

Report from Dagstuhl Seminar 15131

# Normative Multi-Agent Systems

Edited by

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## Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 15131 “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. Normative multi-agent systems provide a promising model for human and artificial agent coordination because they integrate norms and individual intelligence. They are a prime example of the use of sociological theories in multi-agent systems, and therefore of the relation between agent theory—both multi-agent systems and autonomous agents—and the social sciences—sociology, philosophy, economics, legal science, etc. The aim of this Dagstuhl Seminar was to feature two fresh themes in broader computing and software engineering: social computing and governance. These themes are highly interdisciplinary, bringing together research strands from computing, information sciences, economics, sociology, and psychology. Further there is considerable excitement about these areas in academia, industry, and public policy organizations. Our third theme was agreement technologies, a more traditional topic but nonetheless relevant for the NorMAS community. A norm is a fundamental social construct. Norms define the essential fabric of a society. Our purpose in this seminar was to explore the connections of norms to each of the themes, especially from a computational perspective. Moreover, the seminar has been conceived for the writing of a volume titled “Handbook 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.

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## 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 organized as follows: the organizers identified three relevant themes of research covering a wide and comprehensive spectrum of topics in the field of Normative Agents, namely Social Computing, Governance, and Agreement Technologies. In the months preceding the workshop the chairs collected material from the participants. During the first day each participant present herself to the audience, and the chairs introduced the goal of the seminar, i.e., writing an handbook of Normative Multiagent Systems based on the roadmap produced during the previous edition of the Seminar, and the discussions during the current one. The participants were divided in groups corresponding to the areas identified as relevant in the field of Normative Multiagent Systems. Four invited talks have been proposed by scholars from different areas in the field, targeting in particular the three themes of the Seminar and an overview about Normative Multiagent Systems. 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. During the morning sessions, we started with an invited talk and we continued with short presentations by the Seminar participants about their personal contribution to Normative Multi-Agents (plus some time for QA). 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 the handbook for this emerging area of computer-science with close interactions with other disciplines.

### Results

During the seminar, participants split in different working groups, centered around discussion themes relevant to NorMAS. Each working group was further divided into smaller working groups, each of which worked on specific topics. In the following paragraphs there is a summary of the discussion held by each working group.

**Logic and reasoning.** This theme included subgroups on topics such as *deontic logic, argumentation, computation approaches, motivational attitudes, social games, and emotions.*

**Modeling.** This theme included subgroups on issues such as *taxonomies, law, conflicts, and norm dynamics.*

**Engineering.** This theme included subgroups on themes such as *interactions, agent programming, agent architecture, data-driven norms, institutions and technology, and reference architectures.*

**Simulation.** This theme discussed issues of simulating multiagent systems to understand norm dynamics such as *emergence and diffusion.*

**Applications.** This theme included subgroups on killer applications for norms. Identified applications included *governance*, *audit control*, *cybersecurity*, *jurisinformatics*, and *sociotechnical systems*.

Each subgroup presented its findings twice to the entire seminar. Each subgroup identified past work, connections to other subgroups, and future work. Based on their presentations, we decided that each subgroup should write a chapter on its topic. This chapter will become part of a Handbook of Normative Multiagent Systems. This is in line with the roadmap produced during the previous edition of the Seminar and the discussions held during the present Seminar. The handbook will be an authoritative and detailed introduction for anyone seeking information on normative multiagent systems. The handbook will give a historical overview, present a survey of established techniques and open challenges, and discuss applications and directions. Our aim is to have the handbook sent for publication in a year's time. We already have a publisher lined up (College Publications).

