Project-pre-Team LogicA

Logics and Applications

Rennes

Activity Report
2014

1 Team

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2 Overall Objectives

2.1 Overview

Many of our activities which were in the past performed in the physical world and in interaction with other humans, are nowadays carried out in a digital world in interaction with both human and non-human 'agents': classic examples are e-commerce, e-voting, e-banking, e-government, etc... This transposition of some of our activities into the digital world already plays an important role in our everyday life. This transposition is expected to develop in the future, which is certainly desirable in order to harmonize the rate at which our society evolves. This large picture exhibits an urgent need for both taming already existing e-activities and assisting the birth of new ones.

Existing e-activities, such as e-voting, e-commerce, e-banking, e-government etc. rely on a combination of numerous technologies either at the physical/hardware level or at the digital/software one. The nature of interaction between different services that form the whole

application is very complex and leads to critical issues regarding its quality that the research community together with industry try to resolve.

Among the main issues, we can mention privacy, legal process, correction of the functionalities. Also, the growing development of applications to support e-activities urges the designers to elaborate methodologies that would allow them to exploit adaptability or re-usability of existing services. Whichever issue can be picked, rigorous settings are required in order to make evidence of the correctness, the quality, the robustness, etc. of the existing products. Moreover, some sectors of activity are currently far from being computerized or even computer-assisted: typically, legal processes, abilities to remote control some domestic processes such as closing roller blinds when a storm is forecast, and so on.

All in all, not only existing e-activities need to be coupled with meticulous development methodologies, but also accurate approaches need being set up to design new e-activities that support underdeveloped domains currently operated by hand. To that end, important efforts are required to bring out the capabilities to rigorously analyze or design the functionalities[1] of services in e-activities.

The LogicA project aims at contributing to this will, by focusing on interaction issues in e-activities with a logical-based perspective. The project will develop foundations, transfer to practical applications, and convey the tight coupling between research and education.

One of the most challenging feature in e-activities analysis is the ability to "predict/control" the interaction between the numerous involved entities. These entities can be artificial (software agents, distributed systems components) or human (users). As a first step, the project will focus on artificial entities, which are, ideally, designed to act *autonomously* on the behalf of users, *e.g.* for negotiating in an e-commerce activity. These entities are called *software agents*, and they gather into *multi-agent system (MAS)*.

Since MAS are central objects, they need to be preliminary well understood at a mathematical level. The theories that will support their use in practical applications should give rise to different techniques, ranging from the ability to guarantee and certify before their deployment that they will behave properly (verification) to the ability of automatically generating skeletons of MAS (synthesis) or of coordination mechanisms between MAS (control/orchestration/choregraphy/communication).

Whereas successful logic-based techniques in computer science already exist for verification, synthesis and control, it is not clear yet how to transfer this know-how to the paradigm of MAS where interaction is central. Investigations to formally *reason about* and *infer properties of* interacting agents is currently a very active topic in computer science, which actually originates with, *e.g.* artificial intelligence and game theory. The LogicA project aims at cross-fertilizing logic-based techniques from verification in computer science, synthesis in discrete-event control theory, agency in artificial intelligence, concepts and solution concepts in game theory, and interaction concepts in philosophy. In particular, what typically differentiates the MAS framework from its pairs is the inherent information change/exchange in its dynamics, which gives evidence of, *e.g.* epistemic, strategic and normative features to be taken into account.

[1] in terms of what an application offers to its users

2.2 Key Issues

In its current state, the LogicA project studies the following key issues:

Epistemic logics and logics of information change When agent interaction issues are concerned, ability to reason about knowledge is central. To this aim, epistemic logic has been extensively studied [FHMV95], and recent extensions that take dynamics into account draw the attention of a growing community of logicians and computer scientists (see for instance the very much cited book [vvK08] and the recent ERC grant on epistemic protocols coordinated by Hans van Ditmarsch (recently recruited as a DR CNRS, LORIA). The LogicA project explores variants of epistemic logic that can easily mix with time, in order to reason about information change along time. As mixing knowledge and time easily yields to high complexity and even undecidability [HV89], the challenge is to identify settings where the formalism would enjoy good computational features while being expressive enough to capture useful properties.

3 Scientific Foundations

3.1 Strategic reasoning and automata-theoretic approaches

Participants: Sophie Pinchinat, Bastien Maubert.

Modeling strategic abilities is central for reasoning about MAS. We plan to carry on with logical formalism that were already proved or are currently foreseen as powerful approaches in many exciting domains, including software tools for information system security, robot teams with sophisticated adaptive strategies, and automatic players capable of beating expert human adversary, just to cite a few. All these examples share the challenge of developing novel theories and tools for agent-based reasoning that take into account the likely behavior of "adversaries".

The natural setting for strategic reasoning is not surprisingly the one of multi-player games with imperfect information. Although discouraging results from the literature shows that three-player games with safety objectives are undecidable [PRA01], there are however promising results which show that some classes may be manageable. Basically, undecidability comes from the ability for some players to form a coalition: the resulting binary indistinguishability relation of the coalition would correspond to the intersection of the relations of its respective members. Now, it is well-known that intersection of binary relations yields more complex relations that may exit decidable classes (e.g. for membership or emptiness), like e.g., rational relations. Note that such phenomenon cannot arise in two-player games where safety objectives can be solved

[FHMV95] R. Fagin, J. Halpern, Y. Moses, M. Vardi, *Reasoning about knowledge*, MIT Press, 1995.

[vvK08] H. van Ditmarsch, W. van der Hoek, B. Kooi, *Dynamic Epistemic Logic*, Springer, Dordecht, 2008.

[HV89] J. Y. Halpern, M. Y. Vardi, "The complexity of reasoning about knowledge and time. 1. Lower bounds", *Journal of Computer and System Sciences 38*, 1, 1989, p. 195–237.

[PRA01] G. Peterson, J. Reif, S. Azhar, "Lower bounds for multiplayer noncooperative games of incomplete information", *Computers & Mathematics with Applications 41*, 7, 2001, p. 957–992.

by a simple (although costly) power-set construction [Rei84]. Also, undecidability becomes even "stronger" when dealing with more realistic objectives with for epistemic properties, such as seeking a strategy of agent A an outcome "agent B does know Property P until agent C knows it".

More recently, the AI and Formal Methods communities moved closer because of the intrinsic similarity between multi-player games with imperfect information and MAS. Since then, attention has been paid on extensions of game-like settings to objectives intrinsically mixing knowledge and time[2], in order to be able to express, e.g. *opacity properties* in software security such as "Defender has a strategy so that Intruder never knows information I" [35, 33],[DDM10,MY13]. Note that, works on designing logics to feature both knowledge and time has been investigated long ago, with a very natural combination of temporal logics and epistemic logic [HV89,HvdMV04]. Handling these logics (model-checking or synthesis) already proved to be difficult, quickly yielding undecidability [HV89,vdMS99,Dim11]. The critical point lies in the interplay of two "orthogonal" fixed-points modalities when agents' perception ability on the actual system evolution is not bound, e.g. *perfect recall* or *imperfect* (but unbounded) *recall* [vdMS99]; basically, the perception abilities of agents can range from *perfect recall* to *memoryless* and include *imperfect recall*.

