Agreement Technologies

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We would like to dedicate this book to the memory of Marc Esteva. His intellectual contributions to the research domain of Agreement Technologies have been numerous. Most of all, however, we value his friendship and his service to the community. The wealth of joyful moments we have shared with Marc over the years will remain constant in our memories. We miss him and will continue to do so.

Foreword

Our species is unique in this world in the range and sophistication of our social abilities. For sure, other animal species can exhibit impressive social skills of a kind — some insects, such as ants and termites, are capable of jaw dropping feats of apparently cooperative activity; and animals such as wolves, hunting in packs, can cooperate to bring down prey that are well beyond the aspirations of any individual animal. But these feats, impressive though they are, pale into insignificance compared to the feats of social magic that we all perform every day of our lives. The social skills we exhibit go far, far beyond animal instinct and evolutionary conditioning. We are capable of routinely communicating rich, complex, abstract ideas across linguistic and cultural divides. We are capable of explicit, rational cooperation on a global scale – think of all the communication, coordination, and cooperation involved in a task such as organising the Olympic games, involving hundreds of nationalities, dozens of languages, millions of people, and years of preparation.

Of all the social skills we possess beyond a common language, it is perhaps our ability to explicitly *reach agreements* with each other that mark us out from the rest of the animal world. A world without agreement would be unimaginable — a world where life was, in the words of the 17th century philosopher Thomas Hobbes, "solitary, poor, nasty, brutish, and short". It is our ability to make agreements on matters of common interest, and to implement and police these agreements, that makes the social world that we live in, and the global economy, possible.

For researchers in artificial intelligence, human social skills raise an intriguing challenge: can we build *computers* that are capable of exhibiting these skills? Can we build computers that can cooperate, coordinate, and, more generally, *reach agreements* with each other on our behalf? This question is fascinating because it presents deep scientific and technical challenges, but also raises the prospect of game-changing applications if one is successful. This research question has led to the emergence of a new research area, known as *agreement technologies*. This research area is concerned with the theory and practice of computer systems that can make agreements on behalf of human users or owners in situations where the preferences and beliefs of the participants are different.

The present volume represents the state of the art in agreement technologies. It contains papers that address questions such as how computers can allocate scarce societal resources in a reasonable way; how computers can govern their own artificial social systems; and how we can automate the process of negotiation among rational, self-interested participants. We are, I think it is fair to say, still quite some way from realising the dream of computers that can exhibit the same social skills that we all seem to magically possess. But this volume gives a flavour of where we are on the road to achieving this goal, and clearly demonstrates why this is such a fascinating and rewarding area in which to work.

Oxford, July 2012 *Michael Wooldridge*

Preface

This book describes the state of the art in the emerging field of Agreement Technologies (AT). AT refer to computer systems in which autonomous software agents negotiate with one another, typically on behalf of humans, in order to come to mutually acceptable agreements. The term "Agreement Technologies" was introduced by Michael Wooldridge in conversations at the AAMAS conference in 2004. It was also used by Nicholas R. Jennings as title for a keynote talk given in 2005. Carles Sierra was among the first to give shape to the field by defining five key areas as technological building blocks for AT in 2007, in the context of the Spanish *Consolider* Project on AT.

The book was produced in the framework of COST Action IC0801 on Agreement Technologies. The Action was funded for four years (2008-2012) as part of the European Cooperation in Science and Technology (COST) programme. It comprised about 200 researchers from 25 European COST countries working on topics related to AT, plus 8 institution from 7 non-COST countries (Argentina, Australia, Brazil, Mexico, UAE, USA, and New Zealand). The overall mission of the COST Action was to support and promote the harmonization of nationally-funded high-quality research towards a new paradigm for next generation distributed systems based on the notion of agreement between computational agents, fostering research excellence and sowing the seeds for technology transfer to industry. For this purpose, the Action aimed at improving the quality, profile, and industrial relevance of European research in the emerging field of Agreement Technologies, drawing on relevant prior work from related areas and disciplines.

To achieve its mission, the COST Action defined five Working Groups (WGs) around the key areas of AT, where research results needed to be pooled and coordinated: *Semantic Technologies*, *Norms*, *Organisations*, *Argumentation & Negotiation*, as well as *Trust*. These WGs promoted the interaction among researchers and groups already funded by other national or international initiatives, so as to allow for an effective exchange of knowledge and experience, and to facilitate the dynamic development of sub-communities around specific areas of strategic importance. To this end, two Joint WG Workshops were held each year, usually co-located with a major event in the field (e.g. IJCAI, AAMAS, ESWC, and EUMAS). These work-

shops included sessions to advance on WG-related topics, as well as sessions and panels on cross-WG topics. As a result, various interrelations between the WGs became apparent, reinforcing the backbone of AT as a new field in its own right. The workshops finally converged into the First International Conference on Agreement Technologies, held in October 2012 in Dubrovnik, Croatia.