## 2 Table of Contents

### Executive Summary

*Amit K. Chopra, Leon van der Torre, Harko Verhagen, and Serena Villata* . . . . . 163

### Invited talks

Distributed epistemic agency, responsibility and trust in socio-technical systems  
*Judith Simon* . . . . . 167

An Overview on Normative Conflicts Detection and Resolution  
*Viviane Torres da Silva* . . . . . 167

Juris-Informatics and PROlog-based LEGal reasoning system: PROLEG  
*Ken Satoh* . . . . . 167

Governance and accountability  
*Joris Hulstijn* . . . . . 168

### Overview of Talks

Towards Distributed Support of Distributed Software Development Processes  
*Daniel Moldt* . . . . . 168

The Rationale behind the Concept of Goal  
*Guido Governatori and Antonino Rotolo* . . . . . 169

The Complexity of Strategic Argumentation under Grounded Semantics  
*Antonino Rotolo and Guido Governatori* . . . . . 169

Reasoning with Group Norms in Software Agent Organisations  
*Huib Aldewereld, Virginia Dignum, and Wamberto Vasconcelos* . . . . . 169

Indirect Normative Conflict: Conflict that Depends on the Application Domain  
*Viviane Torres da Silva* . . . . . 170

Toward a Norms-Based Theory of Sociotechnical Systems  
*Amit K. Chopra* . . . . . 170

Generating Legal Reasoning Structure by Answer Set Programming  
*Ken Satoh* . . . . . 171

Social Computing with 2COMM4JASON  
*Matteo Baldoni* . . . . . 171

Collaboration Pattern Modeling in Support of Norm Specification, Monitoring, and Preservation  
*Christoph Dorn* . . . . . 171

Compatibility of Licenses in the Web of Data  
*Ho-Pun Lam and Guido Governatori* . . . . . 172

Norms in criminal organizations: inside the evolution of social order  
*Martin Neumann* . . . . . 172

Norms and Collectives – Between Narratives, Simulations and Games  
*Corinna Elsenbroich and Harko Verhagen* . . . . . 172


The Role of Power in Legal Compliance  
*Robert Muthuri and Llio Humphreys* . . . . . 173

Distributed Rule-Based Agents in Rule Responde <i>Adrian Paschke</i> . . . . .	173
Expressing Access Policies and Regulations for Linked Data using ODRL 2.1 <i>Axel Polleres</i> . . . . .	173
From Anarchy to Monopoly: How Competition and Protection Shaped Mafia’s Behavior <i>Luis Gustavo Nardin</i> . . . . .	174
An Abstract Formal Model for Normative Multiagent Systems <i>Munindar P. Singh</i> . . . . .	174
Friday Dropin Talks . . . . .	175
<b>Participants</b> . . . . .	176

### 3 Invited talks

#### 3.1 Distributed epistemic agency, responsibility and trust in socio-technical systems


*Judith Simon (IT University of Copenhagen, DK)*

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Contemporary practices of knowing take place in increasingly complex and dynamic socio-technical systems consisting of human and artificial agents, of people, technologies and infrastructures embedded in socio-economic environments. Given this distribution of epistemic agency, how can we ensure that agents act responsible in such knowledge practices, that trust is placed only in trustworthy agents and informational resources? In my talk, I will first outline a conception of distributed agency and relate this to notions of epistemic trust, i.e. the necessity to trust other entities or agents in our processes of knowing as well as to notions of distributed epistemic responsibility, i.e. the responsibilities of various entangled agents as recipients and providers of information. By using examples related to social computing and big data practices, I will show how individualized understandings of agency, responsibility or even knowledge are not only inadequate, but potentially harmful due to their neglect of issues of power and injustice. I will end my talk with some considerations of how such socio-technical epistemic systems could be governed to support trustworthiness, fair distributions of responsibility and responsible action.

#### 3.2 An Overview on Normative Conflicts Detection and Resolution

*Viviane Torres da Silva (IBM Research – Rio de Janeiro, BR)*

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A conflict between two norms occurs when the fulfillment of one norm violates another norm. When a conflict takes place the agent is unable to fulfill all norms that are active without violating at least one of them. The detection of normative conflicts is one of the main challenges in the specification of normative systems. In this talk I will present several approaches used to detect normative conflicts and, also, several techniques used to solve these conflicts.