The most natural way to incorporate knowledge/agent's perception into logics for strategic reasoning is achieved by adding epistemic modalities into alternating-time logic [vdHW03,Sch04, JÅ06,Dim09]. Still, merging perception and strategic abilities of agents can take different paths, as the two are not independent: the strategic abilities of agents should not overstep their

[2] even if not told this way

[Rei84] J. H. Reif, "The complexity of two-player games of incomplete information", *Journal of computer and system sciences 29*, 2, 1984, p. 274–301.

[DDM10] J. Dubreil, P. Darondeau, H. Marchand, "Supervisory control for opacity", *Automatic Control, IEEE Transactions on 55*, 5, 2010, p. 1089–1100.

[MY13] J. Mullins, M. Yeddes, "Opacity with Orwellian Observers and Intransitive Non-interference", *arXiv preprint arXiv:1312.6426*, 2013.

[HV89] J. Y. Halpern, M. Y. Vardi, "The complexity of reasoning about knowledge and time. 1. Lower bounds", *Journal of Computer and System Sciences 38*, 1, 1989, p. 195–237.

[HvdMV04] J. Y. Halpern, R. van der Meyden, M. Y. Vardi, "Complete Axiomatizations for Reasoning about Knowledge and Time", *SIAM J. Comput. 33*, 3, 2004, p. 674–703.

[vdMS99] R. van der Meyden, N. V. Shilov, "Model Checking Knowledge and Time in Systems with Perfect Recall (Extended Abstract)", *in : FSTTCS*, C. P. Rangan, V. Raman, R. Ramanujam (editors), *Lecture Notes in Computer Science*, *1738*, Springer, p. 432–445, 1999.

[Dim11] C. Dima, "Non-axiomatizability for the linear temporal logic of knowledge with concrete observability", *J. Log. Comput. 21*, 6, 2011, p. 939–958.

[vdHW03] W. van der Hoek, M. Wooldridge, "Cooperation, knowledge, and time: Alternating-time temporal epistemic logic and its applications", *Studia Logica 75*, 1, 2003, p. 125–157.

[Sch04] P.-Y. Schobbens, "Alternating-time logic with imperfect recall", *Electronic Notes in Theoretical Computer Science 85*, 2, 2004, p. 82–93.

[JÅ06] W. Jamroga, T. Ågotnes, "What agents can achieve under incomplete information", *in : Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems*, ACM, p. 232–234, 2006.

[Dim09] C. Dima, "Revisiting satisfiability and model-checking for CTLK with synchrony and perfect recall", *in : Computational Logic in Multi-Agent Systems*, Springer, 2009, p. 117–131.

perception abilities, in the sens that strategies should be defined at a level of abstraction at least equal to the level of what agent perceive from the actual situation: for example, if an agent does not recall the past, its strategies should be memoryless. Some pioneer papers put aside, this dependency is now well understood. Many frameworks lead to undecidability [Dim09]. There are however results relying on strong restrictions on the agents' perception (and thus on their strategic abilities), such as the obvious memoryless perception assumption [vdHW03,JÅ06,BJL11], or very particular imperfect recall [Sch04], but The complete understanding of the landscape is not achieved yet.

Automata are wonderful mathematical tools, tightly coupled to logic, in order to represent sets of models. They offer computational facilities and often reveal intuitive algorithms to handle specifications. For example, tree automata [Tho97,FGW07] denote sets of infinite trees, widely needed in verification to representation branching-time system executions. It is well known that tree automata equipped with the parity condition capture the expressive class of ω-regular tree languages, with the highly expressive propositional μ-calculus logic in the background [EJ91,AN01,GTW02].

Other approaches have been considered to combine knowledge, time and strategies. A fairly old one originates from the control theory of discrete-event systems, from the point of view of (controllers') strategic abilities only. Controllers are seen as state-transition devices, and such devices can be subject to structural constraints, such as looping e-transitions in every state to capture unobservability of event e by the device, or many variants of such constraints [Bri06b]. Structural constraints can be specified by extending temporal logics with a new atomic propositions to express, e.g. existence of looping transitions. The resulting logics, although no more bisimulation invariant, still has automata counterparts [AVW03]. Such automata can be used to synthesize controllers by *automata quotient techniques* [AVW03,PR05,Bri06b,Bri06a]. Note that these approaches cannot address epistemic features in the control objectives.

[BJL11] F. Belardinelli, A. V. Jones, A. Lomuscio, "Model Checking Temporal-Epistemic Logic Using Alternating Tree Automata", *Fundam. Inform. 112*, 1, 2011, p. 19–37.

[Tho97] W. Thomas, "Languages, Automata, and Logic", *in : Handbook of Formal Language Theory, III*, Springer, 1997, p. 389–455.

[FGW07] J. Flum, E. Grädel, T. Wilke, *Logic and Automata: History and Perspectives*, Amsterdam University Press, 2007.

[EJ91] E. A. Emerson, C. S. Jutla, "Tree Automata, Mu-Calculus and Determinacy", *in : Proceedings 32nd Annual IEEE Symp. on Foundations of Computer Science, FOCS'91, San Jose, Puerto Rico, 1–4 Oct 1991*, IEEE Computer Society Press, Los Alamitos, California, 1991, p. 368–377.

[AN01] A. Arnold, D. Niwiński, *Rudiments of μ-calculus*, *Studies in Logic and the Foundations of Mathematics*, *146*, North-Holland, 2001.

[GTW02] E. Grädel, W. Thomas, T. Wilke (editors), *Automata, Logics, and Infinite Games*, *LNCS*, *2500*, Springer, 2002.

[Bri06b] X. Briand, *Sur la décidabilité de certains problèmes de synthèse de contrôleurs*, PdD Thesis, Université de Bordeaux I, June 2006.

[AVW03] A. Arnold, A. Vincent, I. Walukiewicz, "Games for synthesis of controllers with partial observation", *Theoretical Computer Science 1*, 303, 2003, p. 7–34.

[PR05] S. Pinchinat, S. Riedweg, "A decidable class of problems for control under partial observation.", *Inf. Process. Lett. 95*, 4, 2005, p. 454–460.

[Bri06a] X. Briand, "Dynamic Control with Indistinguishable Events.", *Discrete Event Dynamic Systems 16*, 3, September 2006.

We believe that an automata-theoretic approaches is a promising track. For instance, we have started to identify classes solvable multi-player games with imperfect information allowing for epistemic objectives with a focus on the theoretical properties of agents' indistinguishable binary relation along plays [37, 34]. The starting point are rational binary relations. For example, we have shown that if binary relations are restricted to *recognizable*, objectives that mix knowledge and time with classic CTL* operators can be solved. These results stem from our pioneer studies on *uniform strategies* [9], which reveal very powerful and whose study should be pursued, as shown below.

