Report from Dagstuhl Seminar 12111

Normative Multi-Agent Systems

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Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 12111 "Normative Multi-Agent Systems". Normative systems are systems in the behavior of which norms play a role and which need normative concepts in order to be described or specified. A normative multi-agent system combines models for normative systems (dealing for example with obligations, permissions and prohibitions) with models for multi-agent systems. Norms have been proposed in multi-agent systems and computer science to deal with issues of coordination, security, electronic commerce and institutions, agent organization. However, due to the lack of a unified theory, many multi-agent system researchers are presently developing their own ad hoc concepts and applications. The aim of this Dagstuhl Seminar was to formulate a collective appraisal of the current perspectives in the field and the most promising venues for future activity. In particular, the seminar has been conceived for the writing of a volume titled "A Prospective view of Normative Multi Agent Systems" aimed to become a standard reference in the field and to provide guidelines for future research in normative multi-agent systems.

Seminar 11.–16. March, 2012 – hwww.dagstuhl.de/12111
1998 ACM Subject Classification I.2 Artificial Intelligence, I.2.1 Applications and Expert Systems, K.4 Computers and Society, J.4 Social and Behavioral Sciences
Keywords and phrases Normative Multiagent systems, Autonomous agents and Multiagent systems, Agreement Technologies, Norms
Digital Object Identifier 10.4230/DagRep.2.3.23

1 Executive Summary

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The multi-disciplinary workshop on Normative Multi Agents attracted leading international scholars from different research fields (e.g., theoretical computer science, programming languages, cognitive sciences and social sciences).

The workshop was organised as follows: the organisers identified several relevant areas of research covering a wide and comprehensive spectrum of topics in the filed of Normative Agents. For each area, a prominent researcher was appointed as chair for the area. In the

months preceding the workshop the chairs collected material from the participants. During the first day they presented an overview of the areas they were in charge with special emphasis on some open questions and direction for future research.

The participants were divided in groups corresponding to the areas (due to some last minute cancellations some topics were under-represented and the scholars in those areas joined groups for closely related topics). Each group was allocated a morning session during which each member of the group had five minutes to provide an overview of their personal contribution to Normative Multi-Agents (plus some time for QA).

The format was well received by the participants and conducive to discussion. It gave them the opportunity to give very focused presentations while keeping the audience attention. The afternoon sessions, other the contrary, were dedicated to group work and group discussions. The aim of these sessions was to build consensus material of the specific topics and to identify fundamental research directions. The material is expected to be refined and to be articulated in chapters intended as a first step for the development for a road-map for this emerging area of computer-science with close interactions with other disciplines.

Results

During the seminar, participants split in seven working groups, centered around seven discussion themes. In the following paragraphs there is a summary of the discussion held by each working group.

Normative MAS: An Introduction. This working group first focused on three definitions and some related requirements for normative MAS. For each of such definitions, some guidelines for developing normative MAS have been proposed. Second, it has been discussed how to relate the concept of normative MAS to different conceptions of norms and how norms can be used within the systems. Finally, some specific issues that open research questions or that exhibit interesting overlaps with other disciplines have been identified.

Normative Consequence. This working group first provided a definition what deontic logic and normative reasoning is. Second, it discussed why normative reasoning is relevant for normative multi-agent systems and pointed out the advantages of formal methods in multi-agent systems. Finally, it focused on the specificity of normative reasoning in comparison to other kinds of reasoning.

Computational NorMAS. This working group considered normative systems from the computational perspective, proposing the following themes as challenging for the domain: 1) trade-offs in expressive power of the languages for representing deontic notions (such as norms, conflicts of norms, violations of norms, etc.); 2) complexity of algorithms required for a) implementing tools capable of analysing and verifying norms, b) implementing normative system platforms capable of monitoring norm violations and finally c) implementing agents capable of deliberating about norms.

Regulated MAS: Social Perspective. This working group addressed the problem of building normative multi-agent systems. It developed a static conceptual model through which a normative multi-agent system may be specified along with a dynamic conceptual model through which the operation of a normative system can be captured. A demonstration of how the proposed approach may be applied in prototypical applications of normative systems has been proposed.

Norm Compliance in MAS. This working group aimed to understand how norms regulate agent conduct and how norms impact on agent reasoning and behavior. Agents must be endowed with abilities to be able to reason about, process and otherwise manage norms in some appropriate fashion. In short, it demands that agent architectures are considered in terms of their ability to address these concerns, and that suitable architectures are developed.

(Social) Norm Dynamics. The working group aimed to identify the main steps in the dynamics of norms - i.e., generation, spreading, stabilization and evolution - as well as some of the relevant factors or determinants of such a process. The need for a deep understanding of these dynamics is becoming a compelling task for the NorMAS community due to the growing interest in open, evolving and flexible norm regulated and socio-technical systems. The working group pointed out that for a well-founded and innovative study of norms, it is necessary on the one hand to look at the cognitive mechanisms underlying the dynamics of norms and on the other hand to consider the role played by trust and cultural dimensions.

Norms and Simulation. This working group focused on the application of agent-based modeling and simulation to the issue of norm emergence, modification, and change. For the NorMAS community, agent-based simulations offer a platform to evaluate the behaviour of different models of norms and normative processes in a dynamic environment. Vice versa, the NorMAS community can supply (social) agent-based simulation studies with formal models of social concepts and mechanisms, especially those related to normative concepts, such as norms, roles, values, morals and conventions, and their transmission within a society.

The findings of the working groups were reported and discussed during the morning plenary sessions, and led to lively debate. During the seminar, each working group drafted a document presenting the main outputs achieved. Further work within the groups (by email correspondence) followed the end of the seminar, allowing finalizing the documents.

