Horizon 2020

Call: H2020-FETOPEN-2014-2015-RIA

Topic: FETOPEN-1-2014

Type of action: RIA

Proposal number: 664717

Proposal acronym: HESA

Table of contents

How to fill in the forms

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the previous steps in the submission wizard.

Proposal ID **664717** *Acronym* **HESA**

1 - General information

Topic FETOPEN-1-2014 Type of action RIA

Call identifier H2020-FETOPEN-2014-2015-RIA Acronym HESA

Proposal title* Human-inspired reasoning in Embodied, Social, artificial Agents

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months *36*

Fixed keyword 1 *Artificial intelligence, intelligent systems, multi agent systems* Add

Free keywords *Cognitive and social sciences, knowledge representation, cognitive robots, agent behaviors, verification and synthesis*

Abstract

Agent-based systems are increasingly being used as the underlying conceptual architecture for deploying complex, society-critical applications. This is no longer limited to networked software applications, but has begun to permeate physical devices including robotic systems. However, agents in current systems suffer from a sort of "autism" that stems from a their inability to understand and take into account the expected behaviors of other agents and actors in the environment. This prevents them from interacting and coordinating successfully and predictabity with humans and among themselves in complex and unexpected situations. The solution that the HESA project proposes is for a paradigm shift from the current third-person, global designer view in analyzing and realizing these systems to one which is first-person based, whereby agents themselves exhibit "behavioral empathy". This is achieved by ascribing expected behaviors to other agents and use this information to deliberate in a proactive manner. The ascribed behaviors are initially formed on the basis of social stereotypes, but are monitored by the agents and refine at runtime. Technically, the HESA project will develop foundational and implementation principles for realizing social agents that reason about human and artificial agents. The methods to be devised will be grounded in psychological studies on human behavior in social contexts, and realized by using principles from knowledge representation, artificial intelligence, automated verification and synthesis methodologies. The resulting techniques will be implemented on a latest-generation series of robots and deployed on social robotic scenarios. The consortium brings together world-leading experts with different key expertise ranging from cognitive science, to knowledge representation, multi-agent systems, verification, cognitive robotics and industrial expertise in cognitive robot deployment.

Remaining characters 61

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under the 7th Framework Programme, Horizon 2020 or any other EU programme(s)? ○ Yes ◉ No

Proposal ID **664717** *Acronym* **HESA**

Declarations

1) The coordinator declares to have the explicit consent of all applicants on their participation and on the content of this proposal.	☒
2) The information contained in this proposal is correct and complete.	☒
3) This proposal complies with ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct).	☒

4) The coordinator confirms:

- to have carried out the self-check of the financial capacity of the organisation on https://ec.europa.eu/research/participants/portal/desktop/en/organisations/lfv.html. Where the result was "weak" or "insufficient", the coordinator confirms being aware of the measures that may be imposed in accordance with the H2020 Grants Manual (Chapter on Financial capacity check); or	○
- is exempt from the financial capacity check being a public body including international organisations, higher or secondary education establishment or a legal entity, whose viability is guaranteed by a Member State or associated country, as defined in the H2020 Grants Manual (Chapter on Financial capacity check); or	◉
- as sole participant in the proposal is exempt from the financial capacity check.	○

5) The coordinator hereby declares that each applicant has confirmed:

- they are fully eligible in accordance with the criteria set out in the specific call for proposals; and	☒
- they have the financial and operational capacity to carry out the proposed action.	☒

The coordinator is only responsible for the correctness of the information relating to his/her own organisation. Each applicant remains responsible for the correctness of the information related to him and declared above. Where the proposal to be retained for EU funding, the coordinator and each beneficiary applicant will be required to present a formal declaration in this respect.

According to Article 131 of the Financial Regulation of 25 October 2012 on the financial rules applicable to the general budget of the Union (Official Journal L 298 of 26.10.2012, p. 1) and Article 145 of its Rules of Application (Official Journal L 362, 31.12.2012, p.1) applicants found guilty of misrepresentation may be subject to administrative and financial penalties under certain conditions.

Personal data protection

Your reply to the grant application will involve the recording and processing of personal data (such as your name, address and CV), which will be processed pursuant to Regulation (EC) No 45/2001 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data. Unless indicated otherwise, your replies to the questions in this form and any personal data requested are required to assess your grant application in accordance with the specifications of the call for proposals and will be processed solely for that purpose. Details concerning the processing of your personal data are available on the privacy statement. Applicants may lodge a complaint about the processing of their personal data with the European Data Protection Supervisor at any time.

Your personal data may be registered in the Early Warning System (EWS) only or both in the EWS and Central Exclusion Database (CED) by the Accounting Officer of the Commission, should you be in one of the situations mentioned in:
-the Commission Decision 2008/969 of 16.12.2008 on the Early Warning System (for more information see the Privacy Statement), or
-the Commission Regulation 2008/1302 of 17.12.2008 on the Central Exclusion Database (for more information see the Privacy Statement) .

Proposal ID **664717** *Acronym* **HESA**

2 - Administrative data of participating organisations

PIC	***Legal name***
999987745	*UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA*

Short name: UNIROMA1

Address of the organisation

Street Piazzale Aldo Moro 5

Town ROMA

Postcode 00185

Country Italy

Webpage www.uniroma1.it

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes
Non-profit ..... yes
International organisation ..... no
International organisation of European interest ..... no
Secondary or Higher education establishment ..... yes
Research organisation ..... yes
Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code 853 -

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name	Dipartimento di Ingegneria Informatica Automatica e Gestionale
	☐ Same as organisation address
Street	via Ariosto 25
Town	Roma
Postcode	00185
Country	Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Giuseppe** Last name: **De giacomo**

E-Mail: **degiacomo@dis.uniroma1.it**

Position in org.: Full professor

Department: Dipartimento di Ingegneria Informatica Automatica e Gestionale

[ ] Same as organisation address

Street: via Ariosto 25

Town: Roma Post code: 00185

Country: Italy

Website: www.dis.uniroma1.it/~degiacomo/

Phone: +390677274010 Phone 2: +39393477063204 Fax: +390677274002

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Massimo	Mecella	mecella@dis.uniroma1.it	+390677274028
Andrea	Marrella	marrella@dis.uniroma1.it	+390677274013

Proposal ID **664717** *Acronym* **HESA**

PIC	***Legal name***
999974553	*UNIVERSITEIT LEIDEN*

Short name: UL

Address of the organisation

Street RAPENBURG 70

Town LEIDEN

Postcode 2311 EZ

Country Netherlands

Webpage http://www.leidenuniv.nl

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes

Non-profit ..... yes

International organisation ..... no

International organisation of European interest ..... no

Secondary or Higher education establishment ..... yes

Research organisation ..... yes

Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code 853 -

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name	Faculty of Social and Behavioural Sciences
	☐ Same as organisation address
Street	Wassenaarseweg 52
Town	Leiden
Postcode	2333 AK
Country	Netherlands

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Bernhard** Last name: **Hommel**

E-Mail: **hommel@fsw.leidenuniv.nl**

Position in org.: Full professor

Department: Faculty of Social and Behavioural Sciences

[ ] Same as organisation address

Street: Wassenaarseweg 52

Town: Leiden Post code: 2333 AK

Country: Netherlands

Website:

Phone: +31715273714 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Hester	Bergsma	h.w.bergsma@fsw.leidenuniv.nl	+31715277916

Proposal ID **664717** *Acronym* **HESA**

PIC	***Legal name***
999993468	*IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE*

Short name: ICL

Address of the organisation

Street Exhibition Road, South Kensington Campus

Town LONDON

Postcode SW7 2AZ

Country United Kingdom

Webpage www.imperial.ac.uk

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes
Non-profit ..... yes
International organisation ..... no
International organisation of European interest ..... no
Secondary or Higher education establishment ..... yes
Research organisation ..... yes
Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code 853 -

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name	Department of Computing
	☒ Same as organisation address
Street	Exhibition Road, South Kensington Campus
Town	LONDON
Postcode	SW7 2AZ
Country	United Kingdom

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Alessio** Last name: **Lomuscio**

E-Mail: **a.lomuscio@imperial.ac.uk**

Position in org.: Full professor

Department: Department of Computing

☒ Same as organisation address

Street: Exhibition Road, South Kensington Campus

Town: LONDON Post code: SW7 2AZ

Country: United Kingdom

Website: www.imperial.ac.uk

Phone: +44 (0)207594 8414 Phone 2: *+xxx xxxxxxxxx* Fax: +44 (0)207581 8932

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Shaun P	Power	s.p.power@imperial.ac.uk	+44(0)2075948773

Proposal ID **664717** *Acronym* **HESA**

PIC	***Legal name***
999983962	*RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN*

Short name: RWTH

Address of the organisation

Street TEMPLERGRABEN 55

Town AACHEN

Postcode 52062

Country Germany

Webpage www.rwth-aachen.de

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes
Non-profit ..... yes
International organisation ..... no
International organisation of European interest ..... no
Secondary or Higher education establishment ..... yes
Research organisation ..... yes
Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code - Not applicable

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name: Informatik 5

☐ Same as organisation address

Street: Ahornstr. 55

Town: Aachen

Postcode: 52056

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof.

Sex: (•) Male ( ) Female

First name: **Gerhard**

Last name: **Lakemeyer**

E-Mail: **gerhard@cs.rwth-aachen.de**

Position in org.: Professor

Department: Informatik 5

[ ] Same as organisation address

Street: Ahornstr. 55

Town: Aachen

Post code: 52056

Country: Germany

Website: www.kbsg.rwth-aachen.de

Phone: +492418021530

Phone 2: *+xxx xxxxxxxxx*

Fax: +492418022321

Proposal ID **664717** *Acronym* **HESA**

PIC	***Legal name***
999748155	*IDMIND - ENGENHARIA DE SISTEMAS LDA*

Short name: IDM

Address of the organisation

Street ESTRADA DO PACO DO LUMIAR - POLO TEC

Town LISBOA

Postcode 1600546

Country Portugal

Webpage www.idmind.pt

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... no

Non-profit ..... no

International organisation ..... no

International organisation of European interest ..... no

Secondary or Higher education establishment ..... no

Research organisation ..... no

Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code 72 - Computer & related activities

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name	R&D
	☒ Same as organisation address
Street	ESTRADA DO PACO DO LUMIAR - POLO TECNOLO
Town	LISBOA
Postcode	1600546
Country	Portugal

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Mr. Sex: (•) Male ( ) Female

First name: **Paulo** Last name: **Alvito**

E-Mail: **palvito@idmind.pt**

Position in org.: CEO

Department: Management

☒ Same as organisation address

Street: ESTRADA DO PACO DO LUMIAR - POLO TECNOLOGICO DE LISBOA LOT

Town: LISBOA Post code: 1600546

Country: Portugal

Website: www.idmind.pt

Phone: +351217102575 Phone 2: *+xxx xxxxxxxxx* Fax: +351217102576

Proposal ID **664717** *Acronym* **HESA**

PIC	***Legal name***
999658818	*UNIVERSITY OF MELBOURNE*

Short name: UNIMELB

Address of the organisation

Street PARKVILLEOFFICE OF THE VICE CHANCELL

Town MELBOURNE

Postcode 3010

Country Australia

Webpage www.unimelb.edu.au

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes

Non-profit ..... yes

International organisation ..... no

International organisation of European interest ..... no

Secondary or Higher education establishment ..... yes

Research organisation ..... no

Small and Medium-sized Enterprises (SMEs) ..... no

Legal person ..... yes

Nace code

Proposal ID **664717** *Acronym* **HESA**

Department(s) carrying out the proposed work

Department 1

Department name	Department of Computing and Information Systems
	☒ Same as organisation address
Street	PARKVILLEOFFICE OF THE VICE CHANCELLOR
Town	MELBOURNE
Postcode	3010
Country	Australia

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **664717** *Acronym* **HESA**

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title Prof. Sex (•) Male ( ) Female

First name **Peter** Last name **Stuckey**

E-Mail **pstuckey@unimelb.edu.au**

Position in org. Professor

Department Department of Computing and Information Systems

☒ Same as organisation address

Street PARKVILLEOFFICE OF THE VICE CHANCELLOR

Town MELBOURNE Post code 3010

Country Australia

Website www.cis.unimelb.edu.au

Phone +61383441341 Phone 2 +61383441500 Fax +6193494596

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Adrian	Pearce	adrianrp@unimelb.edu.au	+61430294425

Proposal ID **664717** *Acronym* **HESA**

3 - Budget for the proposal

Participant	Country	(A) Direct personnel costs/€	(B) Other direct costs/€	(C) Direct costs of sub-contracting/€	(D) Direct costs of providing financial support to third parties/€	(E) Costs of inkind contributions not used on the beneficiary's premises/€	(F) Indirect Costs / € (=0.25(A+B-E))	(G) Special unit costs covering direct & indirect costs / €	(H) Total estimated eligible costs / € (=A+B+C+D+F+G)	(I) Reimburse-ment rate (%)	(J) Max. grant / € (=H*I)	(K) Requested grant / €
UNIROMA1	IT	468 000	80 000	9 000	0	0	137 000	0	694 000	100	694 000	694 000
UL	NL	356 400	43 600	0	0	0	100 000	0	500 000	100	500 000	500 000
ICL	UK	344 249	53 720	0	0	0	99 492	0	497 461	100	497 461	497 461
RWTH	DE	313 200	87 000	0	0	0	100 050	0	500 250	100	500 250	500 250
IDM	PT	131 920	33 000	0	0	0	41 230	0	206 150	100	206 150	206 150
UNIMELB	AU	604 104	49 739	0	0	0	163 461	0	817 304	100	817 304	49 739
Total		2 217 873	347 059	9 000	0	0	641 233	0	3 215 165		3 215 165	2 447 600

Proposal ID **664717** *Acronym* **HESA**

4 - Ethics issues table

1. HUMAN EMBRYOS/FOETUSES		Page
Does your research involve Human Embryonic Stem Cells (hESCs)?	○ Yes ◉ No	
Does your research involve the use of human embryos?	○ Yes ◉ No	
Does your research involve the use of human foetal tissues / cells?	○ Yes ◉ No	
2. HUMANS		**Page**
Does your research involve human participants?	◉ Yes ○ No	I-8
Are they volunteers for social or human sciences research?	◉ Yes ○ No	I-8
Are they persons unable to give informed consent?	○ Yes ◉ No	
Are they vulnerable individuals or groups?	○ Yes ◉ No	
Are they children/minors?	○ Yes ◉ No	
Are they patients?	○ Yes ◉ No	
Are they healthy volunteers for medical studies?	○ Yes ◉ No	
Does your research involve physical interventions on the study participants?	○ Yes ◉ No	
Does it involve invasive techniques?	○ Yes ◉ No	
3. HUMAN CELLS / TISSUES		**Page**
Does your research involve human cells or tissues (other than from Human Embryos/ Foetuses, i.e. section 1)?	○ Yes ◉ No	
4. PERSONAL DATA (ii)		**Page**
Does your research involve personal data collection and/or processing?	◉ Yes ○ No	I-8
Does it involve the collection and/or processing of sensitive personal data (e.g.: health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	○ Yes ◉ No	
Does it involve processing of genetic information?	○ Yes ◉ No	
Does it involve tracking or observation of participants?	○ Yes ◉ No	
Does your research involve further processing of previously collected personal data (secondary use)?	○ Yes ◉ No	

Proposal ID **664717** *Acronym* **HESA**

5. ANIMALS (iii)		Page
Does your research involve animals?	○ Yes ◉ No	
6. THIRD COUNTRIES		**Page**
Does your research involve non-EU countries?	◉ Yes ○ No	I-15
AUSTRALIA - University of Melbourne. Activities and justification are provided in the technical annex - parts 1 -- 3 *A full profile of the involved partner is provided in parts 4 - 5. The partner requires a small contribution for travels, being financed by Australian funds, as shown in an attached letter (see appendix)*		
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)? (v)	○ Yes ◉ No	
Do you plan to import any material from non-EU countries into the EU? *For data imports, please fill in also section 4.* *For imports concerning human cells or tissues, fill in also section 3.*	○ Yes ◉ No	
Do you plan to export any material from the EU to non-EU countries? *For data exports, please fill in also section 4.* *For exports concerning human cells or tissues, fill in also section 3.*	○ Yes ◉ No	
If your research involves low and/or lower middle income countries, are benefits-sharing measures foreseen? (vii)	○ Yes ◉ No	
Could the situation in the country put the individuals taking part in the research at risk?	○ Yes ◉ No	
7. ENVIRONMENT & HEALTH and SAFETY See legal references at the end of the section. (vi)		**Page**
Does your research involve the use of elements that may cause harm to the environment, to animals or plants? *For research involving animal experiments, please fill in also section 5.*	○ Yes ◉ No	
Does your research deal with endangered fauna and/or flora and/or protected areas?	○ Yes ◉ No	
Does your research involve the use of elements that may cause harm to humans, including research staff? *For research involving human participants, please fill in also section 2.*	○ Yes ◉ No	
8. DUAL USE (vii)		**Page**
Does your research have the potential for military applications?	○ Yes ◉ No	

Proposal ID **664717** *Acronym* **HESA**

9. MISUSE		Page
Does your research have the potential for malevolent/criminal/terrorist abuse?	○ Yes ◉ No	
10. OTHER ETHICS ISSUES		**Page**
Are there any other ethics issues that should be taken into consideration? Please specify	○ Yes ◉ No	

I confirm that I have taken into account all ethics issues described above and that, if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents. ☒

Proposal ID **664717** *Acronym* **HESA**

5 - Call specific questions

Open Research Data Pilot in Horizon 2020

If selected, all applicants will participate in the Pilot on Open Research Data in Horizon 2020[1] , which aims to improve and maximise access to and re-use of research data generated by actions. Participating in the Pilot does not necessarily mean opening up all research data. Actions participating in the Pilot will be invited to formulate a Data Management Plan in which they will determine and explain which of the research data they generate will be made open.

Applicants have the possibility to opt out of this Pilot and must indicate a reason for this choice.

Participation in this Pilot does not constitute part of the evaluation process. Proposals will not be evaluated favourably because they are part of the Pilot and will not be penalised for opting out of the Pilot.