Also, in our attempt to find clean mathematical settings to combine knowledge and time, one may think of an enrichment of the class of tree automata, in such a way that those devices can check properties not only in a given node of tree but also in "related" nodes, where the relation reflects the possible words for a given agent. This amounts to allowing the automata to make jumps between different branches of the tree. Recently, we have developed a class of such devices called *jumping tree automata (JTA)* [37] which permit to consider agents whose distinguishing inabilities are *rational relations*. JTA are promising objects. Even though their language emptiness is undecidable in general, they may enjoy several good properties when. e.g. restricting to *recognizable* relations. Also, we conjecture that JTA coincide with the extension of the propositional μ-calculus by knowledge modalities. Last but not least, the connection between JTA and second-order logic needs being addressed as in essence, JTA handle two binary relations between the nodes of the trees.

The results have been stabilized in journal versions [4] and have successfully applied the theory to Epistemic Protocole Synthesis [11].

3.2 Epistemic planning and epistemic protocol synthesis

Participants: Guillaume Aucher, Bastien Maubert, Sophie Pinchinat, François Schwarzentruber.

Planning is the process of organizing activities required to achieve a desired goal. In the "classical" planning community [GNT04], planning under uncertainty and with multiple agents is acknowledged to be a real challenge. It has been shown that the Dynamic Epistemic Logic framework [vvK08] is a good setting to address planning for goals that may involve agents' knowledge, and even agents' knowledge about other agents' knowledge, etc. [BA11]. The approach is promising with applications to, e.g., privacy issues stemming from the growing use of social networks (for example, we may want to achieve some task while being sure that some adversary will never come to *know* a sensitive fact/information). The area of epistemic planning is becoming very active (cf. Dagstuhl seminar on "Planning with epistemic goals", January 2014), and extends to even more general aims where an entire protocol has to be synthesized.

[GNT04] M. Ghallab, D. Nau, P. Traverso, *Automated Planning: Theory & Practice*, Morgan Kaufmann, San Francisco, 2004.

[vvK08] H. van Ditmarsch, W. van der Hoek, B. Kooi, *Dynamic Epistemic Logic*, Springer, Dordecht, 2008.

[BA11] T. Bolander, M. B. Andersen, "Epistemic planning for single- and multi-agent systems", *Journal of Applied Non-Classical Logics 21*, 1, 2011, p. 9–34.

The LogicA project members are among the leaders of the area: Guillaume Aucher has published on epistemic planning [10, 3, 4, 11], Sophie Pinchinat with Bastien Maubert have published on games with epistemic conditions [35, 33],[9], and recently on *epistemic protocol synthesis* [11].

Also, members of the team keep investigating in logical formalisms for dynamic information changes. The logic RML for "Refinement Modal Logic" is an abstract framework where it is possible to quantify over informative events, or a possible control[3]. This logic has several variants with fixed-points, multi-agents setting, etc. We are currently working on its theoretical properties, among which classic decision problems [44, 16, 15, 17], and [6, 7].

3.3 Epistemic spatial reasoning

Participants: Tristan Charrier, François Schwarzentruber.

By *epistemic spatial reasoning*, we mean reasoning about the knowledge agents can infer from what they perceive. It has several important potential applications such as designing systems of camera surveillance, programming drone systems, video games. Note that since perception depends of the locations, geometry issues are central and in particular the dimension of the space in which we reason.

Nowadays, the behavior of artificial agents is mostly described by low-level imperative languages, whereas the use of knowledge programs [FHMV95], which are based on logic, is very little developed and yet could offer high-level descriptions together with clean analysis tools.

Recently, we proposed a grounded variant of Dynamic Epistemic Logic [vvK08], called *Flatland Logic*, properties about what agents perceive and know about the world [12] can be specified. At the moment, we master the one-dimensional setting by providing an axiomatization of the logic and an elimination procedure for the notoriously complex common knowledge operator [42]. The model checking problem and the satisfiability problem are PSPACE-completeness. On the contrary, such results for the two-dimensional setting are mostly all open. For example, we only know that the problem is decidable for dimensions greater than 2. In the case where there is common knowledge of the positions of the agents, we know that the model checking problem is PSPACE-complete [13]. Additionally, there is still no robust implementation of the framework, but very preliminary ones:

- `http://www.irisa.fr/prive/fschwarz/flatland/`
- `http://www.irisa.fr/prive/fschwarz/publications/AAMAS2014/`

A Master student is currently working on a prototype of a model checker. We plan to solve some open issues and to extend the framework to planning in multi-agent scenarios. Results for static cameras have already been published [13].

We plan to adapt the setting of Flatland logic motion planning/multi robots: for instance, we may wonder if (or make queries like) "it is possible for agent a to move in such a way that b

[3] depending on the interpretation of the accessibility relation in the Krikpe structures

[FHMV95] R. Fagin, J. Halpern, Y. Moses, M. Vardi, *Reasoning about knowledge*, MIT Press, 1995.

knows that a sees agent c at least three times during the move". This is a starting collaboration with Valentin Goranko (Technical University of Denmark) and Hans van Ditmarsch (LORIA, CNRS) where the central application is camera surveillance.

4 Application Domains

4.1 Cour de Cassation project

Participants: Guillaume Aucher, François Schwarzentruber.

This project is a starting collaboration with Cour de Cassation, with a very modest objective which at a first glance does not fall into the main scientific objectives of the LogicA project. However, our will to promote logical approaches for societal concerns is strong. This very opportunity may lead to a long term collaboration where richer languages than first order logic can be useful: in particular, Guillaume Aucher and François Schwarzentruber have strong background in Deontic Logic and Normative Systems [GHvdM+], as witnessed by their publication lists, and wish to end up with its use for legacy purposes.

The Cour de Cassation is aware of the following problem: judges have to handle legal cases that are not frequent. Such a legal case may be the following one: contest the union's representational capacity. It is really difficult for a judge to acquire all the experience in solving such legal cases. Up to now, writing judgments for such legal cases is done manually with the help of documents explaining how to write them. In this subsection, we refer to these documents as the how-to documents.

The Cour de Cassation expressed the need to develop a computer-aided judgment writer. This software should analyze the reasoning process made by the judge, assist him/her in his/her decisions. Meanwhile, the software generates the text of the judgment.

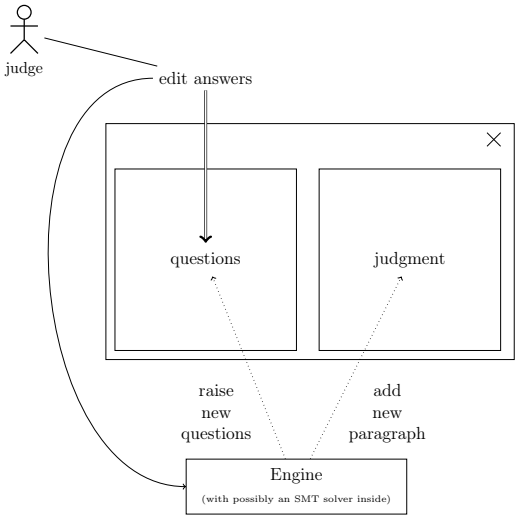
Bridging law and logic The software will take as an input the logical description of a legal case, nowadays described informally in how-to documents. For instance the input may be a file describing formally the contest of a union's representational capacity (such a logical description may have been designed before by experts). Then the engine of the software will propose coherent questions to the user. The first part of the project is to understand the reasoning part of the documents explaining how to write a judgment in order to define the logical description of a legal case and the algorithms in the engine.

