TUM

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On Industry-Academia Collaborations in Robotics

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Technical Report

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1 Overview

This technical report summarizes some results of our efforts to study academia-industry collaborations in the field of robotics. Our analysis concerns four types of investigation.

Section 2 reports on research topics and foci. The goal was to identify both current concerns of the respective communities and future directions and emerging trends. For this purpose two instruments were used. On the one hand we looked at publications in journals and at conferences to see which topics are currently addressed by contemporary research and development efforts. On the other hand we distributed questionnaires ate different venues. The results were compared to similar studies, which were conducted by other parties. We will argue that our results are comparable to those found by the EUCog questionnaire, which was distributed among its members, and the results of a questionnaire, which was distributed at IROS 2012. We will also provide an overview on identified gaps and compare those with research topics covered by ECHORD experiments. At the end of the section future research trends with possible applications are presented.

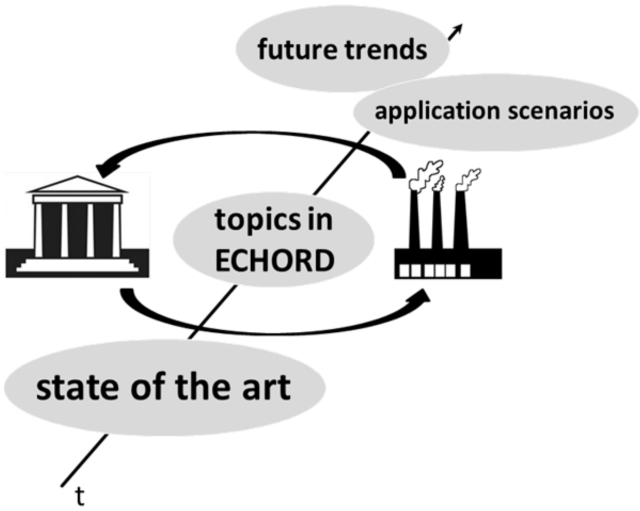

Figure 1: Current research topics under the umbrella of ECHORD as well as future topics and upcoming trends will be covered in section 2.

Next we will present a few insights gained by interviewing experts from Japan and the US (section 3). We interviewed Rodney Brooks, Hiroshi Ishiguro and Minoru Asada at different academic venues. We will compare the answers the three experts gave in order of achieving an overview of what makes collaboration between academic institutions effective and what the obstacles are.

These obstacles and chances for such collaborative projects will be discussed in more detail in section 4 which focuses on industry-university (I-U) collaborations: After summarizing literature on past collaboration experiences, we will detail the methods in ECHORD that will strengthen the knowledge transfer by means of a structured dialog between partners from industrial companies and research institutions. The results of a questionnaire distributed during the Asian Lab Tour forms the basis for the findings reported. We will conclude by outlining ideas for further steps to facilitate future I-U collaborations.

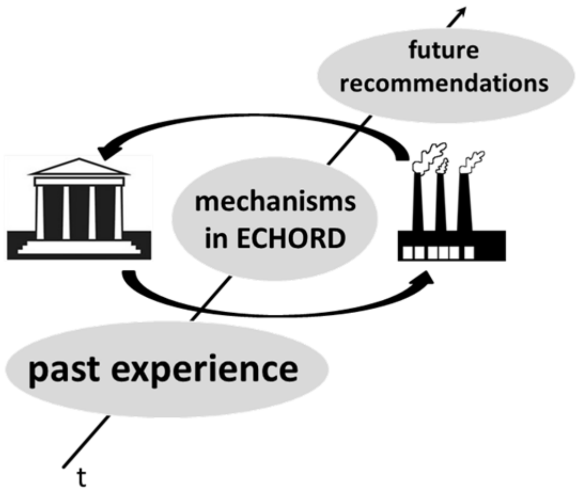

Figure 2: Academia-industry collaboration and knowledge transfer will be treated in section 4. It includes experiences from different continents, suggestions for improvements and mechanisms implemented in ECHORD.

Activities of the structured dialogue can thus be grouped according to two dimensions: time and field of investigation. The latter comprises “research areas” (see Figure 1) and “collaboration and transfer” (Figure 2). Both are looked at with respect to past experiences, the status quo and future directions. A special focus is put on ECHORD, including its position in the current fields of research as well as the methods implemented or planned in order to foster collaboration and knowledge transfer.

Section 5 uses questionnaire responses to discuss means of measuring success in such projects. Industry and academia use different definitions of success and therefore it is often hard to tell whether a collaborative project was actually beneficial to both parties involved. We will investigate whether the ECHORD project is an effective means of increasing academia-industry collaboration given that partners are dispersed across Europe and it has been proposed that proximity is a factor in collaborative research. After a documentation of several workshops organized by ECHORD in section 6, a short summary of the main findings will conclude this report.