We wish to opt out of the Pilot on Open Research Data in Horizon 2020.	○ Yes	◉ No

[1] *According to article 43.2 of Regulation (EU) No 1290/2013 of the European Parliament and of the Council, of 11 December 2013, laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006.*

Data management activities

The use of a Data Management Plan (DMP) is required for projects participating in the Open Research Data Pilot in Horizon 2020, in the form of a deliverable in the first 6 months of the project.

All other projects may deliver a DMP on a voluntary basis, if relevant for their research.

Are data management activities relevant for your proposed project?	○ Yes	◉ No

Proposal full title:	***H*uman-Inspired Reasoning in *E*mbodied, *S*ocial, Artificial *A*gents**
Proposal acronym:	**HESA**
Call:	H2020- FETOPEN-1-2014
Topic:	FET - Open research projects – Novel ideas for radically new technologies
Coordinator:	Prof. Giuseppe De Giacomo
Email:	degiacomo@dis.uniroma1.it

List of participants

Participant No	Participant organization name	Part. short name	Country
1 (Coordinator)	Università degli Studi di Roma La Sapienza	UOR	Italy
2	Universiteit Leiden	UL	Netherlands
3	Imperial College, London	ICL	UK
4	RWTH Aachen University Aachen	RWTH	Germany
5	IDMind	IDM	Portugal
6	University of Melbourne	UNIMELB	Australia

Abstract: Agent-based systems are increasingly being used as the underlying conceptual architecture for deploying complex, society-critical applications. This is no longer limited to networked software applications, but has begun to permeate physical devices including robotic systems. However, agents in current systems suffer from a sort of "autism" that stems from their inability to understand and take into account the expected behaviors of other agents and actors in the environment. This prevents them from interacting and coordinating successfully and predictabity with humans and among themselves in complex and unexpected situations. The solution that the HESA project proposes is for a paradigm shift from the current third-person, global designer view in analyzing and realizing these systems to one which is first-person based, whereby agents themselves exhibit "behavioral empathy". This is achieved by ascribing expected behaviors to other agents and use this information to deliberate in a proactive manner. The ascribed behaviors are initially formed on the basis of social stereotypes, but are monitored by the agents and refined at runtime. Technically, the HESA project will develop foundational and implementation principles for realizing social agents that reason about human and artificial agents. The methods to be devised will be grounded in psychological studies on human behavior in social contexts, and realized by using principles from knowledge representation, artificial intelligence, automated verification and synthesis methodologies. The resulting techniques will be implemented on a latest-generation series of robots and deployed in social robotic scenarios. The consortium brings together world-leading experts with different key expertise ranging from cognitive science, to knowledge representation, multi-agent systems, verification, cognitive robotics and industrial expertise in cognitive robot deployment. The interdisciplinary project will also benefit from a collaboration with leading psychology, knowledge presentation and cognitive robotics experts from the University of Melbourne, Australia, funded independently.

1. S&T Excellence

Multi-agent systems (MAS) are increasingly being used to design and implement complex networked applications. There is an a rising trend to adopt MAS-based architectures and underlying principles when developing interconnected physical devices, such as in cyber-physical systems, in the internet of things, and in cognitive robotics [Weis13]. These systems are intended to be deployed in complex and evolving environments and therefore require important aspects of autonomy and social awareness. At the same time, critical applications require a high-degree of reliability and predictability. Combining these two requirements remains one of the key problems in MAS: autonomous systems are notoriously difficult to predict and analyze, whereas rigid, non-adaptive implementations typical lack the ability to react appropriately in complex and unpredicted situations. As a result, there is reasonable skepticism in society to adopt and interact with these systems because artificial agents display a lack of social awareness. This difficulty is particularly evident in the context of multi-robot systems that are expected to become widespread in the near future. The result is an increasing risk that society will not be able to benefit fully from this key emerging technology.

To remedy this state of affairs, it has been argued that artificial agents should be built to consider other agents and people as peers (and not just as obstacles or as instructors), and that models studied in human psychology in which concepts such as joint action, coordination, expectation, and social norms can provide the building blocks upon which MAS can be analyzed and realized [Brat90, CoLe90, Wool09]. However, current agent-based systems, including multi-robot systems, surprisingly still display a high degree of "autism" [DiPH07, Kami07], because the individual agents, as developed, typically only consider their own goals and knowledge and do not take fully into consideration other agents as peers. In other words, in state-of-the art MAS, mental states are assigned to other agents when designing the MAS, but then they are compiled away from the single agents when in operation. We may call such an approach a *third-person view* (or designer view) of agents, to be contrasted to *first-person view*, where agents at runtime have a model of the world in which they are immersed in (which possibly includes other agents), and use such a model to deliberate about what to do next. In fact a first-person view of agents has long be advocated in reasoning about action in Knowledge Representation [McHa69, Reit01]. However, modeling explicitly other peers and ascribing to them sophisticated theories of mind has been considered notoriously difficult from the computational point of view [FHMV95]. To solve this difficulty, the working hypothesis of the project is rooted in Bateson's psychological insight [Bate72]:

Artificial agents, and in particular robots, do not need to necessarily have a deep understanding what other peers think, they only need to understand how other peers act.

We call such an ability "*behavioral empathy*", as opposed to cognitive or emotional empathy [RDHW07]. In contrast with a full theory of mind, equipping artificial agents with a model of the behaviors of other peers is much simpler, while possibly as effective in many cases [DWVV14]. The project will develop novel techniques that embed the principle of behavioral empathy at the heart of the development process.

1.1 Targeted breakthrough, Long term vision and Objectives

Targeted breakthrough. Based on the above principle, the HESA project aims at:

Developing the interdisciplinary science and the technology to enable artificial agents to embrace behavioral empathy

Technically the project targets the development of a unified, computationally grounded technology that enables the design, analysis, implementation and deployment of embedded agents that can display human-like capability of ascribing and reasoning about others behaviors, and act soundly and predictably in a social context. To achieve this we will develop logic-based techniques inspired by principles in cognitive and social psychology, and computationally grounded in knowledge-representation and formal verification that will permeate all phases of agent-based design and development. The work will take a first-person perspective of agency with particular emphasis on autonomy, the ability to reason about other agents' behavior, social constraints and expectations, and run-time synthesis of strategic behavior in changing environments. The

agents will be assumed to be embodied in sophisticated devices, including robots, thereby enabling social interaction with humans and other agents.

Long term vision. Our long term vision is:

A society in which artificial agents, and in particular robots, will be widespread and interact socially with humans and among themselves by reasoning and predicting each other's behavior. For this to happen, their behavior needs to be predictable, safe and socially competent.

Any successful attempt towards this goal will need a concerted interdisciplinary effort involving cognitive and social psychology, computer science and robot engineering. The consortium reflects this need.

Objectives. The scientific and technical objectives involve three different areas.

Psychological basis of HESA. The first objective includes the development and application of human-inspired psychological principles for predicting the behavior of other agents and people based on what we will call generalized expectations. Such expectations will be derived from generalized dynamic *event models* [StHo96] that represent the behavior that members of a particular social group (i.e., nurses in a hospital) can be expected to exhibit and from representations of situation-specific social norms. Event models will be created from a knowledge base that will initially be created from data collected in experiments and questionnaire studies in humans, so that the robotic agents share the same social information (stereotypes, social norms and rules) that human agents are using. Event models will serve to compute situation-specific expectations about the behavior of others. Following Zacks et al. [ZSSB07], these expectations will be used to inform and guide the robotic agent's own behavior but also to evaluate the validity of the knowledge base. More specifically, failures to predict the actual behavior of others will initiate the updating of the event model and the underlying knowledge base (according to principles taken from the cognitive neuroscience of cognitive control: [FrLO01]), so that both the *validity* of the social information the robotic agent has available and the *accuracy* with which it allows actual prediction increase steadily with experience.

Computing in HESA. The second objective involves the development of all aspects related to the computational side of HESA agents (HESAs). Firstly, this includes the development of novel knowledge-representation formalisms such as the extensions of the situation calculus [Reit01] and verification-oriented dynamic models such as interpreted systems [FHMV95]. This will provide the foundational principles for developing techniques and algorithms for reasoning about other agents from a first-person view. Reasoning will include the selection of ascribed behavioral templates to the other agents and automated synthesis of best-response behavior on this basis. The framework will comprise a monitor component that monitors other agents' behavior and detects discrepancies from their expected behavior. This will enable the agent to adapt, refine the expected behaviors of others, and dynamically replan its actions accordingly. Representation and reasoning will be firmly grounded in logic-based formalisms. This will ensure precise analysis, and provably correct implementations from design within the same unified account. Consideration will be given to the actual realizability of the system by tailoring the richness of the representation and reasoning formalisms with respect to their computational efficiency.

Engineering HESA. The third objective concerns the embedding of selected representation and reasoning methods above into state-of-the-art multi-robot systems. The knowledge representation and reasoning techniques developed in this project will be integrated into the robot programming language Golog [LRLL97, FeLa08]. Since Golog itself is firmly based on the situation calculus, a seamless integration can be expected. Moreover, Golog has been connected to state-of-the-art planning techniques [CELN07], among other things. Existing perception, interaction and execution monitoring capabilities developed for Golog will be adapted and extended to support the HESA approach. To facilitate platform-independence, all software components will be interfaced with the widely used Robot Operating System (ROS).

While a fully robotic society will not be realized in the life of the project, the resulting robots will be deployed in various scenarios and their performance will be evaluated against existing systems by checking coordination, competition and non-interference abilities in complex unannounced situations. Apart from deploying in in-house labs, the consortium will exploit the current involvement of IDM in the EU FP7 Social Robot Project, to deploy and evaluate HESA's results over the operating domain of Social Robot. This domain is related to day-to-day support to the elderly to stay active and independent in their preferred environment. For example, a behavioral empathic robot might remind an elder to take his medication, but not

while he is watching his favorite TV show or receiving visitors; at the same time when bringing medication it would avoid interfering with another robot that is cleaning the room. In addition our Australian partners will exploit their unique position to evaluate the HESA approach into an existing in-operation multi-robot system for automated surface mining.

1.2 Relation to the work programme

The HESA proposal strictly adheres to the FET idea of leveraging on "Europe's excellent science base into a competitive advantage by uncovering radically better technological possibility". Specifically it matches all FET-Open characteristics:

Long-term vision*:* The creation of a society in which artificial agents, and in particular robots, will be widespread, and will interact with social competence with other agents (humans or robots), by predicting their needs and ascribing expected behaviors to them when acting; see 1.1.

Breakthrough S&T target*:* To provide the human-inspired logic-based scientific foundations for a paradigm shift in agent-based research, by moving from a precompiled interaction between agents to the development of behavioral emphatic agents that act autonomously, correctly and predictably; see 1.1.

Foundational*:* The research aims at developing the scientific and technological foundations for behavioral empathic multi-agent and multi-robot systems. This in the long run will provide the basis for creating socially competent robots with advanced forms of coordination among agents and of human-robot interaction that are much closer to how humans act; see 1.1.

Novelty*:* The research is based on a paradigm shift in MAS from third-person approach to a first-person one in which behaviors are ascribed to other peers, reasoned upon, monitored and revised, on the basis of precise psychological principles; see 1.3.

High-risk*:* The research ambitiously combines psychological and social underpinnings and logic-based computing, while requiring computational efficiency to actually be engineered in practice. The quality of the consortium, which is formed by top scientist in all areas involved, will mitigate the high risk; see 1.1.

Interdisciplinary*:* The research is interdisciplinary in nature, involving cognitive and social psychology, computer science and robot engineering, as detailed in 1.5.

1.3 Novelty, level of ambition and foundational character

Our research is grounded in four distinct research areas and will require cross-fertilization among these.

Cognitive/Social Science. Research in Cognitive, Social, and to some degree Developmental Psychology has looked into how humans represent and carry out intentional actions themselves and how they perceive and process intentional actions of others [HMAP01, Iaco01] -i.e., to show "behavioral empathy" (a term that we use to refer to the ability to know about and to take into consideration the behavior of others without necessarily reasoning about their underlying mental states, an implication that the standard empathy concept often also entails). Social psychological studies have investigated how people act in the presence of others, and how people adapt their behavior to social norms and rules and to the expectations of others [CiTr98, DiBa01]. Moreover, work in developmental psychology and the affective (neuro-) sciences has uncovered the development of the ability to take other people's mental states into account (empathy, theory of mind) [MaMP14]. Finally, studies in the cognitive (neuro-) sciences have investigated how events are cognitively represented and how these representations are used to predict upcoming events and updated if these predictions fail [ZSSB07]. However, the available theories and approaches are too abstract and/or too vague to provide artificial agents with a cognitive architecture that generates (behavioral) empathy in concrete social interaction. Moreover, formalized models are very rare in these domains (an exception being the event model of Zacks et al., that we will use and develop further in this project) and far from implementation. Our approach would be the first to bring together empirically founded principles from various psychological subdisciplines in order to model behavioral empathy and prediction in social situations. In particular, it aims at *setting the basis for a computationally grounded theory of (certain aspects of) mind, and social behavior*.

Knowledge Representation and Reasoning. Knowledge Representation and Reasoning (KR) stems from a deep tradition in logic. In particular, it aims at building systems that *know* about their world and are able to act in an informed way in it, as humans do. A crucial part of the system it that knowledge is represented

symbolically, and that reasoning procedures are able to extract consequences of such knowledge as new symbolic representations. Such an ability is used to deliberate in an informed fashion the course of actions to take. This very idea is radically new in human history [Leve14]. It comes about after a long gestation, stemming from Aristotle, who developed the initial notion of logic though unrelated to notion of computation; continued by Leibniz, who brought forward a notion of "thinking as computation", though not yet symbolic; and later by Frege, who developed the notion of symbolic logic, though unrelated to computation; and finally by the breakthrough in human thinking of the early part of last century with Church, Godel, and Turing, who set the bases for symbolic logic bound together with computation and ultimately for Computer Science, though even they did not think about logic as a way of representing knowledge. The KR idea can only be traced back to McCarthy work in 1959 [McCa59], which gave rise to the area of Artificial Intelligence. In KR, a first-person view of an agent reasoning on its knowledge of the world to deliberate its action has been studied in depth through comprehensive frameworks, such as that of Situation Calculus [McHa69, Reit01, LRLL97, DeLL00, DeLP06]. Restricted forms of representations (essentially propositional) have been put forward to study efficient action deliberation or planning which in these years is producing a vast array of particularly fruitful results [GeBo13, DePS10, DFPS10, CaDH11, FeDL12, DePS13, DeVa13, GeTh14, DeDM14, DDGM14]. Recently this work has been complemented by a set of novel results that shows the effective computability of expressive variants of the original full-fledged (predicate based) Situation Calculus [DeLP12, DLPV14, DeLV14]. Such results are being complemented by the possibility of combining action theories with ontological representations in description logics [CDLL13, CDMP13, HCMD14]. Moreover, the techniques for applying belief revision to transition systems based on dynamic logic of assignments proposed recently [HMDW14], open up the possibility of grounding computationally the notion of "behavior revision". However virtually in all the works adopting a first-person view of agent in KR, the agent does not ascribe explicitly behaviors of other agents acting in the same world. To be more precise, such behaviors are blurred together with contingencies and exogenous events occurring in the environment the agent is immersed in. This gives what we have described as a form of autism to the agent, preventing the possibility of considering forms of social awareness and behavioral empathy. *In this project, we will put forward the notion of ascribed behaviors to other agents and develop novel knowledge representation formalisms for giving representational and reasoning means for the agent to act in a socially sound and behavioral empathic way.*

Multi-Agents Systems, verification, synthesis and monitoring. Multi-agent systems (MAS) are a leading paradigm in the design and deployment of distributed, autonomous systems, including robots. While implementation methodologies vary, at the core of an agent-based architecture is the autonomy of the entities, their goal-directedness and their ability to interact with their peers and humans by communicating, negotiating, etc. In MAS agents are often described by means of a high-level mental attitudes such as their knowledge, beliefs, goals, and desires [FHMV95, Wool09, Brat90, CoLe90, RaGe98, HVBM11] as well as their strategic objectives [AlHK02, MoMV10, DeLP06]. MAS behavior in the presence of norms and regulations have also been widely studied [BuDK13, WWW1]. Mental attitudes and norms have been formalized by means of a wide variety of modal languages. These are used, together with temporal logic, to specify the behaviors of MAS. *Verification methodologies* supporting expressive agent-based specification languages have been developed. These include OBDD-based model checking for MAS specified by knowledge-based specifications and strategic behavior [LoRa06], SAT-based bounded model checking [PeLo03], partial-order reductions [LoPQ10], abstraction [LPSS11], and parallel approaches [KwLQ10]. The state-of-the-art includes the availability of efficient, open-source model checkers for MAS such as MCMAS [LoQR09]. While this enabled the formal verification of MAS before deployment, research in MAS has also included the development of *synthesis techniques* for the automatic generation of joint plans and joint behaviors in MAS [CLMM14]. These techniques are closely linked to the model checking approaches described above. Synthesis techniques have found application in a wide range of areas spanning from robotic exploration to service-oriented computing. In services, automata-based synthesis has led to the development of methods to solve the orchestration and choreography problems, thereby providing the foundation for the realization of services that can compose at run-time [BCDL03, DePS13]. The logic-based verification and synthesis research above has also lead to the development of *symbolic monitoring techniques* for MAS. While it is of course important to be able to show properties of a system before deployment, monitoring its execution for faults is also essential. In recent research [LPSS11] methodologies that can monitor stream of events and match them against expected behavior of a system have been put

forward and implemented. By means of these techniques a potential fault of the system, or simply an unexpected behavior, can be efficiently flagged at runtime and remedial action can be taken. While the work above constitutes some of the state-of-the-art in the area, it cannot readily be employed for on board reasoning and monitoring in HESAs. In fact, the methodologies above, in line with all work in verification and testing in software systems, are constructed from the designer's point of view. This enables an observer to state, ascribe and verify mental properties to the agents in the system (e.g., the evolution of their knowledge), but they connot be used by the agents themselves when conducting first-person reasoning. In this project, we will develop logic-based reasoning and monitoring techniques that will enable onboard reasoning for HESA. To do this we will adopt a first-person view and develop synthesis and monitoring methodologies. Some key advantages of this paradigm shift are that: *i) the methodologies will be provably correct, ii) reasoners and monitors developed will be readily implementable on the HESA robots. This will lead to a high degree of predictability and assurance for the HESA robots in their tasks and interaction with humans.*

Cognitive Robotics. A key requirement to develop autonomous robotic systems displaying intelligent behavior is the ability of the individual robots to perform first-person reasoning. For example, team members in the Robocup competition need to be able to consider and reason about the actions of other robots. In domestic robotic scenarios (e.g., Robocup@Home), the interaction with humans also needs to be considered. The current solutions to this problem are largely unsatisfactory as they are designed in an ad-hoc fashion without clear design principles and guarantees on the resulting behaviors. Some approaches in cognitive robotics, including [LeLa07], are deeply rooted in logic-based methods for knowledge representation and reasoning, with an emphasis on representing and reasoning about dynamically changing environments that are only partially known. A number of implemented robotic systems based on these ideas have been successfully deployed [TeBe13, LeIn04, BCFH98, FeLa08]; some of these are based on the Situation Calculus. While these initial approaches succeeded in equipping autonomous robots with powerful reasoning capabilities, these approaches largely do not take into account behaviors, possibly as resulting from goals, and intentions, of other agents (humans or other robots). When they do, e.g., [FeLa08], this is done at design time and creates systems that are rigid and cannot evolve at runtime. *This project aims at equipping robots with reasoning capabilities about behaviors of other robots and humans, taking these into account when deciding on a course of actions, and modifying the ascribed behaviors when necessary*.