We currently have identified the following in the how-to documents.

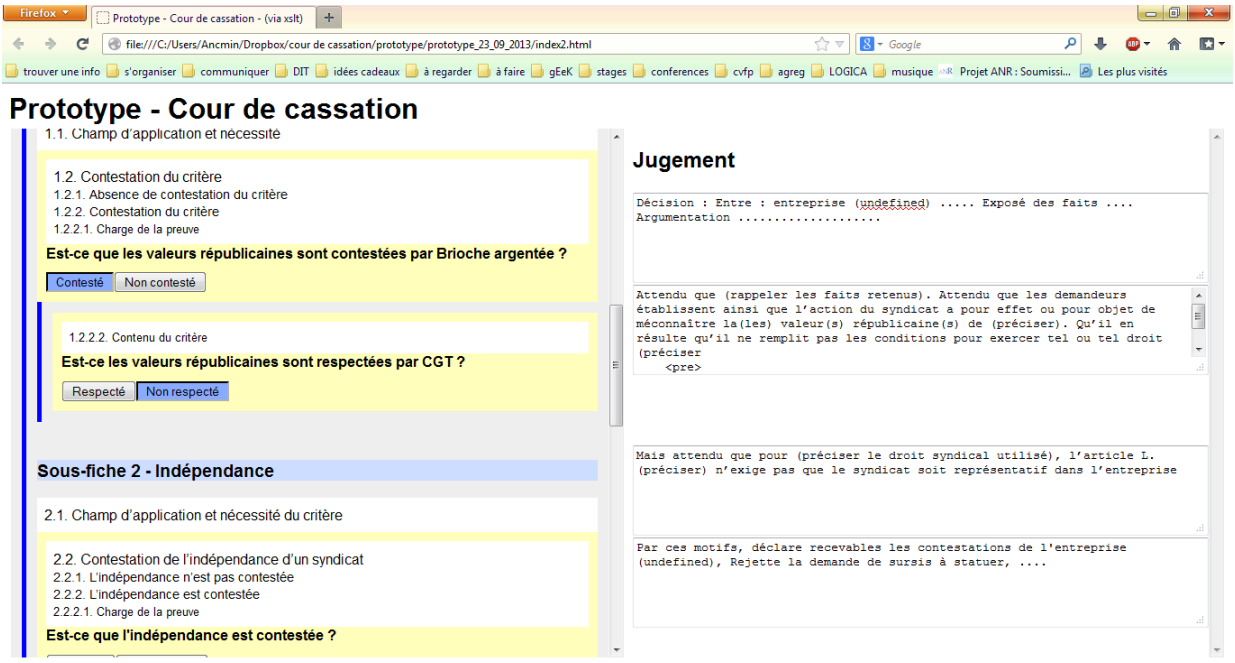
Some paragraph may be applied to several instances. For instance, there may be one paragraph about the description of a current member of the union, and the conditions explained in that paragraph should be verified for several members. This naturally leads to the use of First-order logic.

Some statements are purely syllogisms. Description logic is a suitable decidable logic for representing such kind of statements.

[GHvdM+] D. Gabbay, J. Horty, R. van der Meyden, X. Parent, L. van der Torre (eds), "*Handbook of Deontic Logic and Normative Systems*", To appear with College Publications, London.



(a) Architecture of the Cour de Cassation software



(b) Interface of the Cour de Cassation software

Figure 1: The Cour de Cassation software

In the how-to documents, we may find general rules about a situation and then exceptions. From a logical point of view, exceptions are generally difficult to represent and to add dynamically while elaborating legal texts.

We should also define correctly the completeness of a judgment.

Implementation issues After having designed the logical language for representing the description of a legal case, we will study decidability and complexity issues on the theoretical part. On the practical part, we will first start by using an existing solver, possibly a SMT solver. This solver may check the consistency of the reasoning done up to now by the judge and it is also used to raise new relevant questions. Figure 1(a) shows the global architecture of the software, and screen shot of the user interface as it is for the moment is given in Figure 1(b). After having configured the software to solve a given legal case, the left-part of the screen shows questions the judge should answer. The right-part shows the generated judgment. Of course, questions should be relevant and consistent. At the end, the software should certify that the judgment is complete. This project is the realization of the dream of the jurist and logician Leibniz: use logic to solve legal cases.

4.2 Physical security

Participants: Stéphanie Georges, Sophie Pinchinat.

Risk Analysis is a discipline consisting in identifying and evaluating risks that threaten a given system in order to reduce or annihilate them by defining actions to engage (risk management). Such analysis is central when the aim is to ensure the security of an information system means guaranteeing data availability, integrity and confidentiality.

As seen in [Bur08], current methods follow mostly the same outline : one decomposes the system into subsystems and produces a model, then draws up a list of feared events, and finally determines the potential reasons of their emergence.

For the particular case of risk analysis in physical security, these steps are mostly processed by hand, based on knowledge and experiences of analysts and technicians. In order to match the standards of experts in risk analysis, the whole process is conducted in two steps:

Step 1 One produces an *attack/defense tree*, that is a tree-like structure where one easily reads the attacker's abilities to achieve her attack and the weaknesses of the defender's capabilities to counter them. The attack/defense tree levels describe successful attacks at different level of abstraction. The attack/defense tree is meant to describe all successful attacks, independently of their realism due to intrinsic cost of their application.

Step 2 The attack/defense tree obtained in Step 1 is reworked to incorporate cost features on actions and then exploited to reveal the more realistic scenarios.

[Bur08] E. Bursztein, *Anticipation Games - Théorie des Jeux appliquée à la sécurité réseau*, PdD Thesis, ENS Cachan, 2008.

The project is a collaboration with the French Defense Ministry (2011-1014, contract 2011 81 0323) for physical security. The collaboration involves a PhD student whose research should lead to a assistant tool for semi-automatically synthesizing an attack/defense tree (Step 1. above), given a specification of a building and some critical resource to protect from attacks (a safe containing a classified document).

Following [BLE10], we have developed an entire methodology to achieve the attack/defense tree synthesis: we have first designed a language to specify buildings. Then using a compilation technique, these specifications are compiled into the target language GAL, a modelling language dedicated to the description of data manipulation for formal verification of concurrent systems `http://move.lip6.fr/software/DDD/gal.php`. The resulting describes an *attack graph/one-player arena* where attacks are simply sequences of low level actions, like plans, from the initial situations to dangerous ones. In order to extract these plans, a collaboration with the GAL plate-form designer (Yann Thierry-Mieg, LIP6 lab, Paris) has started: the tools of the plate-form have tuned to adapt the model-checking counter-example (the plans) generation techniques for safety properties into a controlled generation of multiple plans. By coupling the specification with a hierarchy of actions (high-level actions described e.g. by some rewriting system/context-free grammar), these scenarios can be abstracted as trees (using classic syntactic analysis), then gathered together to yield an attack/defense that highlights flaws to bring down and the counter-measures that apply.

