coprin, E-motion, Lagadic, Demar, Maia, Prima, Pulsar and Trio). It is coordinated by David Daney (Inria Sophia-Antipolis, EPI Coprin). The project focuses on the study and experiment of models for health and well-being. Maia is particularly involved in the People Surveillance work package, by studying and developping intelligent environments and distributed tracking devices for people walking analysis and robotic assistance (smart tiles, 3D camera network, assistant robots).

The PhD of Mihai Andries in funded by the PAL project.

8.2.2. PIA LAR Living Assistant Robot

Participants: François Charpillet, Abdallah Dib.

Partners : Crédit Agricole, Diatelic, Robosoft
LAR project has the objective to designing an assistant robot to improve the autonomy and quality of life for elderly and fragile persons. The project started at the beginning of the year. The role of the Maia Team is to develop a simultaneous localisation and mapping algorithm using a RGB-D camera. The main issue is to develop an algorithm able to deal with dynamic environment. An other issue is for the robot to be able to behave with acceptable social skills.

8.2.3. ANR

8.2.3.1. ANR PHEROTAXIS

Participants: François Charpillet, Olivier Simonin.

Dominique Martinez (Cortex team, Inria NGE) is an external collaborator and the coordinator of the project for Nancy members.

PHEROTAXIS is an “Investissements d’Avenir” ANR 2011-2014 (Coordination: J.-P. Rospars, UMR PISC, INRA Versailles).

The theme of the research is localisation of odour sources by insects and robots. By associating experimental data with models, the project aims at defining a behavioral model of olfactive processes. This work provides several applications, in particular the development of bio-inspired components highly sensitive and selective.

The project is organized in five work packages and involves the PISC research unit (Versailles), Pasteur Institute (Paris) and LORIA/Inria institute (Nancy).

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. CoDyCo

Serena Ivaldi, arrived in November 2014, participates to the European Project CODYCO since its beginning. Her participation to the project has been formalized by including Inria as a new partner of the consortium.

Type: FP7

Defi: NC

Instrument: STREP

Objectif: Cognitive Systems and Robotics (b)

Duration: Marc 2013 - February 2017 (4 years)

Coordinator: Francesco Nori (Italian Institute of Technology)

Partners: TU Darmstadt (Germany), Université Pierre et Marie Curie (France), Josef Stefan Institue (Slovenia), University of Birmingham (UK)

Inria contact: Serena Ivaldi

Abstract: The aim of CoDyCo is to advance the current control and cognitive understanding about robust, goal-directed whole-body motion interaction with multiple contacts. CoDyCo will go beyond traditional approaches: (1) proposing methodologies for performing coordinated interaction tasks with complex systems; (2) combining planning and compliance to deal with predictable and unpredictable events and contacts; (3) validating theoretical advances in real-world interaction scenarios. First, CoDyCo will advance the state-of-the-art in the way robots coordinate physical interaction and physical mobility. Traditional industrial applications involve robots with limited mobility. Consequently, interaction (e.g. manipulation) was treated separately from whole-body posture (e.g. balancing), assuming the robot firmly connected to the ground. Foreseen applications involve robots with augmented autonomy and physical mobility. Within this novel context, physical interaction influences stability and balance. To allow robots to surpass barriers between interaction and posture control, CoDyCo will be grounded in principles governing whole-body coordination with contact dynamics. Second, CoDyCo will go beyond traditional approaches in dealing with all perceptual and motor aspects of physical interaction, unpredictability included. Recent developments in compliant actuation and touch sensing allow safe and robust physical interaction from unexpected contact including humans. The next advancement for cognitive robots, however, is the ability not only to cope with unpredictable contact, but also to exploit predictable contact in ways that will assist in goal achievement. Third, the achievement of the project objectives will be validated in real-world scenarios with the iCub humanoid robot engaged in whole-body goal-directed tasks. The evaluations will show the iCub exploiting rigid supportive contacts, learning to compensate for compliant contacts, and utilizing assistive physical interaction.

8.3.2. Collaborations in European Programs, except FP7 & H2020

8.3.2.1. PHC MUROTEX

This project is with Olivier Simonin from Insa Lyon, Citi lab and Jan Faigl from Czech Technical University in Prague.