After a review process, the contributions of the working groups will be collected in a volume of the novel Dagstuhl Follow-up Series titled *A Prospective view of Normative–Multi Agent Systems*, aimed to become a standard reference in the field and to provide guidelines for future research in normative multi-agent systems.

In addition, *The Journal of Logic and Computation* and *Artificial Intelligence and Law* have agreed to publish special issues based on expanded and revised versions of the material presented at the seminar.

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3 Overview of Talks

3.1 Challenges in programming norm-aware agents

Natasha Alechina (University of Nottingham, GB)

There has recently been considerable work on programming frameworks for developing normative organisations. Such frameworks are often designed to inter-operate with existing BDI-based agent programming languages. However, programming norm-aware agents in conventional BDI-based agent programming languages remains difficult, as such languages typically lack support for deliberating about goals, obligations, prohibitions, sanctions and deadlines. These difficulties are compounded by the need to ensure that any normative agent programming framework remains tractable, i.e., deliberation about norms should be computationally feasible. In our opinion, this precludes the uses of approaches such as decision-theoretic scheduling to minimise sanctions or maximise the agent's utility (as this would require exponential computation).

The aim of this contribution is to identify challenges and advance the state of the art in programming norm-aware multiagent systems, by identifying key issues and questions in normative organisations and agent programming with priorities and deadlines.

3.2 Prescribing Norms Through Actions

Giulia Andrighetto (ISTC – CNR – Rome, IT)

Joint work of Andrighetto, Giulia; Castelfranchi, Cristiano

This work is aimed to claim that an understanding of the functioning of the normative competence requires a study of how norms are represented in the minds of individuals, the requisites that such representations must have, and what the mechanisms that allow a normative request to generate the corresponding mental representations are. After a brief overview of the debate in the study of norms, we will present a cognitive model of norms, and in particular we will focus on the role that Behavioral Implicit Communication (BIC) plays in the diffusion and stabilisation of social norms.

3.3 The Same Side of Two Coins? – A Survey on the usage of "Norms" and "Policies" across disciplines

Tina Balke (University of Surrey, GB)

Joint work of Balke, Tina; De Vos, Marina; Mileo, Alessandra; Schiller, Frank; Padget, Julian

"Norms" and "policies" are two terms in use across various areas of the computer science literature (multi-agent systems, security/privacy, web services, business applications, distributed/autonomic computing, decision support,...). However, the definition of these terms is

fuzzy, as is the identification of the purposes to which they are put. Furthermore, the terms are frequently used interchangeably, yet appear to refer to different concepts. Starting from their origins in social and political science, this paper aims to analyse systematically the usage of the terms "norms" and "policies" in computer science in general and multiagent and decision-support systems in particular. As a result of this analysis we aim to put forward for discussion our observations on overlaps and similarities in terminology, modeling and usage of these related concepts, and establish a more interdisciplinary perspective that may foster better concept and model reuse.

3.4 In what sense is deontic reasoning special?

Jan M. Broersen (Utrecht University, NL)

Intuitionistic logic is special in that is prescribes an alternative way to come from arbitrary premisses to entailed conclusions. The same holds for relevance logic and other alternatives to classic logic. I argue that deontic logic is not special in this sense. Deontic logic is the field aimed at designing formal systems for coming from deontic premisses to entailed deontic conclusions. And this is best studied by enriching languages with the appropriate structure. Deontic logic is special because this reasoning requires the modeling of many concepts: time, action, agents, intuitions, agency, etc.

3.5 Social Computing: A Software Engineering Perspective

Amit K. Chopra (University of Trento – Povo, IT)

The nature of applications is changing. Earlier they were logically-centralized; now they are becoming increasingly interaction-oriented. Social networks, social cloud, healthcare information systems, virtual organizations, and so on are evidence of the shift. In such applications, *autonomous* social actors (individuals or organizations) interact in order to exchange services and information. I refer to applications involving multiple autonomous actors as *social applications*.

Unfortunately, software engineering hasn't kept up with social applications. It remains rooted in a logically centralized perspective of systems dating back to its earliest days and continues to emphasize low-level control and data flow abstractions. In requirements engineering, for instance, the idea that specifications are of *machines*, that is, controllers, is firmly entrenched. Software architecture applies at the level of the internal decomposition of a machine into message-passing components. In other words, it helps us *realize* a machine as a physically distributed system. However, the machine-oriented worldview cannot account for social applications in a natural manner.

I understand *social computing* as the joint computation by multiple autonomous actors. By "joint", I refer simply to their interactions and the *social relationships* that come about from the interaction, not necessarily cooperation or any other form of logical centralization. In fact, each actor will maintain its own local view of the social relationships—there is no

centralized computer or knowledge base. The relationships themselves may take the form of commitments, trust, or some other suitable social norm. The purpose of the computation may be to loan a bicycle or a couch to a peer, to schedule a meeting or a party, to carry out a multiparty business transaction, to provide healthcare services, to schedule traffic in smart cities, to manage the distribution of electricity in smart grids, to build consensus on an issue via argumentation, or globally distributed software development itself—*anything* that would involve interaction among autonomous actors.

Clearly, we are already building social applications, even with current software engineering approaches. For example, online banking is a social application in which a customer interacts with one or more banks to carry out payments, deposits, and transfers. Social networks such as Facebook and LinkedIn facilitate interactions among their users. However, just because we can build social applications, it does not mean we are building them the right way. Right now, all these applications are built in a heavily centralized manner: banks provide all the computational infrastructure; so does Facebook. Users of these infrastructures are just that—*users*, no different from those of an elevator or an operating system. In other words, current software engineering produces only low-level technical solutions.