The results of the current state of the methodology and tool has been presented at the poster session of the national conference "Modélisation des Systèmes Réactifs 2013" (`http://hal.inria.fr/MSR2013`) and in [19] and in [15].

4.3 Tools for teaching logic

Participants: Sophie Pinchinat, François Schwarzentruber.

This action of the project may appear unconventional, as, as opposed to other axis which are about "meeting applications", it is about "meeting people". Still, one should keep in mind that behind applications, one faces people, and that it is hopeless to give evidence of the usefulness of logic in applications while neglecting the guarantee that developers will comply with its use.

Information technologies incite the promotion of logic, mostly by the fact that logical languages provides accurate specification languages/declarative programming languages, and that their semantics yields efficient procedures to solve problems. Nevertheless, the relevance of logic in the numeric world seems to be appreciated solely by specialists in computer sciences (NASA engineers that check their critical embedded softwares, mathematicians fascinated by verification of proofs, etc.), which impedes its potential transfer towards practical applications ([Var09]).

[BLE10] E. Bornette, J.-P. Lebée, D. Eymery, "Nouvelle approche méthodologique de l'analyse de risques reposant sur le point de vue de l'attaquant", *in : Proceedings of of the 5th Conference on Network and Information Systems Security (SAR/SSI 2010), Rocquebrune Cap-Martin, France*, 2010.

[Var09] M. Vardi, "From philosophical to industrial logics", *Logic and Its Applications*, 2009, p. 89–115.

Courses in logic.	
Openproof Courseware	Package of undergraduate logic courses `http://ggweb.stanford.edu/`
Logic in action	Undergraduate logic course `http://www.logicinaction.org/`
Kripke's world [1]	A book for learning tableau methods for modal logic
Software tools for teaching logic.	
Pandora [BMSS07]	`http://www.doc.ic.ac.uk/pandora/`
Lotrec [dCFG+01]	`http://www.irit.fr/Lotrec/`
SAToulouse [24]	`http://www.irit.fr/satoulouse/`
Panda [23]	(up to now, used in teaching classes at the University of Toulouse) `http://www.irit.fr/panda/`
LotrecScheme [41]	`http://www.irisa.fr/prive/fschwarz/lotrecscheme/`
Plaza's world [25]	`http://www.irisa.fr/prive/fschwarz/flatland/`
SATRennesPA	`http://satrennespa.irisa.fr/`

Table 1: Courses and tools for teaching logic.

The computer science community together with logicians is now aware of the need for conveying what logic is about, demonstrating its relevance and revealing its accessibility. Following this present-day opinion, we commit to breaking the impediment to logic promotion, so that society can fully enjoy the benefits. In particular, we target to investigate the pedagogy to familiarize students with logic and to teach them what logic is about, and to identifying potential users of logic and filling them in on the feasibility of designing dedicated logics. Our actions will get inspirations from the many efforts made in constructing software tools and also in ways of teaching logic, but also from our own investigations.

Promoting logic Many efforts are made to improve courses in logic, as well as software tools for teaching logic have already been developed. Table 1, although not exhaustive, provides a reasonable list of them. Among the tools, *SAToulouse/SATRennesPA*, *Panda*, *LotrecScheme*, and *Plaza's world* are developed by members of LogicA. The tool *SAToulouse* [24] and its new generation *SATRennesPA*[4], which are surprisingly one of the firsts – and even maybe the only ones – offer user-friendly SAT solver applications to address, e.g. Sudoku games, planning problems, etc.

Our, fairly short-term, perspective is to advocate the introduction of propositional logic in this course and to promote its relevance via *SATRennesPA* at the Bachelor level and even in high-school. Note that, the actual version of french high-school computer science course entitled "Informatique et sciences du numérique" does not approach logic as a declarative programming language. The feedback of teachers and students should lead us to tune the tool so as to reach a equilibrium between its expressive power and the needs for teaching/understanding

[4]Currently, four students of M1 MIAGE are improving the web interface SATRennesPA of the Sat4j library `http://www.sat4j.org/`.

the convenient ways to model concrete problems into propositional logic. This perspective will be addressed at the *International Congress on Tools for Teaching Logic 2015* (the 4th edition) the members of LogicA will take on in June 2015 in Rennes (`http://ttl2015.irisa.fr/`).

A certainly longer-term promising project is to make the use proof assistants attractive and natural to students. The current experience in Master 1 with the use of Isabelle/HOL to verify and generate Scala code makes evidence of a lack of acquaintance with such tools. We will start training the students one year earlier (Bachelor) with a software adaptive to the audience based on the first-order proof assistant Panda ([23]), already developed in the team. The aim of this instruction is twofold: reconcile logic and students and show the pertinence of computer science in checking proofs, while keeping the process amusing. For this, a version of the tool Panda as a video game is currently in progress, see `http://www.irisa.fr/prive/fschwarz/pravdaweb/`.

5 New Results

5.1 Big brother logic: logical modeling and reasoning about agents equipped with surveillance cameras in the plane

Participants: François Schwarzentruber.

We consider multi-agent scenarios where each agent controls a surveillance camera positioned in the plane, with fixed position and angle of view, but rotating freely. The agents can thus observe the surroundings and each other. They can also reason about each other's observation abilities and knowledge derived from these observations. We introduce suitable logical languages for reasoning about such scenarios which involve atomic formulae stating what agents can see, multi-agent epistemic operators for individual, distributed and common knowledge, as well as dynamic operators reflecting the ability of cameras to turn around in order to reach positions satisfying formulae in the language.

We introduce semantics of our basic logic BBL and its extensions on natural geometric models, as well as formal Kripke semantics for them in vision-based finite abstractions of the geometric models. We discuss the expressiveness of our logical languages and provide their translations in PDL style. Using these translations we develop algorithms and obtain complexity results for model checking and satisfiability testing for BBL and its extensions. Notably, we show that even for the extension with common knowledge, model checking remains in PSPACE. Finally, we discuss some further extensions: by adding obstacles, positioning the cameras in 3D or enabling them to change positions.

This work has been published in [13].

5.2 Big brother logic: logical modeling and reasoning about agents equipped with surveillance cameras in the plane (demonstration)

Participants: Tristan Charrier, François Schwarzentruber.

We consider multi-agent scenarios where each agent controls a surveillance camera positioned in the plane, with fixed position and angle of view, but rotating freely. The agents

can thus observe the surroundings and each other. They can also reason about each other's observation abilities and knowledge derived from these observations.

In this demonstration, cameras are located in the plane. The user can interact with the cameras, check epistemic properties and announce formulas. The camera can also turn in order to satisfy an epistemic property.

This work has been published in [12].

5.3 STIT is dangerously undecidable

Participants: François Schwarzentruber.