Program: Hubert Curien Partnerships

Project acronym: MUROTEX

Project title: Multi-agent coordination in robotics exploration and reconnaissance missions

Duration: 2 years from 1st january 2014

Coordinator: O. Simonin (INSA LYON)

Other partners: Czech Technical University in Prague

Abstract: The main objective of the project is to develop a distributed planning framework for efficient task-allocation planning in exploration and reconnaissance missions by a group of mobile robots operating in an unknown environment with considering communication constraints and uncertainty in localization of the individual team members. One main challenge is to decentralize the decision, in order to scaling up with large fleet of robots (existing solutions are centralized or depend on full communication).

8.4. International Initiatives

Serena Ivaldi and Francois Charpillet are part of the joint Inria-TUD team that was selected to participate to the KUKA Innovation Award. On December 2014, the team received a new industrial manipulator, KUKA iiwa, to prepare the challenge for the first quarter of 2015. The manipulator is lent by KUKA and will be returned at the end of the competition.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Dr. Samuel Nicol, postdoctoral researcher at CSIRO, Ecosystem Sciences division (Brisbane, Australia), visited MAIA for 2 weeks in June 2014.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

9.1.1.1. Selection Committees, AERES

- François Charpillet was member of two selection committees in University of Lyon and Lorraine University
- François Charpillet was member of the AERES evaluation commitee for IRIT, Toulouse and LISSI, Université Paris Est.

9.1.1.2. Organizing committee membership

- François Charpillet is member of the scientific concil of the Robotic GDR.
- Vincent Thomas was part of the organizing committee of the "Expressive game seminar", held in Metz, the 24th and 25th of November (http://exgames.event.univ-lorraine.fr/). This international seminar involved two laboratories of the university of Lorraine, the CREM (Centre de recherche sur les médiations) and the LORIA. It gathered international specialists of game design and was part of the PEPS Majestic research program.
- Vincent Thomas was part of the organizing committee of the conference "From traditional game to digital game" (http://tgdg2014-fr.event.univ-lorraine.fr/), held in Nancy, the 26th, 27th and 28th of November.

9.1.2. Scientific events selection

9.1.2.1. Conference program committee membership

- Amine Boumaza was a member of the program committee of the following international conferences: GECCO'14 (The Genetic and Evolutionary Computation Conference), CEC'14 (Congress on Evolutionary Computation), Alife'14 Int. Conf. on the Synthesis and Simulation of Living Systems. He was a member of the jury of the AFIA thesis award.

- Olivier Buffet was a reviewer for the conferences ECAI'14 (European Conference on Articial Intelligence), ICAPS'14 (International Conference on Automated Planning and Scheduling), UAI'14 (International Conference on Uncertainty in Artificial Intelligence), JFPDA'14 (Journées Francophones sur la Planification, la Décision et l'Action pour le contrôle de systèmes), RFIA'14 (conférence sur la reconnaissance des formes et l'intelligence artificielle).
- François Charpillet was member of the program committees for : Macorex workshop at ECAI'14, MSDM 2014 at AAMAS'14, SENSORNETS 2015, ICAART 2015.
- Vincent Chevrier was a reviewer for IAT'14 (IEEE/WIC/ACM International Conference on Intelligent Agent Technology), ACRI'14 ABSim&CA (International Conference on Cellular Automata for Research and Industry, Agent-Based Simulation & Cellular Automata Workshop) JFSMA'14 (Journées francophones sur les Systèmes multi-Agents).
- Francis Colas was member of the program committee of SAB2014 (Simulation of Adaptive Behaviors).
- Alain Dutech was a reviewer for the conferences JFPDA'14 (Journées Francophones sur la Planification, la Décision et l'Action pour le contrôle de systèmes), and ECAI'14 (European Conference on Articial Intelligence).
- Nazim Fatès was a member of the program committe of the international conferences: ACRI'14 (11th International Conference on Cellular Automata for Research and Industry), and the following workshops: ACA'14 (Third International Workshop on Asynchronous Cellular Automata and Asynchronous Discrete Models) and ABSim&CA'14 (First International Workshop on Agent-Based Simulation & Cellular Automata), ANTS'14 (Ninth Int. Conf. on Swarm Intelligence).
- Bruno Scherrer was part of the program committee for for the international conferences NIPS'14 (Neural Information Processing Systems), ECAI'14 (European Conference on Artificial Intelligence) and MED'14 (Mediterranean Conference on Control and Automation), for the international NIPS'14 Workshop "From Bad Models to Good Policies", and for the French conferences CAP'14 (Conférence d'apprentissage automatique) and JFPDA'14 (Journées Francophones sur la Planification, la Décision et l'Action pour le contrôle de systèmes).
- Vincent Thomas was a reviewer for JFPDA'14 (Journées Francophones sur la Planification, la Décision et l'Action pour le contrôle de systèmes).
- Serena Ivaldi was associate editor for the conference Humanoids 2014 (International Conference on Humanoid Robots).