My vision of social computing instead embraces the social. It recognizes the autonomy of actors. Instead of control flow or message flow, it talks about the meanings of messages in terms of social relationships. Computation refers to the progression of social relationships as actors exchange messages, not to any actor's internal computations (although these too could be accounted for). The different aspects of my vision constitute a challenging research program. What form would specifications of social applications take? What would be the principles, abstractions, and methodologies for specifying social applications? On what basis would we say that an actor is behaving correctly in a social application? How would we help an actor reason about specifications of social applications with respect to its own goals and internal information systems? What kind of infrastructure would we need to run social applications? The answers to these questions and the realization of my vision will lead to a software engineering vastly more suited to social applications.

More details on social computing can be found in [1]. The idea of social computing is an elaboration of Munindar Singh's work on protocols and commitments in multiagent systems. To anyone wishing to learn more about the foundations of social computing, I highly recommend starting with [2].

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3.6 Control Automation to Reduce Costs of Control

Rob Christiaanse (TU Delft, NL)

Joint work of Christiaanse, Rob; Hulstijn, Joris

Abstract. Much compliance effort concerns adherence to contracts. Controls are added to the business process to make sure the other party will fulfill his part of the contract. Controls

have costs. In this paper we argue that fully automated controls help to lower control costs, because (i) they help to prevent misstatements (compliance by design) or (ii) they increase the quality of audit evidence and thereby reduce the audit risk and additional audit fees. The line of reasoning is illustrated by a case study of the implementation of automated controls on the procurement process for public transport services for the elderly and disabled. The case study suggests some open issues, which can be linked to concepts from Normative Multi Agent Systems.

3.7 Towards an Abstract Framework for Compliance: Preliminary Results

Silvano Colombo-Tosatto (University of Luxembourg, LU)

Joint work of Colombo-Tosatto, Silvano; El Kharbili, Marwane; Governatori, Guido; Kelsen, Pierre; Ma, Qin; van der Torre, Leendert

The present paper aims to provide an abstract framework to tackle the compliance problem. We first define the compliance problem and its elements such as processes and obligations. Secondly our abstract framework capable to efficiently deal with a fragment of the compliance problem is introduced. We provide the algorithms used in the framework along with the complexity results.

3.8 On the relationship between expectations, norms and commitments

Stephen Cranefield (University of Otago, NZ)

The concept of an agent expectation has been formalised by a number of researchers. A common understanding is that an expectation is a formula describing some future state of affairs, together with an active interest of the agent in tracking the value of the formula over time. At this informal level, there is a commonality with both norms and commitments: both involve expectations on future behaviour and, in general, they presuppose that some agent (or society as a whole) is interested in their fulfilment. However, while the concept of an expectation is related primarily to the temporal issue of whether a formula becomes true or false in the future, commitments and norms have additional social context, such as the debtor and creditor of a commitment and the sanction that may be associated with a norm. Commitments and instantiated norm instances are also created by different mechanisms and have different practical implications when fulfilled and violated.

This paper explores the relationship between expectations, norms and commitments and presents the argument that a logical account of expectations can be seen as representing a common core for logics of commitment and normative concepts. To make this concrete argument concrete we sketch out how this can be achieved for a particular choice of technlogies.

3.9 A Norm-Deliberation Process for Norm-Autonomous Agents

Natalia Criado (Polytechnic University of Valencia, ES)

Joint work of Criado, Natalia; Argente, Estafania; Dignum, Frank; Noriega, Pablo; Botti, Vicente

Norm-autonomous agents must be endowed with capabilities for making a decision about norm compliance. This paper proposes a new norm-deliberation process for allowing agents to make decisions about norm compliance autonomously.

3.10 Fuzzy Legal Interpretation

Celia da Costa Pereira (Université de Nice, FR)

Joint work of Boella, Guido; da Costa Pereira, Celia; Tettamanzi, Andrea; van der Torre, Leon; Villata, Serena

Legal interpretation is a mechanism from law allowing norms to be adapted to unforeseen situations. We focus on the role of interpretation in legal reasoning. A norm may be represented as a rule $b_1, ..., b_n => O$ such that l is the obligation linked to the norm. The degree associated to l depends on the degrees of truth of conditions b_i. These degrees depend in turn on the goal associated to the norm. We propose to define the fuzzy set $b'_i = f(b_i, g_j)$ where the value of b' increases or decreases according to the matching between b_i and the goal associated to norm j. The degree of matching depends on how concepts relevant to the norm are defined in a domain ontology.

3.11 Using Values in Normative Multi-Agent Systems

Gennaro Di Tosto (Utrecht University, NL)

Values can be intended as dispositions to choose one state of the world over another. Used to represent the motivational state of an agent, they can be useful to tackle issues related normative change, norm conflicts and policy making through social simulation. We present an example scenario intended to exemplify the behaviours we are interested in, to describe cultural groups as normative systems, and where the element of change is represented by the introduction of a new norm. Endowing agents with variables expressing what they value allows us to describe the direction of change in the proposed scenario.

3.12 Six Remarks on Normative Multiagent Systems

Frank Dignum (Utrecht University, NL)