This book is the result of the research coordination activities carried out within the framework of COST Action IC0801. It is subdivided into seven parts. Part I is dedicated to foundational issues of Agreement Technologies, examining the notion of agreement and agreement processes from different perspectives. Parts II to VI were put together as a huge collaborative effort within the five WGs of the COST Action, which was coordinated by the respective WG Chairs. Part II outlines the relevance of novel approaches to Semantics and ontological alignments in distributed settings. Part III gives an overview of approaches for modelling norms and normative systems, the simulation of their dynamics, and their impact on the other key areas of Agreement Technologies. Part IV discusses how to design computational organisations, how to reason about them, and how organisational models can be evolved. Part V gives an overview of current approaches to argumentation and negotiation, and how they can be used to inform human reasoning, as well as to assist machine reasoning. Part VI describes different models and mechanisms of trust and reputation, and discusses their relevance for the other key areas of Agreement Technologies. Finally, Part VII provides examples of how the techniques outlined in the previous parts of the book can be used to build distributed software applications that solve real-world problems. Please notice that the parts are supported by a set of video-lectures that can be freely downloaded from the web.

I would like to take the opportunity to thank everybody who contributed to the exciting effort of shaping the vibrant field of Agreement Technologies, whose state of the art is summarised in this book. This includes the researchers and practitioners of the AT community, COST Action IC0801 members and, in particular, the co-editors, chapter authors, and reviewers of this publication. The book is the first one to provide a comprehensive overview of the emerging field of Agreement Technologies, written and coordinated by leading researchers in the field. It is the result of a massive concerted effort – I hope you will enjoy reading it.

Madrid, July 2012 *Sascha Ossowski*

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COST – the acronym for European Cooperation in Science and Technology – is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 36 European countries to cooperate in common research projects supported by national funds.

The funds provided by COST – less than 1% of the total value of the projects – support the COST cooperation networks (COST Actions) through which, with EUR 30 million per year, more than 30 000 European scientists are involved in research having a total value which exceeds EUR 2 billion per year. This is the financial worth of the European added value which COST achieves.

A "bottom up approach" (the initiative of launching a COST Action comes from the European scientists themselves), "à la carte participation" (only countries interested in the Action participate), "equality of access" (participation is open also to the scientific communities of countries not belonging to the European Union) and "flexible structure" (easy implementation and light management of the research initiatives) are the main characteristics of COST.

As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of "Networks of Excellence" in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials,

Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance.

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Acronyms

A&A	Agent & Artifact
AAOL	Autonomous Agents in Organized Localities
ABA	Assumption-Based Argumentation
ABC4MAS	Assembling Business Collaborations for Multi Agent Systems
ABM	Agent Based Modelling
ABML	Argument-Based Machine Learning
ACL	Agent Communication Language
AF	Argumentation Framework
AGM	Alchourron, Gardenfors and Makinson
AI	Artificial Institution
AI	Artificial Intelligence
AIF	Argument Interchange Format
AiG	Agents in Grid
AJAX	Asynchronous JavaScript and XML
ALS	Advanced Life Support
ANTE	Agreement Negotiation in Normative and Trust-enabled Environments
AOCC	Airline Operations Control Centre
AOCP	Airline Operations Control Problem
AOM	Agent-Oriented Modelling
AOSE	Agent-Oriented Software Engineering
API	Application Programming Interface
ArgDSS	Argument-based Decision Support Systems
ASP)	Answer Set Programming
AT	Agreement Technologies
ATE	Agreement Technologies Environment
AUML	Agent Unified Modelling Language
B2B	Business-to-Business
B2C	Business-to-Consumer
BDI	Belief-Desire-Intention
BLS	Basic Life Support

BOID	Beliefs, Obligations, Intentions and Desires
BPEL	Business Process Execution Language
CA	Combinatorial Auction
CArtAgO	Common ARTifact infrastructure for AGents Open environments
CBB	Consumer Buying Behavior
CBR	Case-Based Reasoning
CGO	Core Grid Ontology
CIC	Client Information Center
CPU	Core Processing Unit
CSP	Constraint Satisfaction Problem
CTD	Contrary-To-Duty
CWA	Closed World Assumption
DAI	Distributed Artificial Intelligence
DAML	Darpa Agent Markup Language
DDL	Distributed Description Logic
DEC	Discrete Event Calculus
DeLP	Defeasible Logic Programming
DIO(DE)^2	DIagnostic and DEcision-theoretic framework for DEontic reasoning
DL	Description Logic
DLP	Description Logic Programs
DM	Decision Making
EI	Electronic Institution
EIDE	Electronic Institutions Development Environment
EL	Execution Layer
EMA	Emergency Medical Assistance
EMIL	EMergence In the Loop
EMS	Emergency Medical Services
ERP	Enterprise Resource Planning
FCFS	first-come, first-served
FET	Future and Emerging Technologies
FIPA	Foundation for Intelligent Physical Agents
FOAF	Friend Of A Friend
FORe	Functional Ontology of Reputation
GCI	Global Computing Initiative
GCII	Global Computing II
GORMAS	Guidelines for ORganisational Multi-Agent Systems
GPS	Geographic Positioning System
GRDDL	Gleaning Resource Descriptions from Dialects of Languages
GUI	Graphical User Interface
HTML	HyperText Markup Language
I/O	Input/Output
IA	Institutional Agent
ICL	Individual Context Layer
ICT	Information and Communication Technologies