1.4 Research methods

The *research approach* followed by the project envisions a multi-disciplinary effort involving cognitive and social psychology, computer science and robot engineering, to develop strong scientific foundations for behavioral empathic agents. In our investigation, we will constantly be careful to the actual realizability of the effort, by focusing on computational characterizations of the techniques developed and by implementing selected results and techniques in actual cognitive robots system, which will be validated in cases studies within in-house labs and real-life scenarios. The approach followed will be iterative, in the sense that as theory is developed, computational characteristics are studied and implementations are produced and evaluated, bringing feedback to the theory that can then be refined and extended, starting over the same process. All software developed will be open-source and available. Also open access to all project results will be granted. *Sex and gender* issues do not apply.

1.5 Interdisciplinary nature

The research proposed to be successful requires breaking down discipline barriers. In particular it requires a joint effort among three distinct disciplines, while generating added value to each of them:

Cognitive/Social Science. This project will combine knowledge and empirically based principles from cognitive, social, and developmental psychology, and from the cognitive and affective neurosciences. Focusing on only one or few of these disciplines would either remain too abstract to establish a cognitive architecture that operates in situ (e.g., social psychology describes and measures stereotypes and social rules without saying how they are implemented) or too much focused on the actual mechanism to the expense of the processed information (e.g., theories from cognitive neurosciences are concrete mechanistically but too little constrained to tell how social rules, say, are represented). Accordingly, this project will lead to a *gain in concreteness and insight for the computational grounding of theories related to behavioral empathy and social prediction.*

Computing. This area will bring about notions, techniques and results developed within knowledge representation, reasoning about actions, and MAS in AI, as well as notions like model checking, verification, automated synthesis, and monitoring in from CS. *It will gain a formal grounding for the development of actual behavioral empathic agents.*

Engineering. This area will bring about actual knowledge on multi-robot system development, and cognitive robotics. *It will gain principles for developing non-autistic, socially competent robots, which are going to be more suitable for coexisting in a human environment, being more behavioral empathic, and more predictable.*

2. Impact

2.1. Expected impacts

The expected impact of the project is the development of novel scientific methodologies and technologies for the deployment of behaviorally empathic multi-robot systems, that act in socially sound and predictable manners. The scientific developments will be evaluated both against commonly accepted criteria in Computer Science such as efficiency and scalability, but also through the development of a proof of concept robotic implementation that will enable us to assess the feasibility of the approach. While our primary objectives are scientifically ambitious and a full implementation cannot be realized within the life of the project, we believe the results to be obtained will have a tremendous impact to the deployment of robotic systems in Europe and elsewhere thereby benefiting our citizens, the industry, and society as a whole.

Serious technical difficulties still remain in the development of robotic systems. While engineering aspects such as localization, navigation and robotic vision have made dramatic progress, robots still remain largely unable to perform high-level reasoning and are still incapable of meaningful forms of social behavior. To overcome these difficult problems we need to develop fundamental techniques enabling the social interaction among robots and with humans. This will be one of the key impacts of the HESA project. Equally, considerable concerns and reluctance remain at societal level towards the adoption of multi-robot systems. This largely originates in the pervasive nature of bugs in low-level modern technology such as the software running on mobile phones and desktop computers. A key technology that has been successfully used in hardware to ensure correctness of complex computer chip designs is logic-based automated reasoning and verification. To mitigate this risk and increase societal adoption, a further aim of the HESA project is to develop new logic-based methodologies from the designs to the implementations thereby aiming for correctness by construction for the reasoners in the robots. In summary, the long term impact of the project is to put forward the scientific underpinnings to enable the development of safe, secure, and predictable multi-robot systems that can interact with humans. The changes that robotic technology can bring are so ground-breaking and liberating for society (autonomous systems caring for the elderly, autonomous vehicles, etc.), that any advancement towards more effective, predictable and social competent robots will have a significant impact on developments.

While we believe the most important aspects of our impact will be long term scientific advances, the project will also have some short term technological impact through the HESA partner IDM. IDM have a long and successful history of advances in robotics in conjunction with EU projects. For example, the “4 Wheel Differential Outdoor Robot Platform” [WWW2] was born from the EU FP7 collaborative project FROG; the “Omnidirectional Platform” [WWW3] was the direct result of the EU FP7 collaborative project MOnarCH. IDM has deployed advanced commercial applications, such as the fleet of robots that have been running continuously 24/7 for over 4 years guiding visitors in the Ciudad Grupo Santander, near Madrid, a solution recently exported to the Bank Bradesco branch in the high-end JK Iguatemi Mall, Sao Paulo, Brazil.

As described in WP5, IDM will use the results of the projects to pioneer the development of radically novel robotic systems that can interact with humans and peers not in pre-assigned and monolithic ways as it is currently the case, but by reasoning about the expectations and the behaviors of their peers. This will enable IDM to solve longstanding issues in the deployment of robotic systems that can adapt and react to the specific circumstances and social context they are immersed in. Any success in this direction will be directly implemented into its agile line of products and services. Since the core of our results will be released as open source, any developments will be reusable by other companies and research labs potentially bringing benefits

to a wide range of manufacturing scenarios and public spaces including hospitals, railway stations, airports, urban city centers, exhibitions, offices, etc.

We further note the interest in the project from partners outside Europe. More specifically, in context of our relationship with our Australian project partners, HESA will bring the ability to react to unexpected events and circumstances in the mining domain. The incorporation of HESA techniques into mining operations clearly has significant potential to increase the net present value of mining operations, which will have the effect of extending mine life and reducing energy consumption by minimizing re-handling. This will serve as a testbed of the project and any lessons learnt will be distributed in the European mining industry as well as related domains such as oil and gas exploration and extraction.

2.2 Measures to maximize impact

Dissemination. The HESA project plans to apply three major dissemination strategies. Firstly, the project will have a web site for posting project activity and achievements that will be accessible to the public. Secondly, the members of the project will publish technical and scientific results at scientific events.[1] These events are open to the public and attract the most relevant audience, thus increasing public awareness. Thirdly, we will seek engagement with other researchers in Europe and beyond. Specifically we will exchange results and collaborate with other EU funded initiatives, including the European Network for Social Intelligence (SintelNet) as well as newly funded H2020 projects as well as national projects. For example staff at Imperial College London will interact with personnel employed on related topics on other grants including "Trusted Autonomous Systems" (EPSRC; 2010-2015). All academic Pis in the HESA project are regularly invited (more than twice per year) to give advanced topics at international summer schools and conferences. In these occasions they will disseminate the project result and contribute to forming a new generation of scientists and engineers.

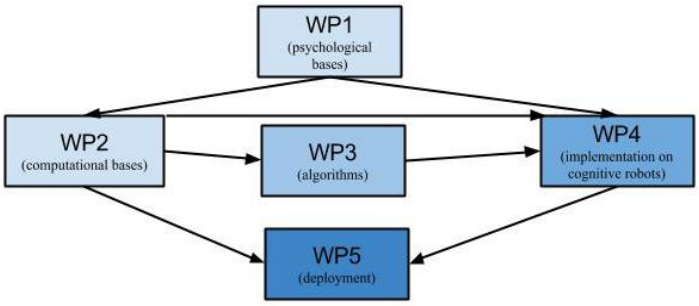
Exploitation. Academic units will exploit HESA results mainly in terms of foundational and applied research, through articles in top-level scientific journals, communications and presentations at top-level scientific conferences, but also in professional and technical press and in business-oriented workshops (including the IST conferences organized by the EC), trade shows, and professional exhibitions. In addition, academic partners plans to carry out technology transfer activities towards third party organizations. Further, they will exploit HESA through the strengthening of degree programs and other high-value courses to students, developing graduate courses based on the project results. Exploitation activities tailored toward industry will be specifically carried out during the project lifetime, and they will include an initial market analysis and elaboration strategy for further exploitation (as part of Deliverable D6.3 in the WP6).

Communication activities. The consortium will inform the public about the project through media outreach, web sites, and publications. HESA will also take advantage of some of the web 2.0 tools to increase awareness, e.g., twittering of news feeds when tool updates are put online or publications are accepted at conferences; blogging intermediate results and announcements.

3. Implementation

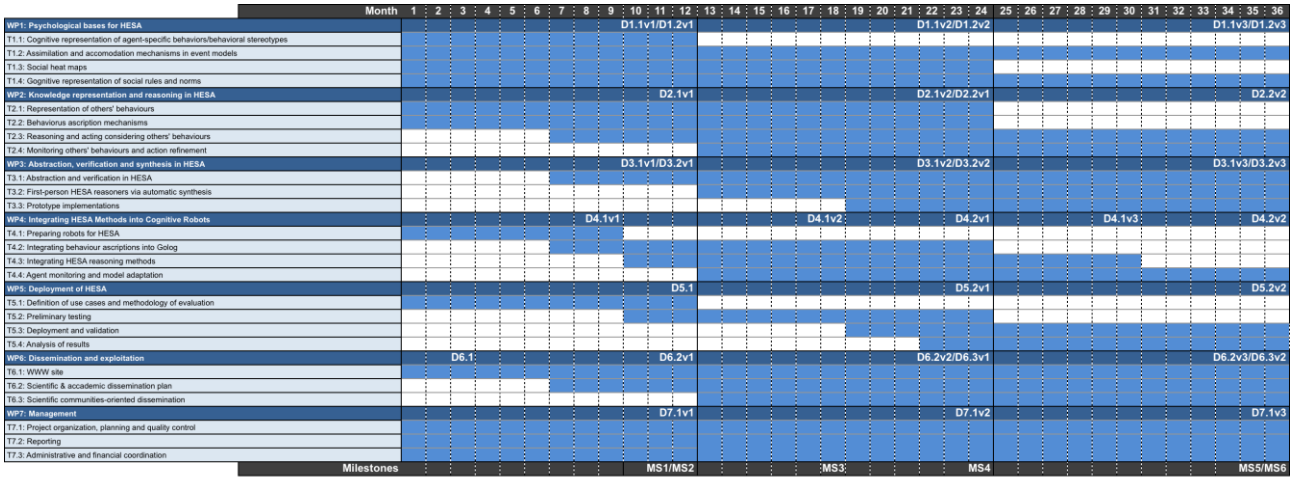
3.1 Project work plan

The project is organized in 7 work packages (WPs). WP1-WP4 deal with the scientific aspects of the project, namely the psychological bases, computational bases, algorithms, and implementation in a system of cognitive robots, respectively. WP5 will be devoted to deployment in actual scenarios of the technology



[1] In particular, venues such as IJCAI, AAAI, KR, AAMAS, CAV, VMCAI, TACAS, AIJ, JAIR, TOCL, TOSEM, JCSS, IS, JAAMS in AI and CS, CogRob, ICRA, IROS, RSSESCOP, Robotics and Autonomous Systems, International Journal of Robotics Research in Robotics, Annual Conference of the European Society for Cognitive Psychology (ESCOP), Annual meeting of the Psychonomic Society, Frontiers in Neurorobotics, Frontiers in Psychology, Cognition, Psychological Science in Psychology.

developed, including the system of cognitive robotics. WP6 deals with dissemination and exploitation, and WP7 deals with management. The main dependencies between the first 5 WPs is depicted in the figure. In fact, feedback between these 5 WPs will be continuously taken into account. The timing of the WPs and their activities are reported in Gantt chart below:



Work package 1 - Psychological basis of HESA

Work package number			WP1	Start Date or Starting Event		M1
Work package title			Psychological basis of HESA			
Participant number	1	2	3	4	5	6
Short name of participant	UOR	**UL**	ICL	RWTH	IDM	UNIMELB
PM per participant:	6	**35**	3	4	0	6

Objectives. Develop an empirically grounded model of agent/action representation and social awareness in social situations.

Description of work

Task 1.1: Cognitive representation of agent-specific behaviors/behavioral stereotypes (UL) [M1-12]. This task aims at creating a database of typical behaviors attributed to key agents of the relevant scenarios. Empirical data will be collected in representative human adults. The behaviors in the database will be weighted for probability and situational significance.

Task 1.2: Assimilation and accommodation mechanisms in event models (UL) [M1-36]. This task will study and carry out experiments on how human adults use previous knowledge about behavioral stereotypes to predict the behavior of others and update their knowledge base if their predictions fail. The empirical findings will used to create a dynamic model of event representation, based on principles from cognitive sciences [ZSSB07] and cognitive neuroscience [FrLO01, McMO95].

Task 1.3: Social heat maps (UL) [M1-24]. This task will include empirical studies to assess how human adults represent groups of agents and how they keep and update such representations. The main idea is that people create situational, dynamic heat maps, in which available social agents are weighted according to their potential actions (i.e., according to the situational social relevance of these actions and the probability that they are carried out).

Task 1.4: Cognitive representation of social rules and norms (UL) [M1-36]. This task will include empirical studies on how humans represent social rules and norms, how they adjust these representations to the current situation (e.g., how they represent the probability that rules and norms are applied by others in the current situation), and how they use these representations to predict the behavior of others.

Deliverables

D1.1 Techniques for the representation of behaviors and stereotypes and dynamic model of action/agent representation [M12, M24, M36]

D1.2 Mechanisms of creating and social heat maps and representing social rules and norms [M24, M36]

Work package 2 - Knowledge representation and reasoning in HESA

Work package number			WP2	Start Date or Starting Event		M1
Work package title			Knowledge representation and reasoning in HESA			
Participant number	1	2	3	4	5	6
Short name of participant	**UOR**	UL	ICL	RWTH	IDM	UNIMELB
PM per participant:	**28**	9	9	9	0	9

Objectives. To develop a logic-based, computational grounding for knowledge representation and reasoning in HESAs and specifically the development of 1) a suitable languages and semantics for representing behaviors ascribed to peers; ascription mechanisms of behaviors to peers; 3) reasoning and acting in social contexts; 4) monitoring and revising behaviors. All methods will be assessed against their computational feasibility in the context of the project, including their computational complexity.

Description of work

Task 2.1: Representation of others' behaviors (UOR) [M1-24]. This task aims to study and developing a first-person based formal representation of the expected behaviors of other peers, and their individual and joint capabilities, their expected deliberation in given situations, their attitude to cooperation, or otherwise, as well as the tasks they are executing. The work will be grounded on knowledge representation and multi-agent systems and will follow closely the research developed in WP1 on human-based theories of interaction (in particular T1.1, and 1.4). Technically, this will involve the development of logic-based, decidable theories representing complex behaviors of HESAs. A key outcome of this work will be novel formalisms based on situation calculus and interpreted systems to represent behaviors in HESAs as described above.

Task 2.2: Behaviors ascription mechanisms (UOR) [M1-24]. This task will study the mechanisms that will enable HESAs to ascribe behaviors to peers at runtime from a set of predefined stereotypes that represent common acting patterns in social situations. The behavior ascribed to peers will change dynamically as the agents change their understanding of the situation they are in in view of their monitoring activities (T2.4). The ascription mechanisms and its runtime adaption will follow the work conducted in cognitive psychology and social awareness studies for humans from WP1, (in particular T1.2 and T1.3). Technically, we will formalize, in collaboration with WP1, repositories of behavioral patterns described as transition systems to be composed and customized during reasoning (T2.3). The outcome of this task will be a collection of ascription mechanisms for the expected behavior of HESA peers.

Task 2.3: Reasoning and acting considering others behaviors (UOR) [M7-36]. This task will study the reasoning and the deliberation mechanisms that HESAs will adopt in order to act socially, by considering others as companions, adversaries, peers and act accordingly. The approach will be based on logic techniques in AI and formal methods in CS. The WP will develop novel approaches to reasoning about actions in a social context and the related problems of situation awareness, incomplete information, information classification and actions ontologies, reasoning about others' expected behaviors and violations, strategic action deliberation, and synthesis and refinement of execution plans. A key concern will be the assessment of any technique identified against its computational feasibility, including its decidability and computational complexity, thereby providing valuable input to WP3. The outcome of the task will be a collection of techniques for reasoning and acting in social contexts from a first-person point of view as well as their computational analysis.

Task 2.4: Monitoring others' behaviors and action refinement (ICL) [M13-36]. This task will develop monitoring and refinement techniques for HESAs. It will consist of a methodology to process the peers' behaviors, as observed by an agent by means of monitors, and revise the future behavior expected by the agent from the peers. The model revision and selection technique will be based on psychological studies in WP1 (in particular T1.2 and T1.3) and implemented through various notions of model distance that take inspiration from the literature of model updates, and revision in AI and CS. Technically we will develop algorithms on logic-based representations including transition systems that will select the most likely model stereotype in view of the observed behavior up to a certain point. The model update will also provide input to the local action refinement component for the agent himself to provide the best action response in the circumstances. The outcome of the task will be a number of novel approaches to select at runtime the most likely behavioral template in view of the observed behaviors.