1. **On the use and meaning of norms.** Although norms have been used in various ways and forms in CS (and MAS in particular) it is still unclear what it is that we try to incorporate in the normative systems that we build. Norms are very fuzzy and subtle instruments that have many aspects. Usually only a few aspects are picked up and implemented. However, it is unclear whether the result will live up to expectations, because the simplifications that are made prevent good predictions on the effect of the norms on the system. Thus I advocate to create a general framework for describing norms in a formal way in which we can include all the different aspects that are relevant in using norms. Because this is very complex (and possibly never concluded) the framework should be flexible and also allow for different techniques to be used to model different aspects of norms. Such a framework would allow people that actually want to use norms in a practical system to check which aspects of norms are important for their implementation and can check what are the consequences of including or excluding certain parts.
2. **On a computational view of norms.** In some sense this is a sequel of the first remark. When implementing norms in any system it is very important to check first which aspects of norms are relevant and important for the system. This should lead to a certain way of implementing the norms. Thus I do not believe that we can have a kind of "norm module" that could be added to a system. The big challenge is how norms can be added to a system that might already be built or is implemented in a certain software platform or according to a fixed architecture. How can these be extended to include norms, without having to start all over again? Can this be done or are normative systems so fundamentally different that we have to create different architectures, languages and platforms to cope with them? Can we characterise the main difficulties in connecting norms to other aspects of (MAS) systems? If so, we might still be able to automatize or support the connection (at least for some part).
3. **On collective norms.** When a norm is issued for a collective it has to be translated to some norms for the individuals that make up the collective. The question is what is the set of individual norms that will properly describe the collective norm. Or is this the same as collective intentions that cannot be defined in terms of individual intentions? If not, what are the exact relations between collective and individual norms? Another question (already being investigated in some of our papers) is the question who is responsible to fulfill the norm and who is responsible when a collective norm is violated. It might be clear that this depends on the structure of the collective. Is it a set of persons, a team, an organization,...How do the structural relations of the collective play a role in the collective norms?
4. **Norms and Groups.** Norms are not just imposed on members of a group, but also form a part of the identity of the group. One can say that a group of friends is tight, because they have a norm that whenever one of them is in trouble the others ought to help. Looking at the identifying role of norms for groups this also becomes part of the reason to comply or violate a norm. Complying to a group norm establishes group membership. In a similar way norms can identify roles within a group and thus determine whether persons can fulfill these roles. How does this influence the spreading and maintenance of norms? What does it mean for the violation and sanctioning of norms?

5. **Emergence of norms.** There has been some work on the emergence of norms, mainly in simulations. In order to determine whether a norm emerges, what should we measure? Can we see the difference between a norm emerging or a coincidental behavioral pattern a convention or something else? This raises the important question when we state that a system is a "normative system" (both artificial as natural systems). Can we pose some minimal requirements on when they can be normative? Should the agents in the system have some capability to have "moral judgements", should they contain value systems?
6. **Why are normative systems better?** Although we advocate norms as being essential elements for open systems it is not really clear where the added value of norms come in. As there seems not to be a standard way of implementing norms in systems it is difficult to predict how normative systems will behave. So, it is also not clear whether they will behave better in some way then systems that are designed without the explicit use of norms. If they are more flexible, what makes them more flexible? If they are more modular, what creates this modularity? And how would these properties reflect on the overall behavior of the normative systems? Can we say that norms provide added value when designing open systems? If so, what is the added value in the design exactly? I claim that we should be able to give precise answers to these questions if we want norms to be used by other people outside our community. It also leads to some research questions about implementing norms that have not been addressed in any systematic way. Nl. What are standard ways of implementing norms and normative behavior. How do norms relate to other design concepts for traditional (multi agent) systems and how should methodologies be adjusted to take them into account properly.

3.13 Formalizing Open Normative Systems Situated in Environment using Semantic Web Technologies

Nicoletta Fornara (Università della Svizzera italiana – Lugano, CH)

The study and analysis of the design and implementation process that brings to the realization of open interaction systems where autonomous heterogeneous components, like agents and humans, may interact in order to reach their goals is a crucial topic of research. This process involve the definition of various components: from the design of the data necessary to represent the state of the interaction, to the rules to describe the evolution of the state, to the norms for regulating the interactions, to the monitoring and enforcement component, to the mechanisms for the definition of the rules for the perception of the events and actions. Taking into account those characteristics, components, and required functionalities, relevant open challenges are: (i) How to design norms and institutions with the goal of reusing them in different applications? (ii) How to combine institutional models with studies on distributed event-based systems, like environments? (iii) What formal languages and architecture is it better to use for designing and implementing efficient and effective open interaction systems?

3.14 Position Paper

Dov M. Gabbay (King's College London, UK)

We view norms as metalevel rules on state of affairs and actions. We distinguish two types of rules:

1. Rules saying whether certain formulas should hold in the state.
2. Rules saying whether certain actions should or should not be taken in the state.

To be able to formalise this set up we need a language for states , a language for actions, a language for formulas which can be evaluated to hold or not hold in a state or on an action and an algorithm, telling us how to apply an action to a state to get new states.

The norms can be defined on top of that, as input output pairs (A, B) where A is a formula and B is a formula, to be evaluated on states and actions. A is the condition and B is the result of the norm.

The norm is violated in a state or action if A holds and B does not hold.

3.15 Bipolar argumentation frames and Contrary to Duty obligations Abstract (preliminary report of a research program)

Dov M. Gabbay (King's College London, UK)

In my papers [5, 3], I modelled the Chishom paradox and generaly Chicholm like sequences of contrary to duty obligations by using Reactive Kripke models [4]. Reactive Kripke frames have two types of arrows: ordinary single arrows $x \to y$ indicating accessibility relations and double arrows of the form $(u \to v) \twoheadrightarrow (x \to y)$, indicating reactive connections.

If the frame ordering is a tree, as it is in the models for contrary to duty obligations, the double arrow $(u \to v) \twoheadrightarrow (x \to y)$ can be uniquely represented by $v \twoheadrightarrow y$. We thus get a bipolar network where we interpret $\to$ as support and $\twoheadrightarrow$ as attack. Of course the same reactive graph can be manipulated in the Deontic way [5], when we read it as modelling contrary to duty obligations and it will be manipulated in the argumentation way [1, 2], when viewed as a bipolar network. The question arises , can we find a family of tree like graphs, (which do not sacrifice generality neither in the contrary to duty area nor in the bipolar argumentation area) for which the Deontic and the argumentation manipulations are the same. This paper shows that this is possible , and thus establishes a connection between the contrary to duty area and the bipolar argumentation area.