STIT is a potential logical framework to capture responsibility, counterfactual emotions and norms, which are main ingredients for specifying behaviors of virtual agents. We identify here a new fragment and its satisfiability problem is NP-complete and in Σ_3 when the number of agents is unbounded. We also identify a slightly more expressive fragment which is undecidable.

This work has been published in [17].

5.4 Belief Merging in Dynamic Logic of Propositional Assignments

Participants: François Schwarzentruber.

We study syntactical merging operations that are defined semantically by means of the Hamming distance between valuations; more precisely, we investigate the Σ-semantics, Gmax-semantics and max-semantics. We work with a logical language containing merging operators as connectives, as opposed to the metalanguage operations of the literature. We capture these merging operators as programs of Dynamic Logic of Propositional Assignments DL-PA. This provides a syntactical characterisation of the three semantically defined merging operators, and a proof system for DL-PA therefore also provides a proof system for these merging operators. We explain how PSPACE membership of the model checking and satisfiability problem of star-free DL-PA can be extended to the variant of DL-PA where symbolic disjunctions that are parametrised by sets (that are not defined as abbreviations, but are proper connectives) are built into the language. As our merging operators can be polynomially embedded into this variant of DL-PA, we obtain that both the model checking and the satisfiability problem of a formula containing possibly nested merging operators is in PSPACE.

This work has been published in [14].

5.5 Drawing Euler Diagrams from Region Connection Calculus Specifications with Local Search

Participants: François Schwarzentruber.

We describe a local search based approach and a software tool to approximate the problem of drawing Euler diagrams. Specifications are written using RCC-8-constraints and radius constraints. Euler diagrams are described as set of circles.

This work has been published in [16].

5.6 Logics with Copy and Remove

Participants: François Schwarzentruber.

We propose a logic with the dynamic modal operators copy and remove. The copy operator replicates a given model, and the remove operator removes paths in a given model. We show that the product update by an action model (with Boolean pre-conditions) in dynamic epistemic logic decomposes in copy and remove operations. We also show that copy and remove operators (of path of length 1) can be expressed by action models. We investigate the complexity of the satisfiability problem of syntactic fragments of the logic with copy and remove operations.

This work has been published in [10].

5.7 Epistemic Probability Logic Simplified

Participants: François Schwarzentruber.

We propose a simplified logic for reasoning about (multi-agent) epistemic probability models, and for epistemic probabilistic model checking. Epistemic probability models are multi-agent Kripke models that assign to each agent an equivalence relation on worlds, together with a function from worlds to positive rationals (a lottery). The difference with the usual approach is that probability is linked to knowledge rather than belief, and that knowledge is equated with certainty.

A first contribution of the paper is a comparison of a semantics for epistemic probability in terms of models with multiple lotteries and models with a single lottery. We give a proof that multiple lottery models can always be replaced by single lottery models. As multiple lotteries represent multiple subjective probabilities, our result connects subjective and intersubjective probability.

Next, we define an appropriate notion of bisimulation, and use it to prove an adaptation of the Hennessy-Milner Theorem and to prove that some finite multiple lottery models only have infinite single lottery counterparts. We then prove completeness, and state results about model checking complexity. In particular, we show the PSPACE-completeness of the model checking in the dynamic version with action models.

The logic is designed with model checking for epistemic probability logic in mind; a prototype model checker for it exists. This program can be used to keep track of information flow about aleatory acts among multiple agents.

This work has been published in [18].

5.8 A General Notion of Uniform Strategies

Participants: Bastien Maubert, Sophie Pinchinat.

We consider two-player turn-based game arenas for which we investigate *uniformity properties* of strategies. These properties involve sets of plays in order to express useful constraints on strategies that are not μ-calculus definable. Typically, we can represent *constraints* on allowed strategies, such as being observation-based. *epistemic winning conditions.* We propose

a formal language to specify uniformity properties, involving an original modality called R, meaning "for all related plays". Its semantics is given by some binary relation between plays. We demonstrate the relevance of our approach by rephrasing various known problems from the literature.

We also study an automated procedure to synthesize strategies subject to a uniformity property, which strictly extends existing results based on, say standard temporal logics. We exhibit a generic solution for the synthesis problem provided the binary relation that defines the sets of related plays is recognizable by a finite state transducer. This solution yields a non-elementary procedure. This work has been published in [9].

Uniform strategies is the core of Bastien Maubert's PhD thesis [2], which he defended on the 17th of January 2014.

5.9 Verification of gap-order constraint abstractions of counter systems

Participants: Sophie Pinchinat.

We investigate verification problems for *gap-order constraint systems* (GCS), an (infinitely-branching) abstract model of counter machines, in which constraints (over $\mathbb{Z}$) between the variables of the source state and the target state of a transition are *gap-order constraints* (GC) [Rev93]. GCS extend monotonicity constraint systems [BA10], integral relation automata [Cer94], and constraint automata in [DD07]. First, we address termination and fairness analysis of GCS. Since GCS are infinitely-branching, termination does not imply *strong termination*, i.e. the existence of an upper bound on the lengths of the runs from a given state. We show that the termination problem, the strong termination problem, and the fairness problem for GCS (the latter consisting in checking the existence of infinite runs in GCS satisfying acceptance conditions à la Büchi) are decidable and PSPACE-complete. Moreover, for each control location of the given GCS, one can build a GC representation of the set of counter variable valuations from which termination (resp., strong termination, resp., fairness) does *not* hold (resp., does *not* hold, resp., does hold).

Next, we consider a constrained branching-time logic, GCCTL*, obtained by enriching CTL* with GC, thus enabling expressive properties and subsuming the setting of [Cer94]. We establish that, while model-checking GCS against the universal fragment of GCCTL* is undecidable, model-checking against the existential fragment, and satisfiability of both the universal and existential fragments are instead decidable and PSPACE-complete (note that the two fragments are not dual since GC are not closed under negation). Moreover, our results imply PSPACE-completeness of known verification problems that were shown to be decidable in [Cer94] with no elementary upper bounds.

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This work has been published in [5].

5.10 Refinement Modal Logic

Participants: Sophie Pinchinat.

In this paper we present *refinement modal logic*. A refinement is like a bisimulation, except that from the three relational requirements only 'atoms' and 'back' need to be satisfied. Our logic contains a new operator $\forall$ in addition to the standard modalities $\Box$ for each agent. The operator $\forall$ acts as a quantifier over the set of all refinements of a given model. As a variation on a bisimulation quantifier, this refinement operator or *refinement quantifier* $\forall$ can be seen as quantifying over a variable not occurring in the formula bound by it. The logic combines the simplicity of multi-agent modal logic with some powers of monadic second-order quantification. We present a sound and complete axiomatization of multi-agent refinement modal logic. We also present an extension of the logic to the modal μ-calculus, and an axiomatization for the single-agent version of this logic. Examples and applications are also discussed: to software verification and design (the set of agents can also be seen as a set of actions), and to dynamic epistemic logic. We further give detailed results on the complexity of satisfiability, and on succinctness.

This work has been published in [6].