9.1.2.2. Reviewing activities

- François Charpillet was reviewer for the IROS 2014 (IEEE/RSJ International Conference on Intelligent Robots and Systems) and ICRA 2015 (IEEE International Conference on Robotics and Automation), ASROB at IROS 2014, Macorex workshop at ECAI'14, MSDM 2014 at AAMAS'14, SENSORNETS 2015, ICAART 2015.
- Francis Colas was reviewer for the IROS 2014 (IEEE/RSJ International Conference on Intelligent Robots and Systems) and ICRA 2015 (IEEE International Conference on Robotics and Automation).
- Nazim Fatès was a reviewer for the ALIFE'14 and MOSIM'14 conferences.
- Serena Ivaldi was reviewer for the HRI'15 conference (International Conference on Human-Robot Interaction).

9.1.3. Journal

9.1.3.1. Editorial board membership

- Amine Boumaza is a review editor of the International Journal *Frontiers in Robotics and AI: Evolutionary Robotics*.
- Olivier Buffet is a member of the editorial boards of the *"revue d'intelligence artificielle"* (RIA), and the "Journal of Artificial Intelligence Research" (JAIR).

- Serena Ivaldi is a review editor of the International Journal *Frontiers in Robotics and AI: Humanoid Robotics*. She is co-organiser of the Special Issue on “Whole-body control of contacts for Humanoid Robots” in the Autonomous Robots journal.

9.1.3.2. Reviewing activities

- Amine Boumaza was a reviewer for the Evolutionary Intelligence journal.
- Olivier Buffet was a reviewer for the journals: AIJ (Artificial Intelligence Journal), JAIR (Journal of Artificial Intelligence Research), and Neurocomputing.
- François Charpillet was a reviewer for Journal of Intelligent and Robotic Systems
- Vincent Chevrier was a reviewer for IEEE Transactions on Services Computing (TSC),
- Francis Colas was a reviewer for the Autonomous Robots journal.
- Alain Dutech was a reviewer for RIA (Revue d’Intelligence Artificielle), EJOR (European Journal of Operationnal Research), and JAIR (Journal of Artificial Intelligence Research).
- Nazim Fatès was a reviewer for *Natural Computing*, *Theoretical Computer Science* and *Proc. of the National Academy of Sciences, Sec. A, India*.
- Serena Ivaldi was a reviewer for the journals: Robotics and Autonomous Systems, Autonomous Robots, IEEE Transactions on Cybernetics.
- Bruno Scherrer made reviews for the following journals: Journal of Machine Learning Research, Annals of Operations Research, Applied Mathematics & Optimization and IEEE Transactions on Neural Networks and Learning Systems.
- Vincent Thomas was a reviewer for IEEE Transactions on Cybernetics.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: Alain Dutech, Numerical Learning in AI, 15h eq TD, Master 1 Cognitive Sciences, Université de Lorraine, France.

Master: Nazim Fatès, Collective and intelligent agents, 15h eq TD, Master 1 Cognitive Sciences, Université de Lorraine, France.

Master: Nazim Fatès, Complex adaptative systems, 20h eq TD, Master 2 Computer Science, Université de Lorraine, France.

Master: Vincent Thomas, Game Design, 20h eq TD, Master 1 Cognitive Sciences, Université de Lorraine, France.

Master: Vincent Thomas, Serious Game, 10h eq TD, Master 2 Cognitive Sciences, Université de Lorraine, France.

Master: Vincent Thomas, Numerical Learning, 12h eq TD, Master 2 Computer Science IPAC (Image, Perception, Action, Cognition), Université de Lorraine, France.

9.2.2. Supervision

PhD: Amandine Dubois, *“Mesure de la fragilité et détection de chutes pour le maintien à domicile des personnes âgées”*, Université de Lorraine, Sept. 2014, F. Charpillet (advisor).

PhD: Jano Yazbeck, *“Secure and precise immaterial hanging for automated vehicles”*, Université de Lorraine, Oct. 2014, F. Charpillet (advisor), A. Scheuer.