#### 3.3 Juris-Informatics and PROlog-based LEGal reasoning system: PROLEG

*Ken Satoh (National Institute of Informatics – Tokyo, JP)*

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We have been doing research on “juris-informatics” which is application of informatics to legal domain. The name is made from a hope that we will make a similar impact to “bio-informatics” and show some related results to “juris-informatics” As a part of research

of “juris-informatics”, we implement “Japanese Ultimate Fact (JUF) theory” to simulate judge’s reasoning at a civil court. JUF theory is a tool for judges to make a judgment based on burden of proof under incomplete information. We show correspondence of burden of proof and negation as failure in logic programming and we introduce a system called PROLEG which we developed using the correspondence. PROLEG consists of general rules and exceptions which directly reflect lawyers’ knowledge structure in legal reasoning. Then, we show that the representation power of PROLEG is same as Answer Set Programming and that PROLEG could be applied to any other legal domains where general rules and exceptions co-exist.

### 3.4 Governance and accountability

*Joris Hulstijn (TU Delft, NL)*

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In NORMAS we study conceptualizations of norm following. Ultimately these should inform the development of software tools. But such tools only work when they are embedded in the right organizational context. That is what governance is all about: the arrangements of governing. Governance structures indicate who have power over whom. However, those who are in power should be accountable for their deeds. How can we ensure accountability in a normative multi-agent system? In this lecture, I would like to tell you stories – based on research I have done or supervised – about ill-fitting governance structures that caused failure of some sort. The lesson we can draw from these stories is that it is in fact possible to institutionalize “opposition” into a governance structure to ensure a basic level of accountability.

## 4 Overview of Talks

### 4.1 Towards Distributed Support of Distributed Software Development Processes

*Daniel Moldt (Universität Hamburg, DE)*

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Processes and structures of distributed teams are of special interest for the support by tools. Considering these teams as multi-agent systems or as multi-organization systems requires to provide an adequate conceptual modeling perspective. Within this perspective the flexible support of development processes is difficult, due to the heterogeneous requirements and hence somehow unstructured processes. The unstructuredness is however quite well structured when observing professional developers at work. My talk will give insight into a multi-agent and multi-organization based modeling perspective and how we support software development process based on social metaphors and still with the formal background of high-level Petri nets.

## 4.2 The Rationale behind the Concept of Goal

*Guido Governatori (NICTA – Brisbane, AU) and Antonino Rotolo (University of Bologna, IT)*

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The paper proposes a fresh look at the concept of goal and it advances that motivational attitudes like desire, goal and intention are just facets of the broader notion of (acceptable) outcome. We propose to encode the preferences of an agent as sequences of “alternative acceptable outcomes”. We study how the agent’s beliefs and norms can be used to filter the mental attitudes out of the sequences of alternative acceptable outcomes. We formalize such intuitions in a novel Modal Defeasible Logic and we prove that the resulting formalization is computationally feasible.

## 4.3 The Complexity of Strategic Argumentation under Grounded Semantics

*Antonino Rotolo (University of Bologna, IT) and Guido Governatori (NICTA – Brisbane, AU)*

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We study the complexity of the Strategic Argumentation Problem for 2-player dialogue games where a player should decide what move to play at each turn in order to prove (disprove) a given claim. We shall prove that this is an NP-complete problem. The proof covers Dung (1995)’s grounded semantics with structured and abstract arguments.