5.11 The Complexity of One-Agent Refinement Modal Logic

Participants: Sophie Pinchinat.

We investigate the complexity of satisfiability for one-agent *refinement modal logic* (RML), a known extension of basic modal logic (ML) obtained by adding refinement quantifiers on structures. It is known that RML has the same expressiveness as ML, but the translation of RML into ML is of non-elementary complexity, and RML is at least *doubly* exponentially more succinct than ML. In this paper, we show that RML-satisfiability is 'only' *singly* exponentially harder than ML-satisfiability, the latter being a well-known PSPACE-complete problem. More precisely, we establish that RML-satisfiability is complete for the complexity class $\mathsf{AEXP}_{\mathsf{pol}}$, i.e., the class of problems solvable by alternating Turing machines running in single exponential time but only with a polynomial number of alternations (note that $\mathsf{NEXPTIME} \subseteq \mathsf{AEXP}_{\mathsf{pol}} \subseteq \mathsf{EXPSPACE}$).[5]

This work has been published in [7].

5.12 Automata Techniques for Epistemic Protocol Synthesis

Participants: Guillaume Aucher, Bastien Maubert, Sophie Pinchinat.

In this work we aim at applying automata techniques to problems studied in Dynamic Epistemic Logic, such as epistemic planning. To do so, we first remark that repeatedly executing *ad*

[5] This work is the revised and expanded version of [BvDP12].

infinitum a propositional event model from an initial epistemic model yields a relational structure that can be finitely represented with automata. This correspondence, together with recent results on *uniform strategies*, allows us to give an alternative decidability proof of the epistemic planning problem for propositional events, with as by-products accurate upper-bounds on its time complexity, and the possibility to synthesize a finite word automaton that describes the set of all solution plans. In fact, using automata techniques enables us to solve a much more general problem, that we introduce and call *epistemic protocol synthesis*.

This work has been published in [11].

5.13 Analysis of partially observed recursive tile systems

Participants: Sophie Pinchinat.

The analysis of discrete event systems under partial observation is an important topic, with major applications such as the detection of information flow and the diagnosis of faulty behaviors. These questions have, mostly, not been addressed for classical models of recursive systems, such as pushdown systems and recursive state machines. In this paper, we consider *recursive tile systems*, which are recursive infinite systems generated by a finite collection of finite *tiles*, a simplified variant of deterministic graph grammars (slightly more general than pushdown systems). Since these systems are infinite-state in general powerset constructions for monitoring do not always apply. We exhibit computable conditions on recursive tile systems and present non-trivial constructions that yield effective computation of the monitors.

We apply these results to the classic problems of state-based opacity and diagnosability (off-line verification of opacity and diagnosability, and also run-time monitoring of these properties). For a decidable subclass of recursive tile systems, we also establish the decidability of the problems of state-based opacity and diagnosability.

This work has been published in [8].

5.14 Uniform Strategies, Rational Relations and Jumping Automata

Participants: Bastien Maubert, Sophie Pinchinat.

A general concept of uniform strategies has recently been proposed as a relevant notion in game theory for computer science, which subsumes various notions from the literature. It relies on properties involving sets of plays in two-player turn-based arenas equipped with arbitrary binary relations between plays; these properties are expressed in a language based on CTL^* with a quantifier over related plays. There are two semantics for our quantifier, a *strict* one and a *full* one, that we study separately. Regarding the strict semantics, the existence of a uniform strategy is undecidable for *rational* binary relations, but introducing *jumping tree automata* and restricting attention to *recognizable* relations allows us to establish a 2-Exptime-complete complexity – and still capture a class of two-player imperfect-information games with epistemic temporal objectives. Regarding the full semantics, relying on *information set automata* we establish that the existence of a uniform strategy is decidable for rational relations and we provide a nonelementary synthesis procedure. We also exhibit an essentially optimal subclass of rational relations for which the problem becomes 2-Exptime-complete. Considering rich

classes of relations makes the theory of uniform strategies powerful: it directly entails various results in logics of knowledge and time, some of them already known, and others new.

This work has been published in [4].

5.15 Towards Synthesis of Attack Trees for Supporting Computer-Aided Risk Analysis

Participants: Sophie Pinchinat.

Attack trees are widely used in the fields of defense for the analysis of risks (or threats) against electronics systems, computer control systems or physical systems. Based on the analysis of attack trees, practitioners can define actions to engage in order to reduce or annihilate risks. A major barrier to support computer-aided risk analysis is that attack trees can become largely complex and thus hard to specify. This paper develops a methodology, the formal foundations as well as automated techniques to synthesize attack trees from a high-level description of a system. Attack scenarios are expressed as a succession of elementary actions and high-level actions can be used to abstract and organize attacks into exploitable attack trees. We illustrate the tool-supported approach in the context of analyzing risks of a military building.

This work has been published in [15].

5.16 Intricate Axioms as Interaction Axioms

Participants: Guillaume Aucher.

In epistemic logic, some axioms dealing with the notion of knowledge are rather convoluted and it is difficult to give them an intuitive interpretation, even if some of them, like axioms textsf.2 and
textsf.3, are considered by some epistemic logicians to be key axioms. I showed that they can be characterized in terms of understandable interaction axioms relating knowledge and belief or knowledge and conditional belief. In order to show it, I first sketch a theory dealing with the characterization of axioms in terms of interaction axioms in modal logic. I then apply the main results and methods of this theory to obtain specific results related to epistemic and doxastic logics.

This work has been published in [3].

6 Contracts and Grants with Industry

6.1 French Ministry of Defense on Physical Security

Participants: Salomé Coavoux, Maël Guillemé, Sophie Pinchinat.

The project is a collaboration with the French Defense Ministry (2011-1014, contract 2011 81 0323) for physical security. The goal is to design an assistant tool for semi-automatically synthesizing an attack/defense tree, given a specification of a building and some critical resource to protect from attacks (a safe containing a classified document). This collaboration

has been made informal from 31 August 2014, after the PhD student has resigned for personal reasons, but the implemenation has progressed a lot with the help all summer long of two students Salomé Coavoux (Master 1), Maël Guillemé (Bachelor). The proptotype has been presented twice to a DGA board, and we are on the way for a new collaboration via a PhD contract starting in September 2015.

6.2 Cour de Cassation

Participants: Guillaume Aucher, François Schwarzentruber.

The contract was signed on the 22^{nd} of April 2013 and started soon afterwards. Since then, I have developped a software prototype as well as an editor prototype. This eased a lot the communication with the jurists. I have also elicited the different requirements that the language for lawyers should fulfill and have written a short paper on this topic. The software prototype was presented on the 18^{th} of November 2013 to the 30 presidents of the 'Cour d'appels' of France who all met at the Cour de cassation on this occasion (this meeting is annual). Their reaction after our presentation of the prototype was rather enthusiastic and positive. An interview about the project has also been published on the emergence newsletter `http://emergences.inria.fr/lettres2013/newsletter-n28/L28-OUTILDECISION`.