Note the following:

1. This connection with bipolar argumentation frames is made possible because of the modelling of contrary to duty obligation using reactive Kripke models. The connection between Reactivity and Bipolarity is more easy to see.
2. The way the game is played in each area is different. So we have here a wide scope for interaction and exchange of ideas between argumentation and contrary to duties. These include:

2a. Deontic like modelling and axiomatisations for bipolar argumentation.

2b. Argumentation semantics for contrary to duty paradoxes which can especially handle contrary to duty loops (a subject not even mentioned in the contrary to duty literature).
2c. The equational approach to contrary to duty, imported from the equational approach to argumentation.
2d. The fact that bipolar frames can be instantiated as contrary to duty obligation might shed some light on the polarised debate in the argumentation community on how to instantiate argumentation networks, see [7].
2e. Settle questions of how to model (what is) support in argumentation.
3. Doing Modal Logic in Bipolar Argumentation Theory (compare with [6]).

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3.16 Norms as Objectives: Revisiting Compliance Management in Mulit-agent systems

Aditya K. Ghose (University of Wollongong, AU)

Joint work of Ghose, Aditya K.; Savarimuthu, Bastin Tony Roy

This paper explores a hitherto largely ignored dimension to norms in multi-agent systems: the normative role played by optimization objectives. We introduce the notion of optimization norms which constrain agent behaviour in a manner that is significantly distinct from norms in the traditional sense. We argue that optimization norms underpin most other norms, and offer a richer representation of these. We outline a methodology for identifying the optimization norms that underpin other norms. We then dfine a notion of compliance for optimization norms, as well as a notion of consistency and inconsistency resolution. We

offer an algebraic formalization of valued optimization norms which allows us to explicitly reason about degrees of compliance and graded sanctions. We then outline an approach to decomposing and distributing sanctions among multiple agents in settings where there is joint responsibility.

3.17 Combining different perspectives on norms and agency

Max Knobbout (Utrecht University, NL)

Norms in Multiagent Systems generally allow for different modes of analysis. On one hand we can see them as constructs specified by some formal language denoting what ought (or ought not) to be the case. Such approaches generally do not answer what incentives the agents have to comply, nor do they answer how these norms can emerge. On the other hand we can see norms as the emerging coordination between interacting (rational) agents. This allows for a more game-theoretic oriented approach, where for example a norm can be seen as an equilibrium choice in a game that possesses multiple equilibria. This approach suffers from different problems; for example it does not specify where the preference from the agents come from. I believe that an important challenge for researchers in the field of norms and agency is to find the underlying connection between these different approaches (this is also the topic of my current research). This will hopefully allow us to get a better and more broader understanding of the current issues within this field of research.

3.18 Open Normative Environments

Henrique Lopes-Cardoso (University of Porto, PT)

Joint work of Lopes-Cardoso, Henrique; Oliveira, Eugenio

Open multi-agent systems relying on autonomy as an intrinsic property of agents cannot be addressed with constraining approaches, in which agent behavior is concerned. Moreover, in normative multi-agent systems autonomy is fully accommodated at the level of norms: agents being able to choose which norms to adopt. It is therefore important to develop appropriate infrastructures that assist software agents in two tasks: first, that of negotiating or selecting the norms that they deem more appropriate to govern their interactions; second, that of monitoring and enforcing the normative system thus created. From this perspective, an open normative environment is envisaged as one with an evolving normative space, whose norms apply if and when agents commit to a norm-governed relationship.

3.19 Norm generation from experience

Maite Lopez-Sanchez (University of Barcelona, ES)

Joint work of Morales, Javier; Lopez Sanchez, Maite; Esteva, Marc
Main reference J. Morales, M. Lopez-Sanchez, M. Esteva, "Using Experience to Generate New Regulations," in Proc. of the Int'l Joint Conf. on Artificial Intelligence (IJCAI'11), pp. 307–312, 2011.
URL http://ijcai.org/papers11/Papers/IJCAI11-061.pdf

Defining the norms for bright new organizations or Multi-Agent systems may not be a straightforward process, so the aim of this paper is to advance in the automatic generation of norms based on experience. If we understand norms in their broad sense of social conventions, a number of approaches, such as norm synthesis, norm agreement or norm emergence have been studied by the research community. Nevertheless, they present some limitations in terms of complexity or required domain knowledge that we aim at overcoming. Thus, we present a proposal for norm generation where a regulatory authority proposes new norms whenever conflicts arise. Proposed norms are continuously evaluated in terms of the compliance behavior of agents and their effects in the system. Therefore, agents can decide whether to comply or violate norms, and this may result in conflicts. We consider this information to be valuable when assigning a meaning to this effect. For instance, the fact that a norm that is being repeatedly violated and no conflicts have arisen can be interpreted as evidence against the necessity of the norm. This top-down proposal combined with the bottom-up evaluation closes the loop of the generation of norms, and leaves room for dynamic changes both in the system or the agents behaviour.