## 4.4 Reasoning with Group Norms in Software Agent Organisations

*Huib Aldewereld, Virginia Dignum, and Wamberto Vasconcelos*

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Norms have been used to represent desirable behaviours that software agents should exhibit in sophisticated multi-agent solutions. Existing research has mostly focused on the study of norms that affect a single individual. An important open research issue refers to group norms, i.e. norms that govern groups of agents. Depending on the interpretation, group norms may be intended to affect the group as a whole, each member of a group, or some members of the group. Moreover, upholding group norms may require coordination among the members of the group. We have identified three sets of agents affected by group norms, namely, i) the addressees of the norm, ii) those that will act on it, and iii) those that are responsible to ensure norm compliance. We present a formalism to represent these, connecting it to a minimalist agent organisation model. We use our formalism to develop a reasoning mechanism which enables agents to identify their position with respect to a group norm, so as to further support agent autonomy and coordination when deciding on possible courses of action.



## 4.5 Indirect Normative Conflict: Conflict that Depends on the Application Domain

*Viviane Torres da Silva (IBM Research – Rio de Janeiro, BR)*

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**Joint work of** Christiano Braga, Viviane Torres da Silva, and Jean Zahn

Norms are being used as a mechanism to regulate the behavior of autonomous, heterogeneous and independently designed agents. Norms describe what can be performed, what must be performed, and what cannot be performed in the multi-agent systems. Due to the number of norms specified to govern a multi-agent system, one important issue that has been considered by several approaches is the checking for normative conflicts. Two norms are said to be in conflict when the fulfillment of one norm violates the other and vice-versa. In this paper, we formally define the concept of an indirect normative conflict as a conflict between two norms that not necessarily have contradictory or contrary deontic modalities and that may govern (different but) related behaviors of (different but) related entities on (different but) related contexts. Finally, we present an ontology-based indirect norm conflict checker that automatically identifies direct and indirect norm conflicts on an ontology describing a set of norms and a set of relationships between the elements identified in the norms (behavior, entity and context).

## 4.6 Toward a Norms-Based Theory of Sociotechnical Systems

*Amit K. Chopra (Lancaster University, GB)*

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Researchers and practitioners are increasingly concerned with the challenge of engineering sociotechnical systems. Healthcare, emergency response, and smart cities are examples of sociotechnical systems, and experience bears out that these systems are not easy to build and maintain. In the present paper, I discuss of some of the challenges of engineering sociotechnical systems and their potential solutions. In particular, I focus on challenges related to software engineering, distributed computing, and information and programming models. I also discuss the governance of sociotechnical systems. My proposal to address these challenges centers around the concept of norms, thereby constituting an outline of a coherent theory of sociotechnical systems. Research on norms and organizations is a strength of the multiagent systems community, which gives us a leg up in addressing the challenges of engineering complex sociotechnical systems.

## 4.7 Generating Legal Reasoning Structure by Answer Set Programming

*Ken Satoh (National Institute of Informatics – Tokyo, JP)*

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Joint work of Duangtida Athakravi, Ken Satoh, Krysia Broda, and Alessandra Russo

In legal reasoning, different assumptions are often considered when reaching a final verdict and judgment outcomes strictly depend on these assumptions. In this paper, we propose an approach for generating a declarative model of judgments from past legal cases, that expresses a legal reasoning structure in terms of principle rules and exceptions. Using a logic-based reasoning technique, we are able to identify from given past cases different underlying defaults (legal assumptions) and compute judgments that (i) cover all possible cases (including past cases) within a given set of relevant factors, and (ii) can make deterministic predictions on final verdicts for unseen cases. The extracted declarative model of judgments can then be used to make automated inference of future judgments, and generate explanations of legal decisions. The rules generated by our approach can also be automatically translated into a representation compatible with the legal reasoning system PROLEG, so making our method a useful computational mechanism for generating PROLEG models from past cases.

## 4.8 Social Computing with 2COMM4JASON

*Matteo Baldoni (University of Turin, IT)*

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Joint work of Matteo Baldoni, Cristina Baroglio, Federico Capuzzimati, and Roberto Micalizio

Social Computing (SC) requires agents to reason seamlessly both on their social relationships and on their goals, beliefs. We claim the need to explicitly represent the social state and social relationships as resources, available to agents. We built a framework, based on JaCaMo, where this vision is realized and SC is implemented through social commitments and commitment protocols.