Deliverables

D2.1 Representation of others' behaviors and behavior ascription mechanisms. [M12; M24]

D2.2 Reasoning on other's behavior and monitoring. [M24; M36]

Work package 3 - Abstraction, verification and synthesis in HESA

Work package number			WP3	Start Date or Starting Event		M7
Work package title			Abstraction, verification and synthesis in HESA			
Participant number	1	2	3	4	5	6
Short name of participant	UOR	UL	**ICL**	RWTH	IDM	UNIMELB
PM per participant:	16	0	**29**	6	0	6

Objectives. To develop logic-based, computationally efficient techniques for verification, first-person reasoning and monitoring in HESAs. Proof of concept implementations will also be released.

Description of work

Task 3.1. Abstraction and verification in HESAs (ICL) [M7-36]. This task will be concerned with developing logic-based verification methodologies for HESAs so that HESA systems can be analyzed and any bug can be detected and rectified. The work conducted here will naturally follow the semantics and algorithms developed in WP1 and WP2. Technically, we will develop symbolic model checking techniques for verifying the correctness of HESA systems. We expect HESA systems to be complex to analyze; given this, we will also develop abstraction methodologies to reduce the state spaces appropriately. The outcome of this task will be a number of verification methodologies to assess the correctness of HESAs at design time.

Task 3.2. First-person HESAs reasoners via automatic synthesis (ICL) [M13-36]. In this task, we will develop reasoners for the individual HESAs in a system. This will enable the agents to deliberate at run-time on what specific course of action to take in the social situation they inhabit in view of the expectations they have of their peers' behavior. Technically, we will develop automatic synthesis algorithms against specifications expressing strategic behavior (e.g., expressed in ATL, strategy logic, etc.). We will benefit from the work in Task 3.1 as synthesis and model checking share basic underlying methodologies. They will be used on the same semantics from WP1 and be guided by the worst-case complexity analysis of WP2. The outcome of the task will be a suite of synthesis algorithms to be used as prototype reasoners.

Task 3.3: Prototype Implementations (**ICL) [M18-36]**. In this task, we will realize open-source prototype implementations for the algorithms developed in T3.1 and T3.2. The outcome will be prototype reasoners that use logic-based technology for verification, first-person reasoning and monitoring in HESAs.

Deliverables

D3.1 Verification algorithms for HESAs and prototype [M12; M24; M36]

D3.2 First-person reasoning algorithms for HESAs and prototype [M24; M36]

Work package 4 - Integrating HESA Methods into Cognitive Robots

Work package number			WP4	Start Date or Starting Event		M1
Work package title			Integrating HESA Methods into Cognitive Robots			
Participant number	1	2	3	4	5	6
Short name of participant	UOR	UL	ICL	**RWTH**	IDM	UNIMELB
PM per participant:	6	6	6	**26**	9	6

Objectives. The objective of this WP is to implement and integrate methods developed in WP2+3 into the high-level control software of cognitive robots. The starting point will be the robotic software framework developed at Aachen. Suitable modifications and extensions of Golog need to be developed to implement the ascription of behaviors of other agents, their adaptation due to monitoring of other agents at runtime, and the action selection based on these ascriptions.

Description of work

Task 4.1: Preparing robots for HESA (RWTH) [M1-9]. The work is based on the robotic software framework developed at RWTH, which includes middleware [NFBL10] with an interface to ROS, and the high level control language Golog based on the situation calculus. (Work on porting the software to a robot identical to those used in this project is already under way.) To prepare the robots for HESA-specific requirements, existing 2D and 3D perception methods needed for agent monitoring (T4.4) will be adapted.

At the logic-based control level, symbolic representations of actions and fluents, together with their connections to actuators and perception routines suitable for in-house and deployment application scenarios in WP5 will be developed. In-house scenarios will be implemented and evaluated within the RWTH robotic lab (see RWTH description in part 4), as well as in public spaces of the university.

Task 4.2: Integrating behavior ascriptions into Golog (RWTH) [M7-24]. Based on WP 2.1, Golog representations need to be extended to allow for behavior ascriptions of other agents, taking a first-person point of view. A starting point for this work can be a multi-agent version of the knowledge-based programming paradigm developed in [ClLa06]. Stereotypical behaviors from in-house and deployment application scenarios will be implemented and used for testing.

Task 4.3: Integrating HESA Reasoning methods (RWTH) [M10-30]. Reasoning methods and behavior synthesis methods developed in WP2+3 need to be integrated into the Golog framework and combined with existing methods for classical planning [CELN07] and decision-theoretic planning [FeLa08].

Task 4.4: Agent monitoring and model adaptation (RWTH) [M13-36]. Monitoring of other agents' behavior will be based on existing perception methods from T4.1. The recognition of behavior will use the methods developed in WP2+3, combined with existing plan recognition techniques in Golog [SBSL12]. Rather than aiming for a general solution, the focus will be on solving monitoring issues as they arise in the application scenarios of WP5. Based on this, update mechanisms for ascribed behaviors will be integrated into the framework. Methods from WP2+3 for action refinement will be combined with existing re-planning techniques such as [FeLa08].

Deliverables

D4.1 A Golog interpreter with built-in facilities for behavior ascription and HESA reasoning techniques [M9,M18; M30]

D4.2 Behavior monitoring and action selection adaptation mechanisms integrated into Golog [M24; M36]

Work package 5 - Deployment of HESA

Work package number			WP5	Start Date or Starting Event		M12
Work package title			Deployment of HESA			
Participant number	1	2	3	4	5	6
Short name of participant	UOR	UL	ICL	RWTH	**IDM**	UNIMELB
PM per participant:	6	6	2	8	**21**	16

Objectives. Proof of concept of actual deployment of HESAs system.

Description of work

Task 5.1: Definition of Use Cases and methodology for evaluation (IDM) [M1-M12]. This task addresses the definition of the use case scenarios that will be used to demonstrate and evaluate the achievements of the project. Two use cases are being considered: robot assistants in daily care centre, and multi-robot system for automated surface mining.

Task 5.2: Preliminary testing (IDM) [M10-M24]. The aim of this task is the testing and validation of the intermediate achievements from the project. This will define further improvements to mitigate integration issues and fine-tuning processes.

Task 5.3: Deployment and validation (IDM) [M19-M36]. This task comprises the deployment and validation of the developed components over the two use case scenarios. Previous experience of partners IDM and UNIMELB with these scenarios will facilitate integration of the developed software components.

Task 5.4: Analysis of results (IDM) [M21-M36]. This task will apply the methodologies and tools defined in T5.1 to analyze the results collected from the two trials. From this analysis a set on conclusions and recommendations will be issued, which will serve as input for the dissemination and exploitation of the project achievements.

Deliverables

D5.1 Definition of use cases and system functionalities [M12]

D5.2 Evaluation Report on the deployed system [M24; M36]

Work package 6 - Dissemination and Exploitation

Work package number			WP6	Start Date or Starting Event		M1
Work package title			Dissemination and Exploitation			
Participant number	1	2	3	4	5	6
Short name of participant	UOR	UL	ICL	RWTH	**IDM**	UNIMELB
PM per participant:	4	1	1	1	**4**	1

Objectives. This work package is about the dissemination of the research and development work carried out in the framework of the HESA project, and about the potential use of the resulting technologies in real commercial and industrial settings.

Description of work

Task 6.1: Website (UOR) [M1-36]. Develop a HESA website to help to disseminate the project to the research communities and facilitate the internal communication of consortium members.

Task 6.2: Dissemination Plan and Publications (UOR) [M7-M36]. Develop and disseminate material on HESA through various channels, including top ranked conferences and journals in artificial intelligence, robotics, and cognitive science; YouTube videos; press releases; public science and industry expositions.

Task 6.3: Exploitation Plans for Results Developed within HESA (IDM) [M13-36]. Develop yearly exploitation plans to facilitate adoption of the results, methodologies and technologies, developed within HESA. In the last year this activity will focus on the adoption of HESA technologies by industrial/public third party organizations involved in constructing complex MAS and multi-robot systems.

Deliverables

D6.1 Public website [M3]

D6.2 Description of knowledge generated by the consortium and dissemination achieved [M12; M24; M36]

D6.3 Exploitation plan for adoption of the HESA technologies, and future developments [M24; M36]

Work package 7 - Management

Work package number			WP7	Start Date or Starting Event		M1
Work package title			Management			
Participant number	1	2	3	4	5	6
Short name of participant	**UOR**	UL	ICL	RWTH	IDM	UNIMELB
PM per participant:	**12**	0	0	0	0	0

Objectives. The aim of this WP is to oversee the overall management activities related to the project.

Description of work

Task 7.1: Project organization, planning and quality control (UOR) [M1-36]. Organization of project's meetings. Monitoring, progress and quality of research. Ensure communication among partners at all levels.

Task 7.2: Reporting (UOR) [M1-36]. Interim and Annual reports to be prepared for the EU Commission.

Task 7.3: Administrative and financial coordination (UOR) [M1-36]. Document and periodic reports production and archive. Costs to be controlled coordinated and consolidated. EC payments and distribution coordination and follow-up.

Deliverables

D7.1 Annual reports [M12; M24; M36]

D7.2 Final report [M36]

3.1.4 List of Work Packages

WP No	Workpackage title	Lead contractor	Person-months	Start month	End month	Del. No
WP1	Psychological basis of HESA	**UL**	54	**1**	**36**	D1.1, D1.2
WP2	Knowledge representation and reasoning in HESA	**UOR**	64	**1**	**36**	D2.1, D2.2
WP3	Abstraction, verification and synthesis in HESA	**ICL**	57	**7**	**36**	D3.1, D3.2
WP4	Integrating HESA Methods into Cognitive Robots	**RWTH**	59	**1**	**36**	D4.1, D4.2
WP5	Deployment of HESA	**IDM**	59	**1**	**36**	D5.1, D5.2
WP6	Dissemination and Exploitation	**IDM**	12	**1**	**36**	D6.1, D6.2, D6.3
WP7	Management	**UOR**	12	**1**	**36**	D7.1, D7.2
			317			

3.1.5 List of Deliverables

No	Deliverable title	Date	Nature	Diss. level
D1.1	Techniques for the representation of behaviors and stereotypes and dynamic model of action/agent representation	12,24,36	R	**PU**
D1.2	Mechanisms of creating social heat maps and representing social rules and norms	24,36	R	**PU**
D2.1	Representation of others' behaviors and behavior ascription mechanisms	12,24	R	**PU**
D2.2	Reasoning on other's behavior and monitoring	24,36	R	**PU**
D3.1	Verification algorithms for HESAs and prototype	12,24,36	R, OTHER	**PU**
D3.2	First-person reasoning algorithms for HESAs and prototype	24,36	R, OTHER	**PU**
D4.1	A Golog interpreter with built-in facilities for behavior ascription and HESA reasoning techniques	9,18,30	R, OTHER	**PU**
D4.2	Behavior monitoring and action selection adaptation mechanisms integrated into Golog	24,36	R, OTHER	**PU**
D5.1	Definition of use cases and system functionalities	12	R, DEM	**PU**
D5.2	Evaluation Report on the deployed system	24,36	R, DEM	**PU**
D6.1	Public website	3	DEC	**PU**
D6.2	Description of knowledge generated by the consortium and dissemination achieved	12,24,36	R	**PU**
D6.3	Exploitation plan for adoption of the HESA technologies, and future developments	24,36	R	**PU**
D7.1	Annual reports	12,24,36	R	**PU**
D7.2	Final report	36	R	**PU**

3.2 Management and risk assessment

The aim of the project management is to guarantee that the objectives of the project are achieved on time, on budget, and with high quality. The HESA project will be managed with sound and efficient decision-making, execution, and control, and will maximize partner accountability, commitment, involvement, and prospects of success. To implement the above goals, the proposed project management structure includes the following figures: Project coordinator, WP Leaders, and General Assembly (GA), the latter consisting of the principal investigators of all units, and chaired by the project coordinator. The relationship between all contractors will be fixed in a *Consortium Agreement.* The project units will meet at least quarterly. In addition, periodic meetings among WPs teams will be organized depending on the work to be carried out as well as specific integration meetings when *milestones* are reached. Milestones are reported in the table below.

Milestone	Name	Related WPs	Date	Means of verification
M1	Definition of behavior representation, reasoning tasks and stereotypes	WP1, WP2	M12	All partners fully understand and approve the first iteration of D1.1 and D2.1
M2	Definition of in-house and deployment use cases and system functionalities	WP4, WP5	M12	All partners fully understand and approve D4.1 and the first iteration of D5.1
M3	Scripted demo of in-house use cases, preliminary testing successful	WP5	M18	Demo successfully shows the novel capability of the pro- posed framework; all partner approve first iteration of D5.2
M4	Definition of monitoring and behavior adaptation techniques	WP1, WP2, WP3, WP4	M24	All partners fully understand and approve of the second iteration of D1.1, D2.1 and D3.1, and the first iteration of D1.2, D2.2, D3.2, D4.2
M5	Methods, techniques and technologies for HESA	WP1, WP2, WP3, WP4	M36	All partners fully understand and approve of the final iteration of D1.1, D2.1, D3.1, D1.2, D2.2, D3.2, and D4.2
M6	Final demo on cognitive robots that reason and act using behaviors ascribed to other agents	WP5	M36	Successful integration of HESA techniques into existing robotic software; demo successfully run and evaluated; all partners approve the final iteration of D5.2.

Risk assessment. As a scientifically and technologically challenging initiative, the HESA project carries a degree of risk, which the partners will control. During the quarterly meetings, the GA will hold a dedicated session to identify, evaluate, and track project risks. Members of the consortium have very significant experience in collaborative EU projects and have an excellent shared understanding of the technical issues ahead. Because of this we believe the coordination risks are minimal.

Description of risk	Inv.ed WPs	Proposed risk-mitigation measures
One partners fails	All	Carefully previous selected and fully engaged partners, most with cooperation and experience in EU projects.
UNIMELB cannot coordinate enough with EU partners	All	The project is carefully designed so as to guarantee success even in case UNIMELB drops out. In particular no critical tasks are assigned to UNIMELB. On the other hand, UNIMELB is very committed to the project and with great experience in international projects. Its contribution can potentially be of great benefit to the research.
Failure to coordinate and follow up on project progress and work plan, resulting in delays and failed tasks.	All	The prime contractor has significant experience in managing international projects, including the coordination of EU projects (e.g. WORKPAD, SM4All, SAPHARI). A strong management structure will be established including control measures to assure progress according to the work plan.
Some research tasks might be too complex	All	Research is organized through an iterative process to deal with complexity
Project results do not create exploitable impacts	WP5, WP6	The project includes a specific WP5 for deploying the developed technologies in a real use case as a proof of concept, creating a feedback loop for keeping the research industrially feasible and exploitable. The WP is led by a SME (IDM) with great experience in successfully conduct such activities. Moreover significant amount of resources are allocated in WP6 to dissemination and exploitation, and the WP is led again by IDM to emphasize dissemination and exploitation through industry channels.

3.3 Consortium as a whole

The consortium is formed by world leading research units with an outstanding scientific track record in the disciplines involved in the project: Cognitive Psychology (UL), Knowledge Representation and Reasoning (UOR), Multi-Agent Systems (ICL), Cognitive Robotics (RWTH), and by an industrial partner with extensive expertise in the development of robotic applications (IDM). The consortium members have a long experience in collaborative projects. They also share an excellent understanding of the technical matter. The industrial partner IDM has often been often involved in projects requiring the transfer of cutting-edge research results to actual deployment (see Section 2.1). All principal investigators of WP1-WP4 are very

active in the most prestigious conferences (over the years they have covered hundreds of PC roles) and journals in their respective areas, hence collectively have the full picture of all research trends and synergies in the areas of the projects. For example, Prof. De Giacomo (UOR) was the Program Co-Chair of KR in 2014 and is the Review Editor in AIJ and Associate Editor of JAIR; and Prof. Lomuscio (ICL) was the Program Co-Chair in AAMAS 2014 and is in the Editorial Board of JAIR; Prof. Hommel (UL) is the Editor-in-Chief of *Frontiers in Cognition* and of *Psychological Research*; Prof. Lakemeyer is the Chair of the Steering Committee of the Cognitive Robotics Workshops series and the Completion Editor of AIJ. The consortium is complemented by UNIMELB, led by constraints programming pioneer Prof. Stuckey, bringing unique expertise in optimizing, deploying and scheduling, including mining operations involving robotics, which will be used for evaluating deployment of the HESA approach. The UNIMELB team has proven scientific track records in cognitive psychology (Prof. Kashima) and cognitive robotics and multi-agent systems (Prof. Sonenberg & Prof. Pearce). UNIMELB will be funded through a Horizon 2020 Research Consortia and Networks grant by University of Melbourne (see appendix).

3.4 Resources to be committed

The ambition reflected in the objectives of the project and its workplan is paired by the quality, variety and volume of resources to be set into motion. In estimating HESA budget, the Consortium has taken full advantage of previous experience in analogous projects, as well as the new regulations of Horizon 2020. In this respect, the budget has been drafted with contributions from all partners. Therefore, the adequacy of the financial planning to ensure the integration of resources and the proper development of the workplan has been secured. Completing HESA workplan will require the Project team to deploy an estimated human effort of 317 Person Months (PMs) over the project 36 months lifecycle. Due to the nature of the project, the major effort is concentrated in research activities and in deployment, which represent about 92% of the total PMs, while the effort planned for project management, as well as dissemination and exploitation activities represents 8% of total PMs. Based in our combined experience, we understand the budget is properly adapted to secure the attainment of HESA objectives and foreseen impacts. The cost for completing the HESA project is estimated in € 3.215.165 (€ 2.397.861 for EU member states and AUD $877.194 for Australia). HESA cost structure is it follows.