PhD in progress: Mihai Andries, *“Calcul spatialisé pour l’assistance à la personne: étude d’un réseau de dalles intelligentes”*, Université de Lorraine, Oct. 2012, F. Charpillet (advisor), O. Simonin.

PhD in progress: Benjamin Camus, *“Un laboratoire virtuel pour la multi-modélisation”*,Université de Lorraine, Oct 2012, Christine Bourjot, Vincent Chevrier (advisor).

PhD in progress: Abdallah Dib, *“Assistance à la personne en perte d’autonomie: étude de l’apport d’un robot compagnon"*, Université de Lorraine, March. 2013, F. Charpillet (advisor).

PhD in progress: Iñaki Fernández-Pérez, *“Apprentissage incremental évolutionnaire”*, Université de Lorraine, Oct. 2013, F. Charpillet (advisor), A. Boumaza.

PhD in progress: Nassim Kaldé, *“Exploration et reconstruction d’un environnement inconnu par une flottille de robots”*, Université de Lorraine, Oct. 2012, F. Charpillet (advisor), O. Simonin.

PhD in progress: Manel Tagorti, *“Sur les abstractions et les projections des processus décisionnels de Markov de grande taille”*, Université de Lorraine, Nov. 2011, J. Hoffmann (advisor), B. Scherrer, O. Buffet.

PhD in progress: Arsène Fansi Tchango, *“Suivi multi-caméra en environnement partiellement observé”*, Université de Lorraine, Oct. 2011, A. Dutech (advisor), V. Thomas, O. Buffet.

PhD in progress: Mohamed Tlig, *“Coordination locale et optimisation distribuée du trafic dans les réseaux de transport de véhicules autonomes”*, Université de Lorraine, Dec. 2010, O. Simonin (advisor), O. Buffet.

PhD in progress: Julien Vaubourg, *“Multi-modélisation, multi-simulation dans le cadre des Smart-grids”*,Université de Lorraine, Oct 2013, Laurent Ciarletta, Vincent Chevrier (advisor).

PhD in progress: Matthieu Zimmer, *“Developmental Reinforcement Learning”*, Université de Lorraine, Oct 2014, Alain Dutech (advisor) and Yann Boniface.

PhD in progress: Van Quan Nguyen, *“Mapping of a sound environment by a mobile robot”*, Université de Lorraine, Dec. 2014, Emmanuel Vincent (advisor), Francis Colas, and François Charpillet.

9.2.3. Juries

- François Charpillet was reviewer a member of the PhD committee (as referee) of
  - Alexandru Rusu, Toulouse, dec. 12th 2014,
  - Ricardo CHAVEZ GARCIA, Grenoble, sep. 25th 2014,
  - Abdelhak Chatty, Cergy Pontoise, June 30th 2014.
- Vincent Chevrier was a member of the PhD committee (as referee) of
  - Jérémy Boes, March 28th, 2014, Université de Toulouse;
  - Baudouin Dafflon, Sept. 30th, 2014, Université de Technologie de Belfort-Monbéliard.
- Alain Dutech was a member of the PhD committee of
  - Simon Gay, December 15th, 2014, Université Lyon I.
- Nazim Fatès was a member of the PhD committee of
  - Simon Stuker, December 17th, 2014, Université de Toulouse.
- Bruno Scherrer was a member of the PhD committee of
  - Gabriel Dulac-Arnold, February 7th, 2014, Université Paris 6;
  - Bilal Piot, November 14th, 2014, Supélec (Université de Lorraine).

9.3. Popularization

- Nazim Fatès was the president of the Jury of the *Festival du film de chercheur*, see: an article in the Eureka magazine
- Vincent Thomas participated in “Journée ISN-EPI” (Apr. 17 2014) whose audience is computer science teachers of secondary school by organizing a workshop on “artificial intelligence and games”. Vincent Thomas is participating in the LORIA IDEES group dedicated to teaching activities.

- Vincent Thomas previously organized an exposition about game design and cognitive sciences. The materiel of the exposition was presented this year in several BU (Biliotheques universitaires) including IUT Charlemagne BU, Campus Medecine BU and Campus Brabois BU. This exposition is planned to be presented in other libraries in 2015 (Epinal, St Die).
- Vincent Thomas is participating in “Exporoute” meetings organized by Inria. The aim of these mettings is to create the content of a mobile scientific exposition about computer science in general. This exposition is planned to be held in 2017.
- Vincent Thomas participated in “la nuit des chercheurs” (Sep. 26 2014, Metz) and “ARTEM fête la science” during “Fête de la Science” (Oct. 18 2014, Nancy) by organizing discussions on video games, artificial intelligence and the links between those two domains.