## 4.9 Collaboration Pattern Modeling in Support of Norm Specification, Monitoring, and Preservation


*Christoph Dorn (TU Wien, AT)*

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Collaboration-intensive environments call for technical systems that permit flexible user interactions. Rigid workflows are no suitable collaboration paradigm. As users apply various patterns such as shared artifact, social networks, client/principal, or publish/subscribe for interaction, their cooperative behavior becomes largely determined by norms. In this paper, we make the case for explicit modeling of collaboration patterns as the substrate for specifying, monitoring, and preserving norms. Describing collaboration patterns in the form of human-centric component and connector architecture views provides a means for reasoning on collaboration control, flexibility, and ultimately adaptability. We report on recent work targeting executable collaboration patterns and outline resulting synergies with norms.

#### 4.10 Compatibility of Licenses in the Web of Data

*Ho-Pun Lam and Guido Governatori (NICTA – Brisbane, AU)*

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While several proposals have been offered to represent licensing information through ad-hoc ontologies and patterns, only few approaches have addressed the problem of reasoning over such information. In this paper, we propose and evaluate a deontic logic semantics which allows us to define the deontic modalities of licenses, i.e., permission, obligation and prohibition, to verify the compatibilities among the deontic components of different licenses, and can compose them into a single theory if they are compatible. Based on this, heuristics for composing different deontic components of licenses are proposed, and an extension based on the SPINdle defeasible reasoner has been developed to evaluate our framework. Our results show that our approach provides a flexible and efficient solution to the problem.

#### 4.11 Norms in criminal organizations: inside the evolution of social order


*Martin Neumann (Universität Koblenz-Landau, DE)*

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This paper presents two simulation models about internal conflict resolution within criminal organizations. Securing compliance in the absence of state monopoly of violence makes criminal organizations a test bed for studying evolution of social order. Target systems are briefly described: One case is the Sicilian Mafia and temporary Mafia wars. The other case describes the breakdown of a criminal group in its infancy. While the Mafia has a strict hierarchical organization, the contrasting case had a flat structure. This difference corresponds to cognitive trust in the organization in case of the Mafia and affective trust in interpersonal relations in the contrasting case. This enables Mafiosi to cognitively trust the organization while affectively mistrusting other Mafiosi. This stabilizes organizational endurance. The paper ends with remarks about the insights for evolution of social order from investigating criminal organizations.

#### 4.12 Norms and Collectives – Between Narratives, Simulations and Games

*Corinna Elsenbroich (University of Surrey – Guildford, GB) and Harko Verhagen (Stockholm University, SE)*

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In this paper we describe a narrative of a civic resistance movement to defeat the Italian Mafia, a model comparing strategic and normative modes of reasoning in an individual and collective interpretation of an extortion racket situation and a serious game through which to collect data on the four types of behaviours used in the simulation. These three elements

will be used to discuss the reflexive and iterative nature of simulation research, in particular in a field as elusive as changing motivations of agents. Finally we will describe how online games can be used to calibrate the model parameters and to accomplish social change.

### 4.13 The Role of Power in Legal Compliance

*Robert Muthuri and Llio Humphreys (University of Turin, IT)*

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**Joint work of** Sepideh Ghanavati, Robert Muthuri, Andre Rifaut, Llio Humphreys, and Guido Boella

Powers constitute a significant foundation for the law as we know it yet their role has largely been neglected in requirements engineering in favour of more familiar deontic notions. We therefore explore the different conceptualizations of legal power to facilitate their incorporation in modelling the legal requirements. We apply our analysis to the legal-urn framework.