IDDL	Integrated Distributed Description Logic
ILP	Induction Logic Programming
IM	Institution Manager
IST	Information Science Technologies
IT	Information Technology
JADE	Java Agent DEvelopment Framework
KR	Knowledge Representation
LREP	Reputation Language
MA	Mixed Auctions
MAGNET	MultiAgent NEgotiation Testbed
MANET	Multi-AGent Normative EnvironmenTs
MAS	Multiagent System
MASDIMA	Multi-Agent System for DIsruption MAnagement
MDP	Markov Decision Process
ML	Machine Learning
ML	Mechatronic Layer
MMUCA	Mixed Multi-Unit Combinatorial Auction
MMUCATS	MMUCA Test Suit
$\mathscr{M}$oise	Model of Organisation for multI-agent SystEms
MSM	Minimal Service Model
N3	Notation3
NAO	Network of Aligned Ontologies
NoA	Normative Agent
norMAS	normative Multi-Agent Systems
OAEI	Ontology Alignment Evaluation Initiative
OASIS	Organization for the Advancement of Structured Information Standards
OCeAN	Ontology CommitmEnts Authorizations Norms
OCMAS	Organisation-Centred Multi-Agent System
OCML	Operational Conceptual Modelling Language
ODR	Online Dispute Resolution
OE	Organisational Entity
OMAS	Open Multi-Agent Systems
OMI	Organisation Management Infrastructure
OML	Organisation Modelling Language
OMS	Organisation Management System
OS	Operating System
OS	Organisational Specification
OSGi	Open Services Gateway Initiative
OU	Organisational Units
OWA	Open World Assumption
OWL	Web Ontology Language
P2P	Peer-to-Peer
P3P	Platform for Privacy Preferences
PDA	Proactive Dialogical Agent

P-DL	Package-based Description Logics
PIUP	Partial Identity Unlikability Problem
PLING	Policy Languages Interest Group
PnP TCM	Plug and Play Transport Chain Management
PPC	Pay Per Click
PS	Performative Structure
PSA	Persuasive Selling Agent
QAD	Qualitative Assessment Dynamics
RDF	Resource Description Framework
RDFS	RDF Schema
RFQ	Request For Quotation
RIF	Rule Interchange Format
RoP	Range of Perception
SAT	Boolean SATisfiability problem
SAWSDL	Semantic Annotations for WSDL
SCF	Supply Chain Formation
SCL	Social Context Layer
SESA	Semantically Enbaled Service-Oriented Architectures
SF	Service Facilitator
SIOC	Semantically Interlinked Online Communities
SLA	Service Level Agreement
SM	Scene Manager
SMA	Sequential Mixed Auction
SOA	Service Oriented Architecture
SPARQL	SPARQL Protocol and RDF Query Language
SPPCA	Semantic Pay-Per-Click Agent
SQL	Structured Query Language
SRM	Supplier Relationship Management
SWRL	Semantic Web Rule Language
THOMAS	MeTHods, Techniques and Tools for Open Multi-Agent Systems
TM	Transition Manager
T-MAS	Task-oriented Multi-Agent Systems
TMC	Technology Management Centre
TOE	Dempster-Shafer Theory of Evidence
UBL	Universal Business Language
UML	Unified Modelling Language
URI	Uniform Resource Identifier
VAF	Value-based Argumentation Framework
VI	Virtual Institution
VIXEE	Virtual Institution eXEcution Environment
VO	Virtual Organisation
VOF	Virtual Organisation Formalisation
VOM	Virtual Organisation Model
VSM	Vector-Space Model
VW	Virtual World

VWBT	Virtual World Builder Toolkit
W3C	World Wide Web Consortium
WDP	Winner Determination Problem
WRL	Web Rule Language
WSDL	Web Service Description Language
WSML	Web Service Modeling Language
WSMO	Web Service Modeling Ontology
WUI	Web-based User Interface
XACML	eXtensible Access Control Markup Language
XHTML	eXtensible Hypertext Markup Language
XML	eXtensible Markup Language
XSLT	eXtensible Stylesheet Language Transformation
YARS2	Yet Another RDF Store version 2