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Publications of the year

Doctoral Dissertations and Habilitation Theses

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[2] J. YAZBECK. *Secure and precise immaterial hanging for automated vehicles*, Université de Lorraine, June 2014, https://hal.inria.fr/tel-01074868

Articles in International Peer-Reviewed Journals

[3] N. FATÈS. *A guided tour of asynchronous cellular automata*, in "Journal of Cellular Automata", December 2014, vol. 9, n° 5-6, pp. 387-416, forthcoming, https://hal.inria.fr/hal-00908373

[4] E. A. FEINBERG, J. HUANG, B. SCHERRER. *Modified policy iteration algorithms are not strongly polynomial for discounted dynamic programming*, in "Operations Research Letters", 2014, vol. 42, pp. 429 - 431 [*DOI :* 10.1016/J.ORL.2014.07.006], https://hal.inria.fr/hal-01091370

[5] M. GEIST, B. SCHERRER. *Off-policy Learning with Eligibility Traces: A Survey*, in "Journal of Machine Learning Research", January 2014, vol. 15, n° 1, pp. 289-333, https://hal.inria.fr/hal-00921275

[6] B. SCHERRER, M. GHAVAMZADEH, V. GABILLON, B. LESNER, M. GEIST. *Approximate Modified Policy Iteration and its Application to the Game of Tetris*, in "Journal of Machine Learning Research", 2015, 47 p. , forthcoming, https://hal.inria.fr/hal-01091341

[7] O. SIMONIN, F. CHARPILLET, E. THIERRY. *Revisiting wavefront construction with collective agents: an approach to foraging*, in "Swarm Intelligence", June 2014, vol. 8, n° 2, pp. 113-138, forthcoming [*DOI :* 10.1007/S11721-014-0093-3], https://hal.inria.fr/hal-00974068

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Invited Conferences

[9] E. Vincent, A. Sini, F. Charpillet. *Audio source localization by optimal control of a mobile robot*, in "IEEE - International Conference on Acoustics, Speech and Signal Processing (ICASSP)", Brisbane, Australia, April 2015, https://hal.inria.fr/hal-01103949

International Conferences with Proceedings

[10] L. Ciarletta, L. Gilpin, Y. Presse, V. Chevrier, V. Galtier. *Co-simulation Solution using AA4MM-FMI applied to Smart Space Heating Models*, in "7th International ICST Conference on Simulation Tools and Techniques", Lisbon, Portugal, March 2014, https://hal.inria.fr/hal-00966461

[11] A. Dib, N. Beaufort, F. Charpillet. *A real time visual SLAM for RGB-D cameras based on chamfer distance and occupancy grid*, in "International conference on advanced intelligent mechatronics", Besancon, France, July 2014, pp. 652 - 657 [*DOI :* 10.1109/AIM.2014.6878153], https://hal.inria.fr/hal-01090998

[12] *Best Paper*
J. S. Dibangoye, C. Amato, O. Buffet, F. Charpillet. *Exploiting Separability in Multiagent Planning with Continuous-State MDPs*, in "13th International Conference on Autonomous Agents and Multiagent Systems", Paris, France, A. Lomuscio, P. Scerri, A. Bazzan, M. Huhns (editors), ACM, May 2014, https://hal.inria.fr/hal-01092066.

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of the Seventh European Starting AI Researcher Symposium", Pragues, Czech Republic, August 2014, https://hal.inria.fr/hal-01073427

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[20] N. FATÈS. *Quick convergence to a fixed point: A note on asynchronous Elementary Cellular Automata*, in "ACRI 2014", Krakow, Poland, Cellular Automata, Springer, September 2014, vol. 8751 [*DOI :* 10.1007/978-3-319-11520-7_62], https://hal.inria.fr/hal-01088166

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[22] H. FUKŚ, N. FATÈS. *Bifurcations of Local Structure Maps as Predictors of Phase Transitions in Asynchronous Cellular Automata*, in "ACRI 2014", Krakow, Poland, Cellular Automata, Springer, September 2014, vol. 8751, A long version can be found as HAL report hal-00921295, see: https://hal.inria.fr/hal-00921295 [*DOI :* 10.1007/978-3-319-11520-7_58], https://hal.inria.fr/hal-01088158

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