7 Other Grants and Activities

7.1 International Collaborations

- Guillaume Aucher collaborated in 2014 with Vaishak Belle (University of Toronto) and Davide Grossi (University of Liverpool).

- Sophie Pinchinat collaborates with Tim French [University of Western Australia] on logical foundations of multi-agent systems, and with Laura Bozzelli [Universidad Politécnica de Madrid] on complexity issues in verification. Tim French visited the LogicA team last summer (01-30 August 2014), with a PhD student James Hale to work on Refinement Modal Logic [6] for the particular class of reflexive and transitive frames where interesting phenomena can be observed. This work is ongoing.

- François Schwarzentruber collaborates with Davide Grossi [University of Liverpool] for logics in Artificial Intelligence, Valentin Goranko [University of Denmark].

7.2 National Collaborations

- Guillaume Aucher is involved in the associated team of INRIA (DISTOL project, for "DIStributed and STOchastic systems, Logic").

- Sophie Pinchinat is collaborating with the DGA (French Defense Ministry) on Physical Security, supervising a PhD student Stéphanie Georges. She is involved in an associated team of INRIA (DISTOL project, for "DIStributed and STOchastic systems,

Logic") `http://www.irisa.fr/sumo/DISTOL/` with the Institute of Mathematical Sciences, Chennai and the Chennai Mathematical Institute (2013-2017). She has a strong collaboration with Hans van Ditmarsch (DR CNRS) at LORIA, Nancy, principal of the ERC starting grant project 313360 EPS "Epistemic Protocol Synthesis" (2013-2018) `http://personal.us.es/hvd/313360eps_publiccontentonly.pdf`.

- François Schwarzentruber is collaborating with researchers of IRIT (Toulouse). He is also involved in the associated team of INRIA (DISTOL project, for "DIStributed and STOchastic systems, Logic"). He has also strong collaboration with Hans van Ditmarsch (LORIA, CNRS, Nancy).He has also a collaboration with Jin-Kao Hao(university of Angers).

7.3 Project submissions

- Sophie Pinchinat has submitted a 48-month project to the ANR 2015 call under the name ADTGA for "**A**ttack-**D**efense **T**rees: **G**eneration and **A**nalysis". Its characteristics are "Instrument de financement : Projet de recherche collaborative - Entreprise (PRCE); Axe scientifique pour le défi : Risques, gestion de crise quelle que soit son origine et résilience; Objet principal de recherche: Sciences et Technologies de l'Information et de la Communication (STIC); Application principale de votre recherche : Prévention des risques et menaces."

- François Schwarzentruber has submitted a project to the ANR 2015 call "JCJC" under the name DYNASTIA standing for 'A **Dyna**mic logic as a General Executable **S**pecification Language for solving **T**asks **i**n **A**rtificial intelligence'.

8 Dissemination

8.1 Scientific Responsabilities

- Guillaume Aucher was in the Program Committee of AAMAS 2014, EUMAS 2014, DEON 2014, CLIMA 2014 and the workshops DARE 2014, IDAS@ESSLLI 2014.

  Guillaume Aucher reviewed submissions for the following international journals: *Journal of Logic and Computation*, *IEEE Transactions on Control Systems Technology*, *Journal of Applied Non-Classical Logic*, *The Review of Symbolic Logic*, *Studies in Logic*.

  He also served as a reviewer for a chapter of the *Handbook of Deontic Logic*.

  He was reviewer for the international journal *Synthese*.

  He also served as auxiliary reviewer for TACAS 2014, WODES 2014 and JELIA 2014.

  Guillaume Aucher is member of the consortium of the ERC starting grant 313360 EPS Epistemic Protocol Synthesis, led by Hans van Ditmarsch (DR CNRS at LORIA).

- Sophie Pinchinat is an Associate Editor of the Journal of Discrete-event Dynamic Systems.

She is a permanent member of the Advisory Board Marie Curie Fellows Association (Public Relations Associate and Science Policy Adviser).

She was in the Program Committee of SR2014 and GandALF2014.

She is the scientific adviser at the International Affairs of the IRISA laboratory.

She is member of the consortium of the ERC starting grant 313360 "EPS Epistemic Protocol Synthesis" (2013-2018)
`http://personal.us.es/hvd/313360eps_publiccontentonly.pdf`.

She is a member of the Computer Science and Electrical Engineering Department (ISTIC) Board.

- François Schwarzentruber was in the Program Committee of CLIMA2014 and of the workshops DARE-14 and IDAS@ESSLLI2014.

  He has been reviewer for AAMAS 2014, AiML2014, AIMSA2014, for the journal *Synthese*.

  He is member of the scientific council of ENS Rennes.

8.2 Involvement in the Scientific Community

- Guillaume Aucher has been invited and participated to a Dagstuhl Seminar 14032 entitled "planning with epistemic goals" which took place between the 12^{th} and the 15^{th} of January 2014.

- Sophie Pinchinat has been the president of 2 PhD thesis jurys over 4 PhD thesis jurys.

  She is a member of the consortium of the ERC starting grant 313360 EPS Epistemic Protocol Synthesis, led by Hans van Ditmarsch (DR CNRS at LORIA).

- François Schwarzentruber has been invited and participated to a Dagstuhl Seminar 14032 entitled "planning with epistemic goals" which took place between the 12^{th} and the 15^{th} of January 2014. François Schwarzentruber has been invited speaker at the *Kanazawa Workshop for Epistemic Logic and its Dynamic Extensions* (21-22 february 2014).

8.3 Teaching

- Guillaume Aucher spent a lot of time in the first half of the year to work on a new course entitled "Logic and Knowledge Representation for Multi-Agent Systems" at the University of Rennes 1 (M1). This course gathers students of the University of Rennes 1, ENS Rennes and it is also open to the students of the Master KIC of the EIT-ICT Lab. The syllabus of this course (150 pages), as well as the slides and exercises and other ressources are available at the following address:

  `http://www.irisa.fr/prive/gaucher/Teaching/2015/LRC.html`

  The username and password to access this website are: etudiant2015 and LRC2015, respectively.

- Sophie Pinchinat teaches at Université de Rennes 1: ENS Rennes: Advanced Techniques of Verification (Master 2 Research), Software Formal Analysis and Design (Master 1), Advanced Algorithmics (Master 1), Automata-theoretic approaches for Formal Verification (Master 1), An introduction to Writing and Research (Master 1), Algorithmics (Bachelor), Introductory course in Logic (Bachelor).

  She also teaches Game Theory at Supélec.

  She is an associate Professor at ENS Rennes. She participates to numerous jurys for training students of ENS Rennes at "Agrégation de Mathématiques".

  She is in co-charge of the stream "Parcours Recherche et Innovation" of the Master Informatique of the Computer Science and Electrical Engineering Department of the University of Rennes 1.

- François Schwarzentruber teaches at ENS Rennes: Design and verification (M1), Computability and complexity theory ("Agrégation de Mathématiques"), Algorithms ("Agrégation de Mathématiques"), (Programming in C++ and UML ("Agrégation de mécatronique"), organization of seminars for students (L3, M1).

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