Personnel costs (69% of project costs). Personnel costs were calculated on the basis of person months agreed to be allocated to the Project by the partners' own personnel, and the corresponding PM cost rates provided by each of the partners. The effort per partner are depicted in the following table.

	Science				Deployment	Exploitation	Management	
WP#	**WP1**	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**	**WP10**	**Total PMs/Partner**
Short name	UL	UOR	ICL	RWTH	IDM	IDM	UOR	
UOR	6	**28**	16	6	6	4	**12**	**78**
UL	**35**	9	0	6	6	1	0	**57**
ICL	3	9	**29**	6	2	1	0	**50**
RWTH	4	9	6	**26**	8	1	0	**54**
IDM	0	0	0	9	**21**	**4**	0	**34**
UNIMELB	6	9	6	6	16	1	0	**44**
Total PMs/WP	**54**	**64**	**57**	**59**	**59**	**12**	**12**	**317**

Travel and subsistence costs (6,8% of project costs) cover all participants' travel and daily allowance that are likely to be needed to assure an adequate participation of partners in bilateral and Consortium-wide meetings, working sessions, as well as in events organized by third parties in direct relationship with project development. Costs estimations are based on 1.000 Euros/trip/participant average cost of travelling & subsistence. Notably, travel costs are also needed to set-up the deployment of the pilots, as well maintenance over the 18-months of pilots' running.

Equipment costs (1,8% of project costs) include three service robots, augmented with additional 2D and 3D sensors and interaction capabilities, needed by RWTH for testing and demonstration purposes (average cost: 3 x 15K€).

Dissemination and outreach costs (1,5% of total project efforts) include the logistics and related expenses related to the performance of activities in the area of outreach with targeted audiences beyond the Consortium borders, including dissemination events and open-access publication costs. In particular, 10K€ per partners have been budgeted for open-access publication costs.

Subcontracting. Subcontracting is considered only for audits.

Proposal full title: **Human-inspired reasoning in Embodied, Social, artificial Agents**

Proposal acronym: **HESA**

Call: H2020- FETOPEN-1-2014

Topic: FET - Open research projects – Novel ideas for radically new technologies

Coordinator: Prof. Giuseppe De Giacomo

Email: degiacomo@dis.uniroma1.it

List of participants

Participant No	Participant organization name	Part. short name	Country
1 (Coordinator)	Università degli Studi di Roma La Sapienza	UOR	Italy
2	Universiteit Leiden	UL	Netherlands
3	Imperial College, London	ICL	UK
4	RWTH Aachen University Aachen	RWTH	Germany
5	IDMind	IDM	Portugal
6	University of Melbourne	UNIMELB	Australia

(PART B – Sections 4 & 5)

4. Members of the consortium

4.1. Participants (applicants)

4.1.1 Sapienza Università di Roma (coordinator) – (UOR)

The legal entity and its main tasks

Sapienza Università di Roma is one of the largest and oldest universities in Italy. It has established itself as one of the most prestigious academic institution in science and technology in Europe. The Department of Computer, Control, and Management Engineering ("Dipartimento di Ingegneria Informatica, Automatica e Gestionale", aka DIAG) is a multidisciplinary research center that hosts more than 70 Sapienza faculties and 10 research labs from the School in Computer Science & Engineering. The department is one of the world leaders in academic research on Artificial Intelligence, Knowledge Representation, Robotics, Service Oriented Computing, Data Management and Integration, and Algorithms. In particular, Microsoft Academic (http://academic.research.microsoft.com) ranks Sapienza first among the Italian research institutions in Artificial Intelligence in a recent ranking. The department has a long tradition in leading advanced research projects both at European and at National level. It is also deeply involved with technology transfer activities toward large and mid-sized public and private organizations, including public administrations, main telecom and software companies in Italy, large banks, and health care organizations. DIAG has deep experience working in EU programs. As an example, currently, DIAG manages more than 20 among International and National projects. The groups working in the project are internationally renowned and have gathered support from the European Commission, the Italian Ministry for Research, and the Italian Ministry for Finance, Monte dei Paschi di Siena, Finmeccanica, Telecom Italia, and IBM among others.

Role attributed in HESA

Sapienza participates through the group on Knowledge Representation and Data and Service Management coordinated by Giuseppe De Giacomo. In particular, it will bring about all competences on knowledge representation, reasoning about action, ontologies and ontology based data access, process composition and synthesis.

Principal Investigator

Prof. Giuseppe De Giacomo, Ph.D, is full professor in Computer Science and Engineering. His research activity concerns theoretical, methodological and realization aspects in different areas of Computer Science (CS) and Artificial Intelligence (AI), including Reasoning about Actions, Knowledge Representation and Reasoning (KR), Verification and Synthesis for Data Management and Integration, Service Composition and Orchestration. He has been the principal investigator of Sapienza in several national, European, and overseas projects including FP7 ACSI. He is the author of more than 200 publications in international journals, conference and workshop proceedings. According to Google Scholar, Apr. 2014, his h-index is 60, which is one of the highest in Europe in CS. According to a study (based again Google Scholar) on the top CS scientists working in Italy available at http://via-academy.org/, Giuseppe De Giacomo ranked 3rd among the most cited researchers working in Italy, and the 1st among those under 50. He was the PC chair of the 14th International Conference of Knowledge Representation and Reasoning (KR 2014), which is the most

important conference in KR and one of the most important in the whole AI field.

Scientific expertise relevant to HESA

Giuseppe De Giacomo and his research unit contributed deeply in: *(i) Reasoning about Actions*, in particular, he, together with Yves Lesperance and Hector Levesque, is the inventor of ConGolog and of the transition semantics for high level robot programs (incidentally he was the organizer of the original Cognitive Robotics workshop in 1998), more recently he and his group devised general conditions that guarantee decidability of reasoning and verification in Situation Calculus; *(ii) Knowledge Bases and Ontologies*, in particular together with Diego Calvanese and Maurizio Lenzerini, in the 90's he devised reasoning techniques for expressive description logics that evolved into standard OWL, and more recently, together with other people in his group he developed the DL-lite family of description logics which, gave rise OWL2QL Profile of OWL2, and has become a major subareas of description logics in top AI conferences; *(iii) Data Management*, where, together with Maurizio Lenzerini and Diego Calvanese he did foundational work on data integration, and with the addition of Moshe Vardi he did some of the most influential work on view based query processing with regular path expressions in graph databases; *(iv) Service-Oriented Computing*, where together with Massimo Mecella and others, he developed one of the best known formal approach for service composition, now universaly known as the "Roman Model"; the first paper on the Roman approach *Automatic Composition of E-services That Export Their Behavior*, which is possibly the most cited paper in Service Composition, got the award at the 11th International Conference on Service Oriented Computing series of conferences (ICSOC 2013) as the most influential paper ever appeared in the ICSOC conference series; (v) *Business Process Analysis*, where in the context of the EU project ACSI, together with Fabio Patrizi, Alessio Lomuscio, Rick Hull, and others, he provided foundational results on artifact-based business processes, showing the decidability of verification and synthesis in infinite state data-aware systems.

The unit has a very a large experience in running national and international research projects, and supervising researchers and students in the design and development of innovative technologies and systems. In particular, among other, the unit was involved in the FET-Open TONES: Thinking ONtologiES, which ended in 2007, and contributed to the definition of the OWL2 W3C standard as well as the development of current modern ontology reasoners. The unit was involved in EU project ACSI where and integration hub of artifact based business services was developed, as well as automated verification techniques and synthesis for data-aware processes. The unit successfully coordinated the WORKPAD project (FP6), developing a complete orchestration system running on mobile devices, and the SM4All project (FP7), developing a fully operational service composition engine. The SM4All composition engine has been deployed in a smart home in Rome and it is currently used in several courses held by Sapienza for acquainting students with the concepts of service composition and of research prototype. In precedence, the unit lead the development of an orchestration engine, with adaptation capabilities, during the project MAIS (Italian FIRB 2001). Others software prototypes of orchestration engines, all of them with specific features not available in current commercial products, include the VISPO (Italian project) Orchestrator and SmartPM, an academic effort aimed at developing an orchestration engine with automated adaptation and recovery capabilities based on planning techniques.

Project experience relevant to HESA

The unit has been involved in several European project including the following past EU funded projects: Esprit 22469 DWQ, IST-2001-34825 SEWASIE, IST-2001-33570 INFOMIX, IST-508011 INTEROP, FP6-7603 TONES, FP6-5-034749 WORKPAD, and FP7-224332 SM4All, FP7-ICT-2007-C-FET-Open VISMASTER CA, FP5 project EU-PUBLI.com, and FP6-2004-IST-4-027517 SemanticGov, FP7-ICT-225407 CoMiFin; FP7-ICT-257593 ACSI, FP7-INFSO-ICT-258888 GreenerBuilding, FP7-ICT-318338 Optique(up to 2015), FP7-257899 SmartVortex (up to 2014). Apart from European projects the unit is currently involved in various overseas projects, including the following ones: IBM Open Collaboration Research Agreement W0954341 on "data aware business processes and operation" with Rick Hull; UK Royal Society International Joint Project 2009/R2 on "web services automatic synthesis through ATL

symbolic model checking" and UK Engineering and Physical Sciences Research Council (EPSRC) Project EP/I00520X/1 "Trusted Autonomous System" with Alessio Lomuscio; Australian Research Council (ARC) Competitive Research Grant - DP120100332 "Optimisation of embedded virtual complex systems by re-using a library of available component" with Sebastian Sardina and Maurice Pagnucco.

List of 5 most relevant publications

Giuseppe De Giacomo, Yves Lespérance, Fabio Patrizi and Stavros Vassos. *Progression and Verification of Situation Calculus Agents with Bounded Beliefs*. In Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems (AMAAS 2014), 2014.

Giuseppe De Giacomo, Moshe Y. Vardi: *Linear Temporal Logic and Linear Dynamic Logic on Finite Traces.* In proceedings of the 23rd International Joint Conference on Artificial Intelligence (IJCAI 2013), 2013.

Giuseppe De Giacomo, Fabio Patrizi, Sebastian Sardiña: *Automatic behavior composition synthesis*. Artif. Intell. 196: 106-142, 2013.

Babak Bagheri Hariri, Diego Calvanese, Marco Montali, Giuseppe De Giacomo, Riccardo De Masellis, Paolo Felli: *Description Logic Knowledge and Action Bases.* J. Artif. Intell. Res. (JAIR) 46: 651-686 (2013)

Giuseppe De Giacomo, Yves Lespérance, Hector J. Levesque: *ConGolog, a concurrent programming language based on the situation calculus*. Artif. Intell. 121(1-2): 109-169 (2000)

List of most relevant previous projects or activities

(2010 - 2013) FP7-ICT-257593 STREP: ACSI: Artifact-Centric Service Interoperation, evaluated Excellent.

(2004 - 2007) FP6-ICT-7603 FET-Open TONES:Thinking ONtologiES, evaluated Excellent

(2008 - 2011) FP7-ICT-224332 STREP SM4All Smart hoMes hoMes for All, evaluated Excellent

(2010 - 2013) FP7-INFSO-ICT-258888 GreenerBuilding - An Ubiquitous Embedded Systems Framework for Energy-aware Buildings Using Activity and Context Knowledge, evaluation excellent

(2011 - up to 2015) FP7-ICT-318338 IP Optique - Scalable End-user Access to Big Data, still running

4.1.2 Universiteit Leiden – (UL)

The legal entity and its main tasks

Universiteit Leiden (UL) is the oldest university of the country and has been consistently ranked one of the top three academic and research institution in the Netherlands in several independent rankings in recent years. It provides an excellent research environment with numerous labs for behavioural, neuroscientific, and simulation-based investigations of adults and children. The Cognitive Psychology Unit has just been evaluated as the best research unit of the department and one of the two best of the country (2x5+2x4.5 on 5-point scales); it has attracted numerous grants including two EU FET IPs (PACO+, ROBOHOW) and an ERC starting grant (Nieuwenhuis); and two national (NWO) grants: a programme of excellence grant (Hommel) and a VIDI grant (Colzato). The university strongly supports and promotes interdisciplinary research between the social sciences, engineering, medicine, and the humanities. This research is facilitated by the Leiden Institute for Brain & Cognition (LIBC), of which Hommel is co-founder and co-director.

Role attributed in HESA

UL participates through the cognitive robotics group of the Cognitive Psychology Unit led by Bernhard Hommel. The group will bring all required competences on the psychological basis of HESA, conduct all the empirical studies required for WP1, and provide the required empirical findings and resulting database as input for the other WPs.

Principal Investigator

Prof. Dr. Bernhard Hommel holds the chair of General Psychology since 1999. He is co-founder and co-director of the Leiden Institute for Brain and Cognition. He has made numerous contributions to the interaction between perception and action in general and the sensorimotor foundation/embodiment of cognition in human infants and young and old adults in particular. Together with Roy de Kleijn and Dr. Pascal Haazebroek (members of the cognitive robotics group) and other colleagues, he has published pioneering work on the contribution of cognitive psychology to cognitive robotics. He has published more than 290 articles on human and artificial cognition in high-impact international peer-reviewed journals (>240) and books (h-index=41). With his colleagues, he has developed the (highly cited: >1000 in Scopus) most integrative theoretical framework on the embodiment of human cognition to date (the Theory of Event Coding) explaining how cognitive representations emerge from, and are grounded in perceptuomotor interactions. This theory, and the numerous empirical studies supporting it, have provided the basis for various network models that successfully simulate/reproduce important human cognitive functions.

Scientific expertise relevant to HESA

UL will offer key competences to the project in human and robotic action control and action perception, in both theoretical modelling and empirical research and experimenting. UL will lead WP1, and will be active in, and provide data for WP2 and WP4. Specifically, UL's contribution will focus on the biological/human plausibility of the project and the models developed therein, and on the provision of experimental findings for the construction of human-inspired cognitive models.

Project experience relevant to HESA

Prof. B. Hommel is currently serving as principal Investigator (PI) for the EU-FET "Robohow.Org", which serves to enable robots to competently perform everyday human-scale manipulation activities. Before he was one PI of the EU-FET "PACO PLUS" that served to design a cognitive robot that is able to develop perceptual, behavioural and cognitive categories in a measurable way and to communicate and share these with humans and other artificial agents. He also is the main PI of the NWO (Dutch research agency) programme of excellence project "Cognitive and motivational components of adaptive and maladaptive decision-making: an integrative approach" and various (>10) DFG (German) and Volkswagen Foundation projects on action control and on the relationship between perception and action.

List of 5 most relevant publications

de Kleijn, R., Kachergis, G., & Hommel, B. (2014). Everyday robotic action: Lessons from human action control. *Frontiers in Neurorobotics, 8:13*.

Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences, 8*, 494-500.

Hommel, B. (2009). Action control according to TEC (theory of event coding). *Psychological Research, 73*, 512-526.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*, 849-878.

Kachergis, G., Wyatte, D., O'Reilly, R.C., de Kleijn, R., & Hommel, B. (in press). A continuous time neural model for sequential action. *Philosophical Transactions of the Royal Society B*.

List of most relevant previous projects or activities

(2000-2003) Neurophysiological mechanisms and temporal dynamics of feature integration in perception and action planning. Volkswagen Foundation (~420.000€)

(2001-2007) Development of executive functions. Priority Program "Executive functions" of the German Research Community (DFG) (~500.000€)

(2006-2010) Perception, action & cognition through learning of object-action complexes. EU Integrated Project Grant (~650.000€)

(2010-2015) Cognitive and motivational components of decision-making: an integrated approach. NWO, Netherlands (~500.000€)

(2012-2016) ROBOHOW.ORG: Web-enabled and experience-based cognitive robots that learn complex everyday manipulation tasks. FP7 EU-Integrated Project (Cognitive Systems and Robotics Initiative)

4.1.3 Imperial College London – (ICL)

Imperial College London

The legal entity and its main tasks

The department of Computing at Imperial College London employs approximately 60 academic staff, about 130 postdoctoral researchers and 130 doctoral students. In the UK Government rating system the department is rated excellent in teaching, was ranked 2nd in the UK-wide Research Assessment Exercise of 2008, and received the highest score in the previous Research Assessment Exercises (1996, 2001). In the 2014 QS world rankings of top universities Imperial College London is rated 3rd (2nd in Europe after Cambridge). The department's main research areas are in logic-based foundations of computing, software engineering, artificial intelligence, high-performance computing, and computer vision. On the specific themes of the project, the Department of Computing has been a leading international centre for research in artificial intelligence and computational logic since 1975, and in particular in knowledge representation and automated reasoning, including recent results in automatic model checking. The project will build directly upon this latter expertise. At Imperial the project will be hosted by the Logic and Artificial Intelligence Section within the group for the Verification of Autonomous Systems led by Professor Lomuscio. The section comprises over 10 permanent members of staff and several post-doctoral and doctoral researchers. Throughout the years, the section has been supported by a number of research grants from the UK, the EU, as well as information technology companies.

Role attributed in HESA

Imperial will offer world-leading expertise in modelling, verification and synthesis techniques for multi-agent systems. Imperial's key contribution will be in WP3 (WP leaders) and WP2 (key participants). Specifically, Imperial's contribution will involve the design and analysis of verification and synthesis algorithms for HESAs in WP3 as well as the definition of a logically well-founded semantics for HESAs in WP2. Both WP combined constitute the backbone for the reasoners to be developed and deployed in the HESAs in WP4.

Principal Investigator

Prof. Alessio Lomuscio, Ph.D, is Full Professor in logic for multi-agent systems in the Department of Computing, Imperial College London, where he leads the VAS (verification of autonomous systems) research group. He currently holds an EPSRC Leadership Fellowship (2010-2015) and serves on the UK Computing Research Committee (2014-present). He received a PhD in Computer Science from the University of Birmingham in 1999 and a Laurea in Electronic Engineering from Politecnico di Milano in 1995. Before joining Imperial he was Lecturer at King's College London and Senior Lecturer at University College London. His research interests concern the specification and verification of multi-agent systems by means of techniques based on computational logic. In particular, he has made theoretical contributions in the area of logic for multi-agent systems (including studying the completeness, decidability and complexity of several temporal-epistemic formalisms) and has done pioneering work in the area of model checking for the verification of agent-based systems. He has applied the techniques developed in his lab to the verification of a range of applications including autonomous underwater vehicles, web-services and security protocols including e-voting.