3.20 Norm Adaptation in MAS

Maite Lopez-Sanchez (University of Barcelona, ES)

Joint work of Campos, Jordi; Esteva, Marc; Lopez-Sanchez, Maite; Morales, Javier; Salamo, Maria
Main reference J. Campos, M. Esteva, M. Lopez-Sanchez, J. Morales, M. Salamo, "Organisational adaptation of multi-agent systems in a peer-to-peer scenario." Computing, 91(2):169–215, 2011
URL http://dx.doi.org/10.1007/s00607-010-0141-9

The overall structure of agent interactions in a Multi-Agent System (MAS) may emerge implicitly as a result of agent activities in Agent Centred MAS approaches (ACMAS) or may be explicitly designed in Organisation Centred MAS approaches (OCMAS). We consider the later to include an organization composed of a social structure, social conventions and organizational goals. Norms can be defined as social conventions that prescribe how agents should interact so to accomplish organizational goals. Nevertheless, at run time, changes in the environment or in the agent population may result in a decrease in goal accomplishment. Organisational dynamic adaptation has attracted a significant amount of research effort since it can improve system performance across changing situations, outweighing the overhead and costs associated with making dynamic changes. In particular, we claim that norm adaptation constitutes a relevant research topic despite the fact that far fewer approaches have tackled it. We envision norm adaptation as a goal driven process, and so, we advocate for acquiring knowledge about the relationship between norms and goal accomplishment at run time by using a machine learning approach. Furthermore, we argue the resulting adaptation mechanism should be robust enough so to be able to cope with different system

instabilities regardless of its origin: changes in system dynamics, agent population changes, or even existence of non-norm- compliant agents. And this may not necessarily require an explicit norm enforcement mechanism but a change in the norms that best compensate for current instabilities.

3.21 On the conceptual and logical foundations of moral agency

Emiliano Lorini (Paul Sabatier University – Toulouse, FR)

The aim of this work is to provide a logical analysis of moral agency. Although this concept has been extensively studied in social philosophy and in social sciences, it has been far less studied in the field of deontic logic and multiagent systems (MASs). We discuss different aspects of moral agency such as the distinction between desires and moral values and the concept of moral agent.

3.22 How to make existing logics for MAS and NorMAS

Emiliano Lorini (Paul Sabatier University – Toulouse, FR)

I propose an Ockhamist variant of Propositional Dynamic Logic PDL, called Ockhamist Propositional Dynamic Logic OPDL. I discuss the relationships between OPDL and existing logics of agency and cooperation used in the area of multi-agent systems such as CTL, PDL, STIT, Coalition Logic and ATL.

3.23 The Harmonious Triad of Social Norms, Complex Systems and Agent-based Simulation.

Samhar Mahmoud (King's College London, GB & PPM Group Univ. of Konstanz, DE)

At the advent of the social computing era, billions of devices are now (i) globally interconnected, (ii) environment-aware, and (iii) embedded in human society with the scope of improving quality of life. Together with the unstoppable increase in on-line communities and social networking, it seems that humans (and devices) are increasingly, and better, connected through virtual environments. The set of interactions between individuals in society results in complex community structure, captured by social networks. However, by virtue of frequent changes in the activity and communication patterns of individuals, their associated social and communication networks are subject to constant evolution. Moreover, due to the magnitude, openness and dynamism of on-line communities, centralised supervision of all possible interactions in real time becomes infeasible and computationally intractable. Social norms provide one potential solution for the regulation of such types of system. The use of social

norms brings several advantages since they are inexpensive for society (as there is no need for trained authorised individuals in supervising interactions), have adaptive capability (as norms are self-imposed and self-controlled, so they can rapidly adapt), are easy to implement (since it is in everyone's social interest to follow them). The main strength of social norms can be found in their decentralised nature: they emerge through the decentralised interactions of individuals within a collective, and are not imposed or designed by an authority, but by the individuals themselves. Despite their value, our understanding of such phenomena is limited. It is thus vitally important to investigate and understand complex systems and their interactions, in the context of different types of norms and different types of normative systems, in order to achieve appropriate adaptability and consequently efficient and effective self-organisation and self- regulation. Critically, the techniques of agent-based simulation provide a key means of developing this understanding in order that the dynamics of social norms can be leveraged in support of such self- regulation. Moreover, these techniques can potentially serve policy-makers and system designers to foresee the effects of specific environmental and social conigurations and react against failures.

3.24 Social And Customary Norms in Multi-Agent Systems

Eunate Mayor Villalba (GET – Toulouse, FR)

Abstract. In order to disentangle the real nature and dynamics of customs and its role within the legal system, the first issue pertains finding the proper way to study the de- velopment of such customary practices: is it a merely spontaneous dynamic process over which individuals have little control, and which depends basically on psycho-cognitive human characteristics, or is it a more complex phenomenon? The aim of this paper is to stimulate debate and foster the development of an interdisciplinary approach to social and customary norms.

Keywords: Social norms, Multi-Agent Systems, Customs, Learning

3.25 Culture and Norms

John McBreen (Wageningen University, NL)

We discuss how group dynamics are an essential part of social interaction that can add to the realism of models of the evolution of social norms. We discuss how relationships to others in a group context may affect one's willingness to emulate, forgive, reproach, oppose, admire etc. the adoption of new social norms by other group members. We also discuss how these group dynamics can differ across countries, and link this to the Hofstede Dimension of Culture.

3.26 Remarks on normative MAS from an institutional perspective

Pablo Noriega (IIIA – CSIC – Barcelona, ES)

This paper has two aims. First, it intended as an outline of the many aspects of normative MAS that become interesting when one sees a Normative MAS as a set of regulations that apply to a population of agents and the elements that support them. It takes an institutional perspective in the sense that the interest is on those aspects that are constitutive of normative MAS, regardless of any particular set of regulations, and regardless of the motivations, rationality or goals of participating agents. The perspective is institutional also in the narrower sense that it is not concerned with the same and similar issues when they are approached from an "organizational perspective" where the normative system presumes the existence of elements such as organizational goals, structure, allegiances and boundaries. The second aim is to use that broad view as a background that gives context to a few questions that might be significant for normative MAS and have been little explored in this community.

3.27 Interdependence of norms, reputation and groups

Mario Paolucci (ISTC – CNR – Rome, IT)

In this paper, I argue how norms and reputation can interact and concur to define groups which are needed to move from "delusional" norms and reputation to actual ones.