### 4.14 Distributed Rule-Based Agents in Rule Responde

*Adrian Paschke (FU Berlin, DE)*

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Rule Responder is a rule-based multi-agent framework in which agents run platform-specific rule engines as distributed inference services. An important aspect for the agent communication is the use of common standardized rule interchange format. In this paper we introduce core capabilities of Reaction RuleML 1.0 for rule interchange and agent communication, supporting functionalities such as knowledge interface declarations with signatures, modes, and scopes; distributed knowledge modules with static and dynamic scopes enabling imports and scoped reasoning within metadata-based scopes (closed constructive views) on the knowledge base; messaging reaction rules enabling conversation-scope based interactions between agents interchanging queries, answers, and rulebases; and evaluation and testing of interchanged knowledge bases with intended semantic profiles and self-validating test suites. We demonstrate these Reaction RuleML 1.0 capabilities with our proof-of-concept implementation, the Rule Responder agent architecture and the Prova 3.0 rule engine.

### 4.15 Expressing Access Policies and Regulations for Linked Data using ODRL 2.1

*Axel Polleres (Wirtschaftsuniversität Wien, AT)*

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**Joint work of** Simon Steyskal and Axel Polleres

Together with the latest efforts in publishing Linked (Open) Data, legal issues around publishing and consuming such data are gaining increased interest. Particular areas of interest include (i) how to define more expressive access policies which go beyond common

licenses, (ii) how to introduce pricing models for online datasets (for non-open data) and (iii) how to realize (i)+(ii) while providing descriptions of respective meta data that is both human readable and machine processable. In this paper, we show based on different examples that the Open Digital Rights Language (ODRL) Ontology 2.1 is able to address all previous mentioned issues, i.e. is suitable to express a large variety of different access policies for Linked Data. By defining policies as ODRL in RDF we aim for (i) higher flexibility and simplicity in usage, (ii) machine/human readability and (iii) fine-grained policy expressions for Linked (Open) Data.

#### 4.16 From Anarchy to Monopoly: How Competition and Protection Shaped Mafia's Behavior

*Luis Gustavo Nardin (LABSS – ISTC – CNR – Rome, IT)*

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Joint work of Luis Gustavo Nardin, Giulia Andrighetto, and Rosaria Conte

Mafia-like organizations are highly dynamic and organized criminal groups characterized by their extortive activities that impact societies and economies in different modes and magnitudes. This renders the understanding of how these organizations evolved an objective of both scientific and application-oriented interests. We propose an agent-based simulation model – the Extortion Racket System model – aimed at understanding the factors and processes explaining the successful settlement of the Sicilian Mafia in Southern Italy, and which may more generally account for the transition from an anarchical situation of uncoordinated extortion to a monopolistic social order. Our results show that in situations of anarchy, these organizations do not last long. This indicates that a monopolistic situation shall be preferred over anarchical ones. Competition is a necessary and sufficient condition for the emergence of a monopolistic situation. However, when competition is combined with protection, the resulting monopolistic regime presents features that make it even more preferable and sustainable for the targets.

#### 4.17 An Abstract Formal Model for Normative Multiagent Systems

*Munindar P. Singh (North Carolina State University – Raleigh, US)*

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Norms provide an elegant basis for modeling and realizing interactions between autonomous parties. The subtle interplay between norms and the structure of a normative multiagent system (MAS) is not adequately understood. We propose a formal model that synthesizes key factors including identity, credentials, naming, autonomy, authority, privileges and liabilities, and forming and disbanding collaborations. This model is abstract and independent of specific norm languages. We demonstrate its power by capturing a variety of real-life cases.

#### 4.18 Friday Dropin Talks

A number of participants gave shorter dropin talks on Friday. Dov Gabbay and Victor Rodriguez Doncel gave a talk on licenses and reasoning; Simon Caton gave a talk on his work on identifying user sentiments in social media; Julian Padget gave two talk on policies and institutions; Robert Muthuri gave a talk on modeling legal concepts; Pablo Noriega gave a talk on institutions and technology.

## Participants

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