He has published over 100 research papers in internationally leading conferences on the topics above. He is co-author of MCMAS, an open-source, BDD-based model checker for multi-agent systems developed at the VAS research group at Imperial. In the past 15 years he has served in a variety of roles at a number of

international conferences on logic, artificial intelligence, and multi-agent systems. In 2014 he was elected to serve as programme co-chair for AAMAS-2014 (the leading scientific conference on multi-agent systems), workshop co-chair for ICSOC 2014 (the leading conference in service-oriented computing) area chair of KR 2014 (the leading conference in knowledge representation) as well as ECAI 2014 (the key European Conference in Artificial Intelligence). In 2015 he will be Senior Programme Committee Member for AAAI-2015 (the 29th AAAI Conference on Artificial Intelligence) and AAMAS-2015 (the 13th Conference on Autonomous Agents and Multi-Agent Systems). He has served in over 100 programme committee roles over the past 15 years. In 2014 he was invited speaker at Time-2014 (the 21st International Symposium on Temporal Representation and Reasoning) and Gandalf-2014 (the 5th International Symposium on Games, Automata, and Formal Verification), SR2014 (the 2nd Strategic Reasoning workshop held as part of ETAPS 2014), and invited lecturer at the AVOCS SPES_XT Summer School on model-based design and analysis of cyber-physical systems. Over the past 15 years, he has given over 50 invited lectures and graduate courses.

Scientific expertise relevant to HESA

Imperial will offer key competences to the project in verification, reasoning, and synthesis techniques for multi-agent systems. Correspondingly, Imperial will lead WP2, and will be active in WP1 and WP2 while focusing at the same time on developments in other parts of the project. Specifically, Imperial's contribution will focus on the definition of the conceptual framework for HESA in WP1 including the definition of a semantics for HESA that can be used to model the primitives of perception, knowledge and ability which will be used to specify MAS as well as HESA as a whole.

Project experience relevant to HESA

Prof. A. Lomuscio is currently serving as principal Investigator (PI) for the EPSRC research project "Trusted Autonomous Systems". He served as PI for 3 FP7 EU Strep Projects and several EU Marie Curie FP7 projects. He served as PI for 4 more national projects. Overall, in the past 10 years he served as PI for over 20 research projects for a total budget of 5m euros. All projects he has been involved in focus on verification methodologies for a wide range of agent-based systems; these methodologies are central to the project and specifically to WP2 and WP3.

List of 5 most relevant publications

P. Kouvaros, A. Lomuscio. *A Cutoff Technique for the Verification of Parameterised Interpreted Systems with Parameterised Environments.* Proceedings of the 23rd International Joint Conference on Artificial Intelligence (IJCAI13). Beijing, China. pp 2013-2019. AAAI Press.

F. Belardinelli, A. Lomuscio. *Interactions between Knowledge and Time in a First-Order Logic for Multi-Agent Systems: Completeness Results.* Journal of Artificial Intelligence Research. Vol 45, pp 1-45.

F. Belardinelli, A. Lomuscio, F. Patrizi. *An Abstraction Technique for the Verification of Artifact-Centric Systems.* Proceedings of the 13th International Conference Principles of Knowledge Representation and Reasoning (KR12). Rome, Italy. pp 319-328. AAAI Press.

Lomuscio, H. Qu, F. Raimondi MCMAS: *A model checker for the verification of multi-agent systems.* Proceedings of the 21th International Conference on Computer Aided Verification (CAV09). Grenoble, France. Lecture Notes in Computer Science. Vol 5643 pp 682-688. Springer.

M. Kwiatkowska, A. Lomuscio, H. Qu. *Parallel Model Checking for Temporal Epistemic Logic.* Proceedings of the 19th European Conference on Artificial Intelligence (ECAI10). Lisbon, Portugal. pp 543-548. IOS Press.

List of most relevant previous projects or activities
(2011 - up to 2016). UK EPSRC. Trusted Autonomous Systems (EP/I00520X/1). Leadership fellowship. Project value: £1,060,000. (2010 - 2013) FP7-ICT-257593 STREP: ACSI: Artifact-Centric Service Interoperation. (2010 - 2012). EU FP7 Marie Curie Mobility Scheme. DiVerMas: Distributed Systems Verification by MAS-based Model Checking (PIEG-GA-2009-252184). (2009 - 2011). EU FP7 Marie Curie Mobility Scheme. FoMMAS: First-order Modal Logics for the Specification and Verification of Multi-Agent Systems (PIEG-GA-2009-235329). (2007 - 2010). UK EPSRC (Responsive mode). Methods for reliability and control for autonomous underwater vehicles. (EP/E02727X). Project value: £305,000.

4.1.4 RWTH Aachen University Aachen – (RWTH)

The legal entity and its main tasks

RWTH Aachen University (www.rwth-aachen.de), established in 1870, is divided into 9 faculties, including the medical faculty. Currently around 40,375 students are enrolled in over 130 academic programs. The number of foreign students (6,395) substantiates the university´s international orientation. Every year, more than 5,800 graduates and 750 doctoral graduates leave the university. Approximately 512 professors as well as 4675 academic and 2443 non- academic colleagues work at RWTH Aachen University. The university budget amounts to 884 million Euros, of which nearly 445 million Euros are funded by third parties. Moreover, special field research, 27 graduate colleges, among them 15 founded by the German Research Foundation, 16 affiliated institutes with strong industrial alignment illustrate the university´s considerable research potential.

The Department of Computer Science at RWTH Aachen University consistently ranks among the top three Computer Science Departments in Germany. With close to 30 faculty members, the Department spans a broad spectrum of Computer Science, including Theoretical Computer Science, Computer Graphics, Human-Computer Interaction, Embedded Systems, Information Systems, Distributed Systems, Security, Artificial Intelligence, and Robotics. The Department participates in several measures of the "Excellence Initiative" funded by the German Science Foundation (DFG), the EU funded Human Brain Project, and many others. Overall, the Department attracts external funding in the amount of 15 Million Euros per year.

Role attributed in HESA

RWTH offers key competences in applying knowledge representation and reasoning techniques, in particular, action languages based on the situation calculus, to the high-level control of autonomous robots. RWTH will play a leading role in integrating methods developed in HESA into robotic platforms.

Principal Investigator

Prof. Gerhard Lakemeyer, Ph.D., received his Ph.D. from the University of Toronto in 1990. After six years at the University of Bonn, he joined the faculty of the Department of Computer Science at RWTH Aachen University, where he heads the Knowledge-Based Systems Group. His research interests include Knowledge Representation and Cognitive Robotics. He has published more than 120 scientific papers and has served on numerous national and international program committees, including IJCAI, AAAI, ECAI, and KR, and he served as Program co-Chair of the Commonsense Symposium, the Robocup Symposium, the German Conference on Artificial Intelligence, and the Cognitive Robotics Workshop, where he also serves as the Chair of the Steering Committee. He is an ECCAI Fellow and an Associate Editor of Artificial Intelligence and Computational Intelligence. He is also a member of the Editorial Board of the Journal of Applied Logic, and he was a member of the Advisory Board of the Journal of Artificial Intelligence Research.

Scientific expertise relevant to HESA

The scientific expertise of the Knowledge-Based Systems Group (KBSG) at RWTH relevant to HESA ranges from the study of formal aspects of Knowledge Representation and Reasoning (KR&R) to their applications in Cognitive Robotics. In particular, KBSG has investigated the foundations of the situation calculus and the action language Golog and it has applied Golog as the high-level control component of

domestic service robots and others. Apart from high-level robot control issues, KBSG has also been concerned with other robotic issues such as robot middle ware, gesture and activity recognition. To demonstrate its research in robotics, KBSG regularly participates in Robocup. The group twice became world champion in the Robocup@Home competition. In 2014, the group became world champion in the Logistics League.

KBSG operates its own Robotics Laboratory, which includes a simulated home environment consisting of a kitchen and living room. It operates a number of robotic platforms and robot arms.

Project experience relevant to HESA

KBSG is the coordinator of the DFG Research Unit FOR1513 on "Hybrid Reasoning for Intelligent Systems," funded by the German Science Foundation (DFG) with seven partners from five German universities. Two of the projects of the Research Unit, which KBSG is participating in, are concerned with planning and action control under uncertainty for mobile manipulation tasks and the verification of Golog programs, namely: the DFG Project “Planning Techniques in Action Languages” (joint with B. Nebel, Freiburg), and the DFG Project “Real-time deliberation in cooperating multi-robot systems in highly dynamic environments”

List of 5 most relevant publications

S. Schiffer, A. Ferrein, G. Lakemeyer. Caesar: an intelligent domestic service robot. Intelligent Service Robotics 5(4): 259-273, 2012.

Tim Niemueller, G. Lakemeyer, and S. Srinivasa. A generic robot database and its application in fault analysis and performance evaluation. IROS 2012, 364-369.

A. Ferrein and G. Lakemeyer. Logic-Based Robot Control in Highly Dynamic Domains, Robotics and Autonomous Systems, Elsevier, 2008.

J. Claßen, P. Eyerich, G. Lakemeyer, and B. Nebel: Towards an Integration of Golog and Planning. IJCAI 2007: 1846-1851.

H. J. Levesque and G. Lakemeyer. Cognitive Robotics. In Frank van Harmelen, Vladimir Lifschitz, and Bruce Porter, editors, Handbook of Knowledge Representation, Elsevier, 2007.

List of most relevant previous projects or activities

(2012-2015) DFG (German Science Foundation) Research Unit (coordinator): Hybrid Reasoning for Intelligent Systems, FOR1513, EUR 1,500,000, extension under review.

(2005-2009) DFG (German Science Foundation) Project: Planning Techniques in Action Languages, LA747/13-2, LA747/14-1, EUR 250,000.

(2001-2008) DFG (German Science Foundation) Project: Real-time deliberation in cooperating multi-robot systems in highly dynamic domains, LA 747/9-3, EUR 700,000.

4.1.5 IDMind (IDM)

The legal entity and its main tasks

IDMind (IDM) is a Portuguese SME, founded in April 2000, and is presently located at the Lisbon Technological Park. The company has extensive experience in the construction of mobile robotic platforms, involving the following main aspects: the design and construction of low-level microcontroller based modular electronics to acquire different type of sensor signals and to control different type of motors; establishing low-level interfaces in-between dedicated electronic modules; interfacing low-level electronics with high-level processing units; robust mechanical design and use of different materials and tools. The company has developed in recent years complete sets of robot platforms: small sized microcontroller based robots; indoor and outdoor PC based differential platforms; indoor holonomic platforms; and outdoor tracked robots for remote inspection. The current core business of IDM is to provide solutions for RTD projects, industry, and services. These projects include complete robot solutions, as well as electronics design and system integration for existing hardware platforms. IDM is member of euRobotics AISBL and SPR (Portuguese Robotics Society).

Role attributed in HESA

IDM will be leading WP5 and WP6. The Company will contribute to overall system integration and validation, system deployment and evaluation in the defined scenarios. Furthermore will use its experience to maximize the visibility of HESA while road-mapping commercial exploitation of its results.

Principal Investigator

Paulo Alvito, Company Manager, received the Licenciatura (5-year degree) in Electrical and Computer Engineering from Instituto Superior Tecnico, Tech. Univ. of Lisbon, Portugal, in 1995. He has been managing IDMind since its foundation in 2000. He lectured Control, Robotics and Industrial Instrumentation at the School of Technology from the Polytech. Inst. of Setubal, from 1997 to 2006. Previous R&D activities include: Robotic Vision applied to Mobile Robotic Navigation at the Milan Polytech. Univ. - Italy, under the European Research Network (ERNET); implementation of control architectures applied to mobile robots at the Intelligent Systems Lab of the Institute for Systems and Robotics (ISR/IST), Lisbon. Recently he has been managing the company's participation in different projects.

Relevant Experience (EU level)

(2006-2009) Leader of integration task in “ROBOSWARM - knowledge environment for interacting ROBOt SWARMs” (European IST Project – FP6). (2011-2014) Leader of robot platform design and construction work package in “FROG - Fun Robotic Outdoor Guide” (collaborative project under the FP7-ICT-2011.2.1). (2011-2015) Leader of system integration work package in “Social Robot” (collaborative project under FP7, People Program, IAPP). (2013-2016) Leader of robot design and construction work package in “MonarCH - Multi-Robot Cognitive Systems Operating in Hospitals” (collaborative project under FP7-ICT-2011.2.1).

Relevant Experience (Exploitation of Results)

Some of the robot platforms and solutions that the company is presently offering are stemming from previous research projects with strong academic collaborations. In particular, the “4WD - 4 Wheel Differential Outdoor Robot Platform” was born from the collaborative project FROG EU FP7. The “Omnidirectional Platform” was born from the collaborative project MOnarCH EU FP7. Another good example is “RAPOSA”, a tracked outdoor remote inspection robot, which was born from project led by the company in partnership with Academia. The RAPOSA project was also among the four finalists for the “EURON 2006 Technology Transfer Award”. Integrated in a joint interactive project with another Portuguese company, IDM developed a fleet of indoor autonomous mobile robots that guide visitors to the Visitor's Centre of the “Ciudad Grupo Santander”, near Madrid, Spain. This installation has been running continuously, on a 24/7 basis, for more than four years. This experience was repeated recently in Sao Paulo, Brazil, with the installation of a set of robots that greet and assist visitors in a new branch of Bank Bradesco, located in Sao Paulo’s high-end JK Iguatemi Mall.

List of most relevant previous projects or activities

2006 - 2009) ROBOSWARM - knowledge environment for interacting ROBOt SWARMs (FP6-IST: 045255)

(2011 - 2014) FROG - Fun Robotic Outdoor Guide (FP7-ICT-2011-7: 288235)

(2011 - up to 2015) SocialRobot (FP7-PEOPLE-2011-IAPP: 285870)

(2013 - up to 2016) MonarCH - Multi-Robot Cognitive Systems Operating in Hospitals (FP7-ICT-2011-9: 601033)

(2013 - up to 2017) SQUIRREL (FP7-ICT-2013-10: 610532)

4.1.6 University of Melbourne – (UNIMELB)

The legal entity and its main tasks

The University of Melbourne is an internationally recognized university with excellence in research over a comprehensive range of disciplines. It is globally engaged, research-intensive, and uniquely positioned to respond to major social, economic and environmental challenges. The University has established itself as a leading research university in the Asia-Pacific region, topping the key indicators in the latest ERA (Excellence in Research for Australia) report. The discipline of Computer Science and Information Systems at the University of Melbourne was ranked equal 24th in the world by the latest QS subject rankings, and was given the maximum rating of 5 ("well above world standard") in the latest ERA evaluation exercise. In the Microsoft Academic 2012 analysis of "top organizations in computer science", the University of Melbourne was ranked first in Australia and sixth in the Asia-Pacific, behind four Israeli and one Singaporean university. The Department of Computing and Information Systems is a large department with a strong focus on research and research training, with excellent facilities and computing resources. These advantages allow it to continually attract top students and researchers from around the world.

Role attributed in HESA

The University of Melbourne will investigate the deployment and evaluation of HESA techniques in automated robotic open-pit mining operations and extension into new domains. The University of Melbourne will utilise key competences in discrete optimization, modelling of, multi-agent systems, cognitive robotics and the psychology of human-robot interactions for the systematic exploitation of HESA techniques.

Principal Investigator

Prof. Peter J. Stuckey, Ph.D, is a Professor in the Department of Computing and Information Systems at the University of Melbourne since 2003 where he leads the Optimization and Programming Languages research group, he is also a project leader in the National ICT Australia Optimization research group. He received his PhD in Computer Science from Monash University in 1988.

Peter Stuckey is a pioneer in constraint programming, involved from its very inception, a form of discrete optimization that has made it possible to solve some kinds of problems (particularly scheduling) that were effectively unsolvable with any previous technology. Since 2005 he has helped create and lead one of the largest teams of constraint programming research in the world. The group is attempting to radically change the way that discrete optimization problems are tackled, and unify the diverse research fields that tackle these problems. He currently leads the platform project with the optimization research group at NICTA, developing the next generation of discrete optimization technology.

He has published over 90 journal papers and almost 200 refereed conferences papers. He has published in the premier journals of artificial intelligence, bioinformatics, operations research, programming languages, and theoretical computer science, as well as the premier conferences in constraint programming, programming languages, and artificial intelligence. Peter Stuckey has over 9500 citations on Google Scholar with an h-index of 47 and i10-index of 175. In July 2009 he was recognized as an ACM Distinguished Scientist. In August 2010 he was awarded the Google Australia Eureka Prize for Innovation in Computer Science for his work on lazy clause generation. In January 2011 he was awarded the University of Melbourne's Woodward Medal for most outstanding publication in Science and Technology across the

university.

Within the last 10 years Peter Stuckey has been chief investigator in 8 Australia Research Council projects with a combined budget of over AUD5.5 million. Note that these grants are for small teams, typically 3 people. He has also been involved in grants from Hong Kong, Singapore, Japan, Belgium, and Spain.

Scientific expertise relevant to HESA

The University of Melbourne offers key competences in discrete optimization, the modelling of, multi-agent systems, cognitive robotics and the psychology of human-robot interactions. The University of Melbourne is actively involved in advancing techniques used for large-scale autonomous mining operations, including two projects including the Australian Research Council (ARC) funded project LP110100115 Making the Pilbara Blend: agile mine scheduling through contingent planning and LP110200524 Mathematics and computing for integrated stockyar-centric management of mining supply chains. These projects are examples of the expertise in scheduling and optimisation for autonomous systems that the University of Melbourne brings to the HESA project.

The University of Melbourne (UNIMELB) team have proven scientific track records with Prof Stuckey and A/Prof Pearce working in the Optimization Group of NICTA at the Department of Computing and Information Systems. Prof Stuckey is the project leader for the well-known G12 constraint programming platform and Professors Stuckey and Pearce are working closely together on scheduling autonomous open-pit mining operations. Prof. Sonenberg and A/Prof Pearce are presently working on ARC Discovery project DP130102825 Foundations of human-agent collaboration: situation-relevant information sharing (2013-15). Prof Kashima from the School of Psychology and is working actively with members of the team on cognitive psychology aspects including the common grounding problem.