3.28 Conflict resolution techniques for normative reasoning

Xavier Parent (University of Luxembourg, LU)

Main reference X. Parent, "Moral particularism in the light of deontic logic." Artificial Intelligence and Law, 19, pp. 75–98, 2011.
URL https://parent.gforge.uni.lu/

Conflicts resolution techniques have been developed in the context of the study of non-monotonic reasoning. We argue they are not suitable to model normative reasoning because of the need to distinguish between norm violation and exception to a norm. A medical example is use to substantiate this point further. It highlights the role of backwards reasoning in the normative domain.

3.29 An Argumentation-based Approach to Trust

Simon Parsons (Brooklyn College, US)

Joint work of Parsons, Simon; McBurney, Peter; Sklar, Elizabeth; Tang, Yuqing
Main reference Y. Tang, K. Cai, P. McBurney, E. Sklar, S. Parsons, "Using argumentation to reason about trust and belief," Journal of Logic and Computation, to appear.

Trust is a mechanism for managing the uncertainty about autonomous entities and the information they store, and so can play an important role in any decentralized system. As a result, trust has been widely studied in multiagent systems and related fields such as the semantic web. Here we introduce a formal system of argumentation that can be used to reason using information about trust. This system is described as a set of graphs, which makes it possible to combine our approach with conventional representations of trust between individuals where the relationships between individuals are given in the form of a graph. The resulting system can easily relate the grounds of an argument to the agent that supplied the information, and can be used as the basis to compute Dungian notions of acceptability that take trust into account.

3.30 The Use and Meaning of Norms in MAS: A Conceptual View

Antonino Rotolo (University of Bologna, IT)

In this paper we discuss the role of norms in MAS. We first argue that the most fruitful way to define norms in this setting is not state what norms are, but what they do or are expected to do. Then, we identify some normative paradigms that MAS can adopt, including those inspired by morality, social norms, and the law. In particular, we argue that the legal paradigm offers a number challenges (and an opportunity) for normative MAS. We finally show that any comprehensive view of normative MAS must be tested against the following research questions: developing (a) generative models of norms; (b) norm change models of norms; and (c) compliance, application and sanction models of norms.

3.31 Norm learning - research issues and opportunities

Bastin Tony Roy Savarimuthu (University of Otago, NZ)

Joint work of Savarimuthu, Bastin Tony Roy; Cranefield, Stephen; Verhagen, Harko

Several simulation-based works in Normative multi-agent systems (NorMAS) have investigated how software agents learn norms that exist in an agent society. However, there are limitations to the research works on norm learning. This position paper aims at discussing these limitations and the research questions that need to be addressed to overcome these limitations. This paper also briefly discusses the suitability of virtual environments such as multi-player games and SecondLife as domains to explore these research questions.

3.32 Towards mining norms in open source software repositories

Bastin Tony Roy Savarimuthu (University of Otago, NZ)

Joint work of Savarimuthu, Bastin Tony Roy; Dam, Hoa Khanh

The concept of norms has attracted a lot of interest in various disciplines including computer science since it facilitates collaboration and cooperation of individuals in societies. Extracting norms from computer-mediated human interactions is gaining popularity since huge volume of data is available from which norms can be extracted or "mined". The emerging open source communities offer exciting new application opportunities for norms mining since such communities involve collaboration and cooperation among developers from different geographical regions, background and cultures. Mining norms from open source projects however has not received much attention from the normative multi-agent system community. Therefore, our position paper addresses this issue by discussing the opportunities and the challenges presented by this domain for the study of norms. It provides a brief description of existing technologies in mining software repositories (MSR) that can be leveraged. In addition, it highlights the motivations for the study of normative behaviour in open source software development from the data available in various software repositories. On this basis, it lays out the main research questions and open challenges in mining norms from these repositories.

3.33 Common Semantics and Complexity - An NMAS Research Agenda Proposal

Fernando Schapachnik (University of Buenos Aires, AR)

Joint work of Mera, Sergio; Schapachnik, Fernando

This short article sketches a proposal for an NMAS research agenda for the upcoming years. The salient topics are finding common families of formalisms that allow for easy comparison of deontic proposals and considering not only their expressiveness but also their complexity.

3.34 A Normative Basis for Trust

Munindar Singh (North Carolina State University, US)

We consider open settings wherein multiple autonomous parties interact. Such settings bring out the problem of decision-making: How can each party decide on how it should engage the others?

Trust is a key ingredient in such decision making. But this leads to another question: How can each party determine how much trust to place in another autonomous party? To be an effective basis for decision making, the estimation of trust must incorporate (1) the

interaction being considered by the first party (i.e., the task or transaction), (2) the social or organizational relationships, and (3) the relevant context.

3.35 Governance in Sociotechnical Systems

Munindar Singh (North Carolina State University, US)

We address the challenge of administering sociotechnical systems, which inherently involve a combination of software systems, people, and organizations. Such systems have a variety of stakeholders, each in essence autonomous. Traditional architectural approaches assume that stakeholder concerns are fixed in advance and addressed out-of-band with respect to the system. In contrast, sociotechnical systems of interest have long lifetimes with changing stakeholders and needs. We propose addressing stakeholders' needs during the operation of the system, thus supporting flexibility despite change. Our approach is based on norms among stakeholders; the norms are streamlined through a formal notion of organizations. We demonstrate our approach on a large sociotechnical system we are building as part of the Ocean Observatories Initiative.

3.36 Actions and Obligations: merging the internal and the external perspective

Paolo Turrini (University of Luxembourg, LU)

When an individual or a group of individuals is confronted with a number of possible choices, often the question arises of what that individual *should* do. Traditionally, the formal study of terms such as should, must, ought to, may etc. has been dealt with by deontic logic, a branch of modal logic that analyzes the structure of normative concepts. In the history of deontic logic two perspective have been taken in modelling these type of concepts:

- In the first, norms assume an *internal* or *utilitarian* character: actions that are obligatory for a player (or a group of players) are those that are best for the player itself (or, in a general sense, meet the preferences of some players).
- In the second, norms assume an *external* or *systemic* character: choices are judged against predetermined interests, specified from outside the system.