Project experience relevant to HESA

Peter Stuckey leads the platform project at NICTA which develops state of the art solving technology for discrete optimization. Using this technology he has recently closed many open scheduling benchmarks, demonstrating its effectiveness. He is involved in three current projects solving discrete optimization problems for industry partners, Rio Tinto, Oracle and the Hunter Valley Coal Chain Collective.

List of 5 most relevant publications

Nir Lipovetsky, Christina Burt, Adrian R. Pearce, and Peter J. Stuckey. Planning for mining operations with time and resource constraints. In S. Chien and A. Fern, editors, Proceedings of the 24th International Conference on Automated Planning and Scheduling, pages 404-412, 2014.

A. Schutt, T. Feydy, P.J. Stuckey, and M. Wallace. Solving RCPSP/max by lazy clause generation. Journal of Scheduling, 16(3):273-289, 2013.

A. Metodi, M. Codish, and P.J. Stuckey. Boolean equi-propagation for concise and efficient SAT encodings of combinatorial problems. Journal of Artificial Intelligence Research, 46:303-341, 2013.

O. Ohrimenko, P.J. Stuckey and M. Codish. Propagation via lazy clause generation. Constraints, 14(3):357-391, 2009.

C. Schulte and P.J. Stuckey. Efficient constraint propagation engines. ACM Transactions on Programming Languages and Systems, 31(1): Article No. 2, 2008.

List of most relevant previous projects or activities
(2012 - up to 2015) ARC (Australian Research Council) Linkage Grant: Making the Pilbara Blend: agile mine scheduling through contingent planning, LP110100115, AUD $1,360,000 (2012 – 2014) ARC Linkage Grant: Mathematics and computing for integrated stockyard-centric management of mining supply chains, LP110200524, AUD $560,000 (2011 - up to 2015) ARC Discovery Grant: Harnessing constraint technologies DP110102579, AUD $479,000 (2004 - 2014) NICTA (National ICT Australia): G12 Constraint Programming Platform (2012 - up to 2015) AOARD (Asian Office of Aerospace Research and Development) - Lifelong Optimization. FA2386-12-1-4056, USD $291,200, extended USD $145,600 until 2015

4.2. Third parties involved in the project (including use of third party resources)

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties[1]	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N

5. Ethics and Security

5.1 Ethics

Each party who provide information to the other party with connect to this project ("Contributor") represents that: (i) it has the authority to disclose the information, if any, which it provides to the other parties; (ii) where legally required and relevant, it has obtained appropriate informed consents from all the individuals involved, or from any other applicable institution, all in compliance with applicable regulations; and (iii) there is no restriction in place that would prevent any such other party from using the information for the purpose of the Agreement.

Any Contributor will not include any information as defined by Article 2 section (a) of the European Data Protection Directive, i.e., any information relating to an identified or identifiable natural person or data subject, where an 'identifiable person' is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his or her physical, physiological, mental, economic, cultural or social identity ("Personal Data").

To this end, the providing party will take all necessary steps to ensure that the Information is "de-identified", i.e., that all Personal Data is removed from the provided information, made illegible, or otherwise made inaccessible to the receiving parties prior to provision.

Each Contributor shall be responsible for ensuring its own compliance with all laws and regulations applicable to its activities, including without limitation the acquisition and sharing of data, the processing of data by it through any tool used in connection with the Project and the use of such data in accordance with the provisions of this CA. Such laws include, but are not limited to, those in respect of rights of privacy, publicity, reputation and intellectual property rights, including patent and copyright rights.

Each Contributor shall be solely responsible for the selection of specific database vendors, data collectors and data providers, and for the performance (including any breach) of any contract between it and any such database vendor, data collector or data provider, to which no other Contributor shall be a party, and under which no other Contributor assumes any obligation or liability.

[1] A third party that is an affiliated entity or has a legal link to a participant implying a collaboration not limited to the action. (Article 14 of the Model Grant Agreement).

A key ethically sensitive issue for the project is related to the aspect of protecting site visitors with regard to the processing and moving of personal data, i.e., privacy. The project consortium hereby commit to carrying out all research activities in strict conformity with EU and national level legislation. First and foremost, the Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data is to be vigilantly adhered to throughout the course of the project prior to any research/development activity for which this Directive bears relevance. The project also plans to follow established general principles (such as 97/66 EC and other rules defined by ISTAG and eEUROPE), namely:

- Obtain the explicit consent of the subscriber.
- Provide complete information about the use and storage of the data.
- Only use the data for the purpose for which they were collected.
- Erase personal data after use or make them anonymous.
- Give the user the possibility to restrict transmission of location information.
- Ensure the security of the network.
- Do not transfer the data to a third party without the consent of the subscriber.

5.1.1 Core ethical issues

The main ethical issue related to the project concerns the use of the data gathered during the interaction between a robot agent and a human. In order to guide the handling of personal data, the consortium will follow the 95/46/EC Privacy directive of 4th April 1995 about individual protection for personal data management and distribution.

Most types of sensors used by the robot agents in the HESA project will not collect (a priori) any type of especially sensible data, such as identity, medical information, genetics, etc. However, during the interaction between a human and a robot, the robot can potentially record and store information about users biometrics and position. The consortium will regard the fulfilment of the European Directive during the project, and all sensible data will be encrypted and protected during storage and transmission (which usually takes place across third-party networks) so that users' identity and privacy will not be compromised because of the introduced sensors.

An Ethical Advisory Board will be constituted within the project to take care of issues related to ethics and confidentiality of collected data. This board will be constituted by members from UOR and IDM partners, for their prominent role in the project. The Ethical Advisory Board will provide guidelines for data handling to the partners, and will ensure that respective companies follow best practices and give appropriate assurances regarding data acquisition, processing, storage and transmission. The legal framework of the project will determine the proper accounting of responsible parties in case of information compromising.

5.1.2 Human participants

All the users involved in the deployment pilots and showcases will be informed prior to their participation that their data will be protected and encrypted and that it will only be used for the platform testing and within the consortium, banning any kind of dissemination for commercial activities. A signed contract will provide them with the information about how the data will be handled. In addition, they will be asked to give their consent to the consortium to use the data for tests purposes. Both the consortium and users will sign the contract, and the Ethical Board will grant its fulfilment. After completion of the project, all collected data will be destroyed after having served its purpose of validating and improving HESA.

In order to involve a human as a participant in research, the investigator will obtain the legally effective informed consent of the participant or the participant's legally authorized representative. All investigators within HESA will seek such consent only under circumstances that provide the prospective participant or the representative sufficient opportunity to consider whether or not to participate and that minimizes the possibility of coercion or undue influence. The information given to the participant or the representative will

be in language understandable to the participant or the representative. In no case people unable to give consent will be involved in any activities related to the project.

All the sensitive data coming from the persons participating to the use cases will be used in the moment of the showcase but not be retained, thus resolving potential data privacy issues.

5.2 Security[2]

Please indicate if your project will involve:

- activities or results raising security issues: NO
- 'EU-classified information' as background or results: NO

[2] Article 37.1 of Model Grant Agreement. *Before disclosing results of activities raising security issues to a third party (including affiliated entities), a beneficiary must inform the coordinator — which must request written approval from the Commission/Agency;* Article 37. *Activities related to 'classified deliverables' must comply with the 'security requirements' until they are declassified; Action tasks related to classified deliverables may not be subcontracted without prior explicit written approval from the Commission/Agency.; The beneficiaries must inform the coordinator — which must immediately inform the Commission/Agency — of any changes in the security context and — if necessary —request for Annex 1 to be amended (see Article 55)*

References

[AlHK02] Alur, R., Henzinger, T. A. and Kupferman, O. Alternating-Time Temporal Logic. *Journal of the ACM, 49(5), 672–713* (2002)

[Bate72] Bateson, G. Steps to an ecology of mind. *University of Chicago Press* (1972)

[BCDL03] Berardi, D., Calvanese, D., De Giacomo, G., Lenzerini, M. and Mecella, M. Automatic composition of e-services that export their behavior. *In: Service-Oriented Computing-ICSOC 2003, 43-58, Springer Berlin Heidelberg* (2003)

[BCFH98] Burgard, W., Cremers, A. B., Fox, D., Haehnel, D., Lakemeyer, G., Schulz, D., Steiner, W. and Thrun, S. Experiences with an interactive museum tour-guide robot. *Artificial intelligence 114(1), 3-55* (1998)

[Brat90] Bratman, M. E. What is intention? *In: Cohen, P. R., Morgan, J. L., and Pollack, M. E (Eds.), Intentions in communication, The MIT Press: Cambridge, MA* (1990)

[BuDK13] Bulling, N., Dastani, M. and Knobbout, M. Monitoring norm violations in multi-agent systems. *Proceedings of the 2013 International Conference on Autonomous Sgents and Multiagent Systems (AAMAS'13), 491-499* (2013)

[CaDH11] Cap, M., Dastani, M. and Harbers, M. Belief/goal sharing modules for BDI languages. *In: 2011 CSI International Symposium on Computer Science and Software Engineering (CSSE), 87-94, IEEE* (2011)

[CDLL13] Calvanese, D., De Giacomo, G., Lembo, D., Lenzerini, M. and Rosati, R. Data complexity of query answering in description logics. *Artificial Intelligence, 195, 335-360* (2013)

[CDMP13] Calvanese, D., De Giacomo, G., Montali, M. and Patrizi, F. Verification and Synthesis in Description Logic Based Dynamic Systems. *In: Web Reasoning and Rule Systems, 50-64, Springer Berlin Heidelberg* (2013)

[CELN07] Claßen, J., Eyerich, P., Lakemeyer, G. and Nebel, B. Towards an Integration of Golog and Planning. *Proceedings of the 20th International Joint Conference on Artificial Intelligence (IJCAI-07), 1846-1851* (2007)

[ClLa06] Claßen, J. and Lakemeyer, G. Foundations for Knowledge-Based Programs using ES. *Proceedings of the 10th International Conference on Principles of Knowledge Representation and Reasoning (KR 2006), AAAI Press* (2006)

[CiTr98] Cialdini, R. B. and Trost, M. R. Social influence: Social norms, conformity, and compliance. *In: D. Gilbert, S. Fiske and G. Lindzey (Eds.), The handbook of social psychology, (4th edition), Vol. 2. McGraw-Hill, New York* (1998)

[CLMM14] Cermák, P., Lomuscio, A., Mogavero, F. and Murano, A. MCMAS-SLK: A Model Checker for the Verification of Strategy Logic Specifications. *Proceedings of the 26st International Conference on Computer Aided Verification (CAV 2014), 525-532* (2014)

[CoLe90] Cohen, P. R. and Levesque, H. J. Intention is choice with commitment. *Artificial intelligence, 42(2), 213-261* (1990)

[DeDM14] De Giacomo, G., De Masellis, R. and Montali, M. *Reasoning on LTL on Finite Traces: Insensitivity to Infiniteness. In: AAAI 2014, AAAI Press* (2014)

[DeLL00] De Giacomo, G., Lespérance, Y. and Levesque, H.J. ConGolog, a concurrent programming language based on the situation calculus. *Artificial Intelligence, 121(1), 109-169* (2000)

[DeLP06] De Giacomo, G., Lespérance, Y. and Pearce A. R. Situation Calculus Based Programs for Representing and Reasoning about Game Structures. *Proceedings of the 12th International Conference on Principles of Knowledge Representation and Reasoning (KR 2006), AAAI Press* (2006)

[DeLP12] De Giacomo, G., Lespérance, Y. and Patrizi, F. Bounded Situation Calculus Action Theories and Decidable Verification. *Proceedings of the 13th International Conference on Principles of Knowledge Representation and Reasoning (KR 2012), AAAI Press* (2012)

[DeLV14] De Giacomo, G., Lespérance, Y., Patrizi, F. and Vassos S. LTL Verification of Online Executions with Sensing in Bounded Situation Calculus. *In: European Conference on Artificial Intelligence (ECAI 2014), 369-374* (2014)

[DePS10] De Giacomo, G., Patrizi, F. and Sardina, S. Agent programming via planning programs. *Proceedings of the 9th International Conference on Autonomous Agents and Multiagent Systems (AAMAS'06), 491-498* (2010)

[DePS13] De Giacomo, G., Patrizi, F., and Sardina, S. Automatic behavior composition synthesis. *Artificial Intelligence, 196, 106-142* (2013)

[DeVa13] De Giacomo, G. and Vardi, M. Y. Linear Temporal Logic and Linear Dynamic Logic on Finite Traces. *Proceedings of the 23th international joint conference on Artificial Intelligence*, AAAI Press (2013)

[DDGM14] De Giacomo, G., De Masellis, R., Grasso, M., Maggi, F. M. and Montali, M. Monitoring Business Metaconstraints Based on LTL and LDL for Finite Traces. *In: Business Process Management (BPM 2014), 1-17, Springer International Publishing* (2014)

[DFPS10] De Giacomo, G., Felli, P., Patrizi, F. and Sardina, S. Two-Player Game Structures for Generalized Planning and Agent Composition. *In: AAAI 2010, AAAI Press* (2010)

[DiBa01] Dijksterhuis, A. and Bargh, J. A. The perception-behavior expressway: Automatic effects of social perception on social behavior. *In: M. P. Zanna (Ed.), Advances in experimental social psychology, 33, 1-40, Academic Press, San Diego* (2001)

[DiPH07] Dignum, F., Prada, R. and Hofstede, G. J. *Proceedings of the 2014 International Conference on Autonomous Agents and Multiagent Systems (AAMAS'14), 1161-1164* (2014)

[DLPV14] De Giacomo, G., Lespérance, Y., Patrizi, F. and Vassos S. Progression and Verification of Situation Calculus Agents with Bounded Beliefs. *Proceedings of the 2014 International Conference on Autonomous Agents and Multiagent Systems (AAMAS'14), 141-148* (2014)

[DWVV14] de Weerd, H., Verbrugge, R. and Verheij, B. Agent-based models for higher-order theory of mind. *In: Advances in Social Simulation, 213-224, Springer Berlin Heidelberg* (2014)

[FeDL12] Felli, P., De Giacomo, G. and Lomuscio, A. Synthesizing Agent Protocols From LTL Specifications Against Multiple Partially-Observable Environments. *Proceedings of the 13th*

International Conference on Principles of Knowledge Representation and Reasoning (KR 2012), AAAI Press (2012)

[FeLa08] Ferrein, A. and Lakemeyer, G. Logic-Based Robot Control in Highly Dynamic Domains. *Robotics and Autonomous Systems, Elsevier* (2008)

[FHMV95] Fagin, R., Halpern, J. Y., Moses, Y. and Vardi, M. Y. Reasoning about Knowledge. *Cambridge: MIT Press* (1995)

[FrLO01] Frank, M. J., Loughry, B. and O'Reilly, R. C. Interactions between frontal cortex and basal ganglia in working memory: A computational model. *Cognitive, Affective and Behavioral Neuroscience, 1, 137–160* (2001)

[GeBo13] Geffner, H. and Bonet, B. A Concise Introduction to Models and Methods for Automated Planning. *Synthesis Lectures on Artificial Intelligence and Machine Learning, 8(1), 1-141, Morgan & Claypool* (2013)

[GeTh14] Genesereth, M. and Thielscher, M. General Game Playing. *Morgan & Claypool* (2014)

[HCMD14] Hariri, B. B., Calvanese, D., Montali, M., De Giacomo, G., De Masellis, R. and Felli, P. Description logic knowledge and action bases. *Journal of Artif. Intell. Res. (JAIR), 46, 651-686* (2014)

[HMAP01] Hommel, B., Müsseler, J., Aschersleben, G. and Prinz, W. The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24, 849-878* (2001)

[HMDW14] Herzig, A., Menezes, V., De Barros, L. N. and Wassermann, R. On the revision of planning tasks. *In: European Conference on Artificial Intelligence (ECAI 2014), 435-440* (2014)

[HVBM11] Harbers, M., van den Bosch K. and Meyer, J. J. Agents with a Theory of Mind in Virtual Training. *In: M. Beer, M. Fasli, and D. Richards (Eds.) Multi-Agent Systems for Education and Interactive Entertainment: Design, Use and Experience, pp. 172-187* (2011)

[Iaco01] Iacoboni, M. Imitation, empathy, and mirror neurons. *Annual Review of Psychology, 60, 653-670* (2009)

[Kami07] Kaminka, G. A. Curing robot autism: A challenge. *Proceedings of the 2013 International Conference on Autonomous Agents and Multiagent Systems (AAMAS'13), 801-804* (2013)

[KwLQ10] Kwiatkowska, M., Lomuscio, A. and Qu, H. Parallel Model Checking for Temporal Epistemic Logic. *Proceedings of the 19th European Conference on Artificial Intelligence (ECAI10), 543-548, IOS Press* (2010)

[LeIn04] Lemai, A. and Ingrand, F. Interleaving Temporal Planning and Execution in Robotics Domains. *In: AAAI 2004, 617-622* (2004)

[LeLa07] Levesque, H. and Lakemeyer, G. Cognitive Robotics. *In: Frank van Harmelen, Vladimir Lifschitz and Bruce Porter (Eds.), Handbook of Knowledge Representation, Elsevier* (2007)

[Leve14] Levesque, H.J. On our best behaviour. *Artificial Intelligence, 212, 27-35* (2014)

[LoPQ10] Lomuscio, A., Penczek, W. and Qu, H. Partial order reduction for model checking interleaved multi-agent systems. *Fundamenta Informaticae 101(1-2), 71-90* (2010)

[LoQR09] Lomuscio, A., Qu, H. and Raimondi, F. MCMAS: A Model Checker for the Verification of Multi-Agent Systems. *Proceedings of the 21st International Conference on Computer Aided Verification (CAV 2009), 682–688, Springer* (2009)

[LoRa06] Lomuscio, A. and Raimondi, F. Model checking knowledge, strategies, and games in multi-agent systems. *Proceedings of the 5th international joint conference on Autonomous agents and multiagent systems (AAMAS'06), 161-168* (2006)

[LRLL97] Levesque, H.J., Reiter, R., Lespérance, Y., Lin, F. and Scherl, R.B. GOLOG: A Logic Programming Language for Dynamic Domains. *The Journal of Logic Programming, 31(1), 59-83* (1997)

[MaMP14] Mahy, C. E. V., Moses, L. J. and Pfeifer, J. H. How and where: Theory-of-mind in the brain, *Developmental Cognitive Neuroscience, 9, 68-81* (2014)

[McCa59] McCarthy, J. Programs with common sense. *Proceedings of the Teddington Conference on the Mechanization of Thought Processes, 756-791* (1959)

[McHa69] McCarthy, J. and Hayes, P. J. Some philosophical problems from the standpoint of artificial intelligence, Machine Intelligence 4, *463-502* (1969).

[McMO95] McClelland, J. L., McNaughton, B. L. and O'Reilly, R. C. Why there are complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory. *Psychological Review, 102, 419-457* (1995)

[MoMV10] Mogavero, F., Murano, A. and Vardi, M. Y. Reasoning About Strategies. *In: FSTTCS 2010, 133-144* (2010)

[NFBL10] Niemüller, T., Ferrein, A., Beck, D. and Lakemeyer, G. Design Principles of the Component-Based Robot Software Framework Fawkes. *In: Simulation, modeling, and programming for autonomous robots (SIMPAR'10), 300-311, Springer Berlin Heidelberg* (2010)

[PeLo03] Penczek, W. and Lomuscio, A. Verifying Epistemic Properties of multi-agent systems via bounded model checking. *Fundamenta Informaticae 55(2), 167-185* (2003)

[RaGe98] Rao, A.S. and Georgeff, M. P. Decision Procedures for BDI Logics. *Journal of Logic and Computation, 8(3), 293-343* (1998)

[Reit01] Reiter, R. Knowledge in action: logical foundations for specifying and implementing dynamical systems. *Cambridge: MIT press* (2001)

[RDHW07] Rogers, K., Dziobek, I., Hassenstab, J., Wolf, O. T. and Convit, A. Who cares? Revisiting empathy in Asperger syndrome. *Journal of Autism and Developmental Disorders, 37, 709-715* (2007)

[SBSL12] Schwering, C., Beck, D., Schiffer, S. and Lakemeyer, G. Plan Recognition by Program Execution in Continuous Temporal Domains. *In: KI 2012: Advances in Artificial Intelligence, 156-167, Springer Berlin Heidelberg* (2012)

[StHo96] Stränger, J. and Hommel, B. The perception of action and movement. *In: W. Prinz and B. Bridgeman (Eds.), Handbook of perception and action, 1, 397-451. Academic Press, London* (1996)

[TeBe13] Tenorth, M. and Beetz, M. KnowRob. A knowledge processing infrastructure for cognition-enabled robots. *International Journal of Robotic Research, 32(5), 566-590* (2013)

[Weis13] Multiagent Systems. *2nd edition, MIT Press* (2013)

[Wool09] Wooldridge, M. An introduction to multiagent systems. *John Wiley & Sons, 2nd edition* (2009)

[ZSSB07] Zacks, J. M., Speer, N. K., Swallow, K. M., Braver, T. S. and Reynolds, J. R. Event perception: A mind/brain perspective. *Psychological Bulletin, 133, 273-293* (2007)

[WWW1**]** JaCaMo Project. http://jacamo.sourceforge.net/

[WWW2] IDMind 4 Wheel Differential Outdoor Robot Platform. http://www.idmind.pt/en/research/4WD.php

[WWW3] IDMind Omnidirectional Platform. http://www.idmind.pt/en/research/hr.php

THE UNIVERSITY OF MELBOURNE

Research@Melbourne: Ensuring Excellence and Impact to 2025

Notice of Intent for Participation in 2014-15 Horizon 2020

This Notice of Intent (NOI) provides University of Melbourne researchers with the opportunity to request a cash contribution toward a specific 2014-15 Horizon 2020 (H2020) funding bid. This funding is to be used by the UoM Chief Investigator (CI) to undertake research at the UoM in collaboration with H2020 consortia partners.

The NOI is for upcoming H2020 calls only. If the NOI is supported, the UoM CI will be able to commit up to $AUD150,000 (maximum of $AUD50,000/yr) as a cash contribution to the H2020 bid. This would be in addition to the full cost of the in-kind contribution the CI will be making to the H2020 project. If the resulting H2020 bid is successful, funds will be released to the UoM CI(s) once all H2020 documentation has been finalised.

Please note: funding will not be allocated for requests that: 1) have not been approved for funding prior to submission of the H2020 application; 2) do not have the UoM CI listed as a formal participant on the H2020 application; and 3) could receive funding via other sources such as the NHMRC-EU scheme.

Only one application can be submitted per researcher at any one time. If a UoM applicant has an existing H2020 NOI pending or approved and subject to evaluation by the EC, then they cannot submit another application until the outcome of their existing H2020 application is known.

A. UOM CHIEF INVESTIGATOR (CI) DETAILS

Title	Prof	Name	Peter J. Stuckey		
Department		Computing and Information Systems			
Faculty		Melbourne School of Engineering			
Telephone		83441341		Email	pstuckey@unimelb.edu.au

Title	A/Prof	Name	Adrian Pearce*** (contact)**		
Department		Computing and Information Systems			
Faculty		Melbourne School of Engineering			
Telephone		83441399		Email	adrianrp@unimelb.edu.au

Title	Prof	Name	Liz Sonenberg		
Department		Computing and Information Systems			
Faculty		Melbourne School of Engineering			
Telephone		9035 8619		Email	l.sonenberg@unimelb.edu.au

Title	Prof	Name	Yoshihisa Kashima		
Department		Melbourne School of Psychological Sciences			
Faculty		The Faculty of Medicine, Dentistry and Health Science			
Telephone		8344 6312		Email	ykashima@unimelb.edu.au

Title	Dr	Name	Tim Miller		
Department		Computing and Information systems			
Faculty		Melbourne School of Engineering			
Telephone		8344 1318		Email	tmiller@unimelb.edu.au

Remove or Duplicate as required. All UoM CIs are to be listed as key or principal personnel and their roles clearly explained in the H2020 application.

B. H2020 COORDINATOR DETAILS AND NOTICE OF SUPPORT

Title	Professor	Name	Giuseppe De Giacomo		
Organisation		La Sapienza University of Rome			
Country		Italy		Email	degiacomo@dis.uniroma1.it

Please attach Letter(s) of Support (emails will suffice) from the H2020 bid coordinator(s) that indicate commitment to support UoM participation as named investigator(s) in the proposed H2020 activities.

C. H2020 CALL DETAILS AND ELIGIBILITY

Action	*Future and Emerging Technologies (FET)*			
Call	*NOVEL IDEAS FOR RADICALLY NEW TECHNOLOGIES*			
Topic	*FET-Open research projects*			
Topic Identifier	*H2020-FETOPEN-2014-2015-RIA - FETOPEN-1-2014*	Deadline (Brussels local time) 17:00	Stage 1*:	*2014-09-30*
			Stage 2*:	

* Please note: Only include deadlines for 2 stage calls where relevant.

D. PROJECT SUMMARY

In plain English briefly describe your role in the H2020 consortium and use of the requested funding.

Human-inspired reasoning in Embodied, Social, artificial Agents (HESA)

Interdisciplinary consortium: This brings together world-leading experts in computing and psychology and industrial experts in cognitive robot deployment.

Context: Agent-based systems are increasingly used as the underlying conceptual architecture for deploying complex, society critical applications, including inter-networked and robotic systems. However, agents in current systems suffer from a sort of autism stemming from their inability of ascribing expected behaviours to other agents. This prevents them from acting empathically and ultimately from interacting and coordinating successfully with humans and among themselves. There is pressing need to adopt and interact with these systems because artificial agents display a lack of social awareness; increasing the risk that society won't be able to benefit fully from this key emerging technology. This paradigm shifting project moves from the current third-person, global designer view in analysing and realizing these systems to one which is first-person based, whereby the agent deliberating the actions takes into account not only its knowledge of the world but also the expected behaviour ascribed to its peers.

Aim: The project will develop the foundation theory and implementation principles for realizing social agents, implemented on latest-generation robots and deployed for education.

UniMelb Role: The University of Melbourne team will optimise, deploy and evaluate the HESA approach for existing state-of-the-art systems that already utilise robotics, such as the scheduling of world-leading automated mining operations(our current ARC-DP project with Rio Tinto Iron Ore) and for educational purposes. This evaluation programme will serve two purposes: on the one hand it will develop new technologies for assessing and deploying the HESA approach; on the other it will guide and ground the proposed approach on long-term, society critical applications.

Shared Research Fellows: UniMelb funds will contribute towards one shared Research Fellow who will spend time between the La Sapienza University of Rome, Imperial College London and The University of Melbourne.

Exchange of Research Fellows: Three Research Fellows from Europe will visit the University of Melbourne each year - funded by the EU project - and three research fellows from the University of Melbourne will visit Europe each year - funded by Departmental funds and travel funds sourced separately from UniMelb Horizon 2020 funds - comprising of 18 trips in total.

Opportunity: This is an excellent opportunity to leverage significant background IP we have developed in scheduling and optimisation for agent systems on an international stage and to build on our current industry linkages (e.g. ARC-LP with Rio Tinto Iron Ore).

ARC-DP/LP project applications: Applications will be made to the ARC with the projects collaborators for Discovery and Linkage projects, together with industrial partners.

Interested Industry Partners: Rio Tinto Iron Ore (automation in mining), Thales Australia (software engineering complex/robotics systems), Schiavello (office automation), BAE (autonomous systems), Microsoft (Natural user interfaces).

E. UOM and H2020 funding requested

Please indicate the funds you are requesting from the University (UoM cash requested) as well as the full cost of your in-kind contribution to the H2020 project (UoM in-kind). If applicable, also indicate if one or more PhD scholarships will be allocated to this activity (UoM PhD scholarships) and the associated value (including fee remission).

Year*	UoM cash requested	UoM in-kind	UoM PhD scholarships		Total UoM Contribution
			No	$Value	
Year 1	$50,000 0.5FTE Research Fellow (Level A6 + on-costs)	$166,222 (3 Professors 0.1FTE, 1 A/Prof 0.3FTE & 1 Senior Lecturer 0.3FTE)	3	$76,176	$292,398
Year 2	$50,000 0.5FTE Research Fellow (Level A6 + on-costs)	$166,222 (3 Professors 0.1FTE, 1 A/Prof 0.3FTE & 1 Senior Lecturer 0.3FTE)	3	$76,176	$292,398
Year 3	$50,000 0.5FTE Research Fellow (Level A6 + on-costs)	$166,222 (3 Professors 0.1FTE, 1 A/Prof 0.3FTE & 1 Senior Lecturer 0.3FTE)	3	$76,176	$292,398
Total	$150,000	$498,666	3	$228,528	$877,194

* Add additional years if required noting that the total UoM funds requested cannot exceed $50,000/yr or $150,000 in total regardless of years of funding. Please provide all figures in $AUD.

In addition, please indicate the funds you are seeking directly from H2020 (H2020 Cash) and the value of any indirect support you would receive (H2020 in-kind). Examples of H2020 in-kind support include any activities to be paid by H2020 including visits by UoM researchers (including PhD students) to EU laboratories, EU collaborator visits to UoM, EU based laboratory costs and/or analysis by EU collaborators. A short description of how UoM and H2020 funding will be utilised should be provided in Project Summary (Section D).

Year*	H2020 Cash	H2020 In-kind	Total Value of H2020 bid
Year 1	$24,000AUD(travel to/from EU/Melb by 3 Research Fellows for 2-month visits)	$0	$3,000,000 EURO
Year 2	$24,000AUD(travel to/from EU/Melb by 3 Research Fellows for 2-month visits)	$0	
Year 3	$24,000AUD(travel to/from EU/Melb by 3 Research Fellows for 2-month visits)	$0	
Total	$72,000AUD	$0	

* Add additional years if required. Please indicate the total value of the H2020 bid in $AUD.

F. CHECKLIST

Please refer to the following checklist to ensure your application is eligible and has all required supporting documentation supplied.

☒ The CI is level A(6) or higher and a UoM employee at time of application and for the duration of the project

☒ Information on the H2020 action, call, topic identifier and deadline(s) is complete.

☒ Letter(s) of support (or emails) from the International H2020 Coordinator are attached; and

☒ This NOI is submitted to Melbourne Research *no later* than 4 weeks prior to the H2020 deadline.

G. SUBMISSION

1. Save the completed NOI as a single PDF using the format FACULTY_H2020NOI_NAME, where NAME is the family name and initial of the Applicant. For example, Prof John Smith from the Faculty of Arts applying for research visit support would name the file: ARTS_H2020NOI_SMITHJ.
2. Submit the completed application via Themis submissions for Head of Department approval.
3. Submit the single PDF file to Melbourne Research at international-research@unimelb.edu.au *no later* than 4 weeks before the advertised H2020 deadline.

THE UNIVERSITY OF MELBOURNE

Thursday 25 September 2014

Prof Giuseppe De Giacomo
La Sapienza Universita di Rome

University of Melbourne Letter of Commitment:
Horizon 2020 Call: Novel Ideas for Radical New Technologies
Topic: FET-Open research projects - Future and Emerging Technologies
Project Title: Human inspired Reasoning in Embodied, Social, Artificial Agents (HESA)
Lead Institution: La Sapienza Universita di Rome

The University of Melbourne hereby confirms its support for participation as a partner in the Horizon 2020 consortia, "Human Inspired Reasoning in Embodied, Social, Artifical Agents (HESA)" under the coordination of La Sapienza Universita di Rome. The University of Melbourne understands and accepts the roles and terms specified by the call regarding partner organizations.

The University of Melbourne is Australia's leading university and among the top universities in the world. It was ranked 34 in the recent Times Higher Education World University Rankings 2013-2014, and 44 in the Academic Ranking of World Universities, demonstrating the significant capacity of its comprehensive and interdisciplinary research portfolio. The University was recently awarded a European Union Centre focused on Shared Complex Challenges demonstrating not only our commitment to the European Union but our ability to play a major role in the consortium.

The University's outstanding research infrastructure, competencies and expertise are fundamental to the objectives of HESA Consortia. Professors Peter Stuckey, Liz Sonenberg and Adrian Pearce from the Melbourne School of Engineering and Professor Yoshi Kashima from the Melbourne School of Psychological Sciences will all contribute significantly to the consortia's expertise in cognitive robotics, scheduling and optimisation and human-robot interactions.

Should the project be successful, The University of Melbourne will contribute up to AUD $150,000 to assist Professors Stuckey, Sonenberg, Pearce and Kashima to participate in the HESA consortium's research activities. To ensure these activities are successful, it is expected that the University of Melbourne will receive at least AUD $72,000 from the Horizon 2020 funds awarded to the HESA consortium.

If you have any questions regarding the administration of this grant, please contact Melinda Heron on +613 8344 2052 or via email at mheron@unimelb.edu.au.

Yours sincerely,

David Cookson

Dr David Cookson
Executive Director, Research
The University of Melbourne

Melbourne Research
The University of Melbourne, Level 5, 161 Barry St, Parkville Victoria 3010 Australia
T: +61 3 8344 2000
W: www.research.unimelb.edu.au

RWTH Aachen University
Knowledge-based Systems Group
Prof. Gerhard Lakemeyer
Ahornstrasse 55

52056 Aachen

FESTO

Datum
24.09.2014

Project HESA — Human-inspired reasoning in Embodied, Social, artificial Agents
Letter of support

Unser Zeichen
DC-ER/pens

Dear Prof. Lakemeyer,

Festo Didactic is the world-leading equipment and solution provider for industrial education. The product and service portfolio offers solutions for rapid learning and retention in the entire spectrum of automation technologies.

Festo Didactic is pleased to support the aims of the HESA project proposal. HESA promises to significantly advance the state of the art in building robots that take into account and adapt to the behavior of other agents. Upon completion of the project, Festo Didactic will be very interested in exploiting the results, for example, in the area of factory automation to improve efficiency and satisfaction in the cooperation between humans and robots.

With a focus on education for automation including mobile robot applications in factory environments, the outcome of the HESA project could mean a closer cooperation between robots and students for a better learning experience, and could serve as a principle how to improve the integration of human and robot workers in common tasks.

With kind regards

Festo Didactic GmbH & Co. KG

i.V. Dr. Reinhard Pittschellis
Head of Product Management and Development

i. A. Dr. Dirk Pensky
Product Management Robotics

Rechtsform:
Kommanditgesellschaft
Sitz: Esslingen a.N.
Registergericht Stuttgart.
HRA 211772
Umsatzsteuerident.-Nummer:
DE 145 339 239

persönlich haftende
Gesellschafterin:
Festo Didactic Management
GmbH
Sitz: Esslingen a.N.
Registergericht Stuttgart
HRB 213347
Geschäftsführer:
Dr. Willfried Stoll
Dr. Theodor Niehaus

Festo Didactic GmbH & Co. KG

Postfach
D-73726 Esslingen
Telefon 0711 / 3467-1334
Telefax 0711 / 347-54-1334
pens@de.festo.com
www.festo-didactic.com
Rechbergstr. 3
D-73770 Denkendorf

Digitally signed by sealingservice.grants.ec.europa.eu
Date: 2014.09.29 15:44:20 CEST
Reason: Acknowledgment of Receipt

This electronic receipt is a digitally signed version of the document submitted by your organisation. Both the content of the document and a set of metadata have been digitally sealed.

This digital signature mechanism, using a public-private key pair mechanism, uniquely binds this eReceipt to the modules of the Participant Portal of the European Commission, to the transaction for which it was generated and ensures its full integrity. Therefore a complete digitally signed trail of the transaction is available both for your organisation and for the issuer of the eReceipt.

Any attempt to modify the content will lead to a break of the integrity of the electronic signature, which can be verified at any time by clicking on the eReceipt validation symbol.

More info about eReceipts can be found in the FAQ page of the Participant Portal. (http://ec.europa.eu/research/participants/portal/page/faq)