We briefly describe the two views on norms and we show a two-steps example where the two views converge at first, but radically differ later. We believe that a challenge for deontic logic is to understand the relations among the two perspectives and, possibly, to suggest a choice among the two.

3.37 Group Norms

Wamberto Vasconcelos (University of Aberdeen, GB)

Group norms address groups of individuals, affecting their joint behaviours, arising in many situations; *e.g.*, an obligation on the sales team to meet once a week, a prohibition on gatherings of more than x people, or a permission for a group visit to a building. This document makes a case for the importance of representing and processing such norms, raises issues which should be investigated, and sketches how research on group norms could connect coordination mechanisms and normative reasoning.

3.38 Putting the agent back together again - needs for integrating social and behavioural sciences for agent-based social simulation

Harko Verhagen (Stockholm University, SE)

Joint work of Verhagen, Harko; Elsenbroich, Corinna

Agent-based modelling has had great success in modelling normative behaviour. Its success is due to agent-based modelling being able to tackle the problem of normative behaviour at the heart by reconstructing the micro macro link, generating macro phenomena from micro specifications. The starting point for models of normative behaviour has so far been an individualist agent, i.e. an agent has its own goals and behaves according to them with social behaviour as an emergent phenomenon. The BDI architecture on which most models are based is a strongly individualist architecture. An agent is defined over its individual beliefs, desires and intentions and any social behaviour results either by emergence (Epstein 2001), by deterrence (Axelrod 1986) or by explicitly defining a set of obligations an agent has to follow, transforming the BDI into the BOID (Broersen et al. 2000, 2001). The most advanced models of normative behaviour to date, those based on the EmiL-a architecture transcend the individualist nature of an agent to some extent by incorporating both perception of norms and reasoning with norms into the agent via the so called normative board. Now the agents are able to have a normative interface with the world rather than just a factual one as is the case in the BOID agent. Still, desires and intentions of the agent are defined individualistically, with normative knowledge evaluated according to these desires and intentions. But what if the agent was not quite as individualistic? What if agents have an active interest in social behaviour, in sharing goals, in cooperating? And how do we integrate emotions into these frameworks or open up for glass-box cognitive models to replace the black box of BDI? And what about emotions? We advocate work on these issues to improve the agent simulation models such that: a) Models will no longer analyse whether social behaviour is possible but what kind of social behaviour might emerge. b) Models give up a long-standing paradigm of atomism. c) Models can no longer be purely behavioural as agents need to understand their own intentions and goals and those of other agents. d) Models of human agency need to address the social, psychological and emotional aspects simultaneously. In the following we will describe we-intentions as an alternative to the I-intentions of homo economicus followed by a description of an agent architecture encompassing the components outlined above. We will conclude by pointing to a set of challenges.

3.39 Data Licensing in the Web of Data: open challenges

Serena Villata (INRIA Sophia Antipolis, FR)

Joint work of Villata, Serena; Gandon, Fabien

A common assumption in the Web is that the publicly avail- able data, e.g., photos, blog posts, videos, can be reused without restric- tions. However, this is not always true, even when the licensing terms are not specified. Consuming Linked Open Data includes the fact that the data consumer has to know the terms under which the data is re- leased. The licensing terms in the Web of Data are specified by means of machine-readable expressions, such as additional triples added to the RDF documents stating the license under which the data is available. We highlight the future trends in data licensing and the possible connections with normative multiagent systems.

3.40 Argumentation and Norms

Serena Villata (INRIA Sophia Antipolis, FR)

Joint work of Villata, Serena; Antonino Rotolo; Nir Oren; Leendert van der Torre

Norms and argumentation are two research areas which are becoming more and more connected over the last decade, in the legal field, in knowledge representation, ethics, or linguistics, and most recently, in agreement technologies in computer science. Norms are used to set the space of legal agreements (or commitments) and argumentation is used to choose among the possible agreements. Moreover, we may consider norms set not only the scope of possible legal agreements, but also the way we can choose among these possible agreements. Existing works, same of them mentioned above, on norms and argumentation can be categorized into two different classes, namely (i) arguing about norms, and (ii) norms about argumentation. The former includes the greater part of existing works in the area of norms and argumentation, such as approaches which aim at resolving conflicts and dilemmas, looking in particular at how norms interact with other norms, arguing about norm interpretation and dynamics, arguing about norm adoption, acceptance and generation, representing norm negotiation, and arguing about contracts. In spite of all the existing literature on these topics, several challenges have still to be addressed and resolved. For instance, the introduction of frameworks where the individuals can discuss about the merits and the effects of the norms to be adopted in the society, or the proposal of reacher preference models to detect and reason about norm interactions are fundamental steps to approach the two research areas. The latter, instead, includes a smaller set of existing works, and it aims at addressing the challenges about dialogue and debate protocols, reasoning about epistemic norms, and enforcement models of the burden of proof. For instance, the introduction of new techniques to verify whether a virtual agent complies with an epistemic norm, or the development of tools able to support the judging entities and the lawyers to enforce the burden of proof are further challenges for agreement technologies.

3.41 Visualizing Normative Reasoning

Leon van der Torre (University of Luxembourg, LU)

Successful reasoning formalisms in artificial intelligence such as Bayesian networks, causal networks, belief revision, dependence networks, CP-nets, Dung's abstract argumentation theory, come with intuitive and simple visualizations. Traditionally deontic logic has been associated with preference orders, which have an intuitive visualization. With the rise of candidates for new standards for normative reasoning, the need emerges to have new visualizations.

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