2 Areas of Research

This section reports on our recent efforts to provide an overview on current research areas, research topics under the umbrella of ECHORD and also future topics and upcoming trends in robotics.

2.1 Current Research Topics in Robotics

Our method used for investigating future topics and emerging trends is comparing results from our own literature survey with results from a recent poll conducted by EUCog[1] and a survey organized by the IROS-2012 organization committee. The main topics resulting from the ECHORD literature survey are the following:

- Autonomy
- Bio-inspiration
- User interface, human robot interaction
- Vision & Recognition
- Sensor technology
- Language and Emotion
- Advanced Control
- Automatic path / motion planning
- Modular robotics & multi-agent systems
- Advanced cognition
- Safety and Security
- Test and Validation

The European Network for the Advancement of Artificial Cognitive Systems, Interaction and Robotics (EUCog) conducted a survey similar to those conducted by ECHORD, but with a broader focus on "future research topics in cognitive systems & robotics". A list of research topics was given to the participants and their task was to rate them on a scale from 1 (not important) to 5 (very important). Figure 3 briefly summarizes the main results[2] by focussing on those topics that received a rating of 4 or higher by at least 50% of all 211 participants.

It is evident that most topics are similar to those identified previously (blue columns), but there are also some noteworthy differences.

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[1] http://www.eucognition.org/index.php?page=applications&apptype=questionnaire_fp8_survey_results [accessed: 3/15/2013 3:00:01 PM]

[2] There are several other highly relevant questions, e.g., on applications, take–up and impact, which are not further analyzed herein, but probably in a future collaboration.

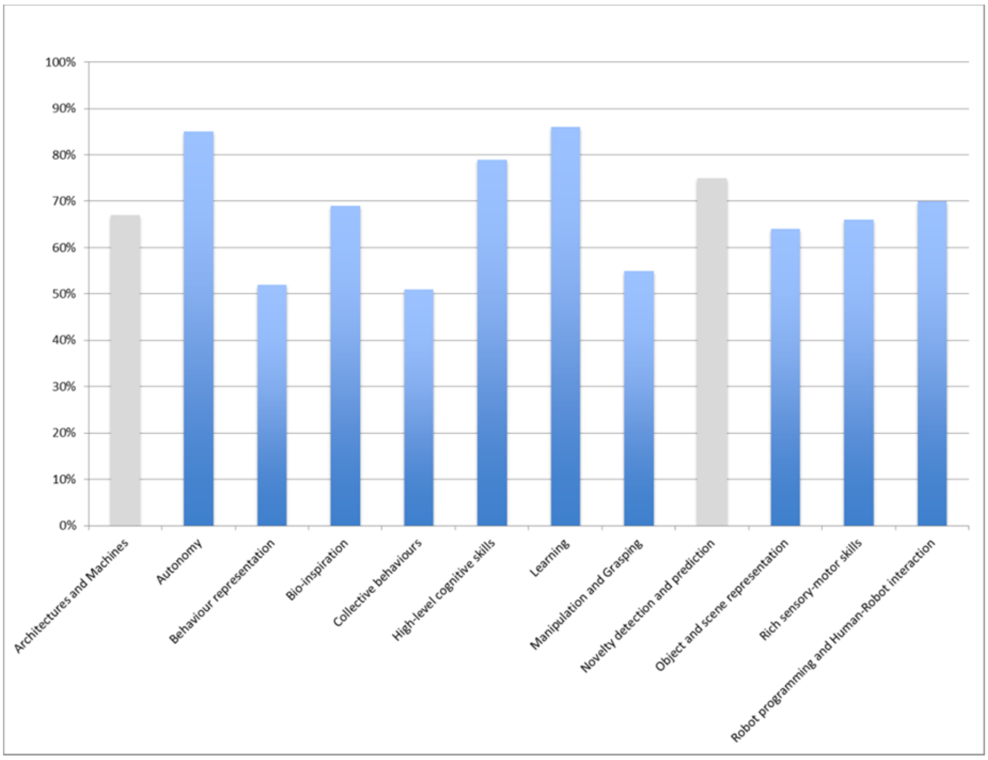


Figure 3: EUCog survey - Future research topics in cognitive systems & robotics that received a rating of 4 or higher (1 = not important, 5 = very important) by at least 50% of all 211 participants.

Topics only mentioned in the EUCog list (grey columns):

- Architectures and machines
- Novelty detection and prediction

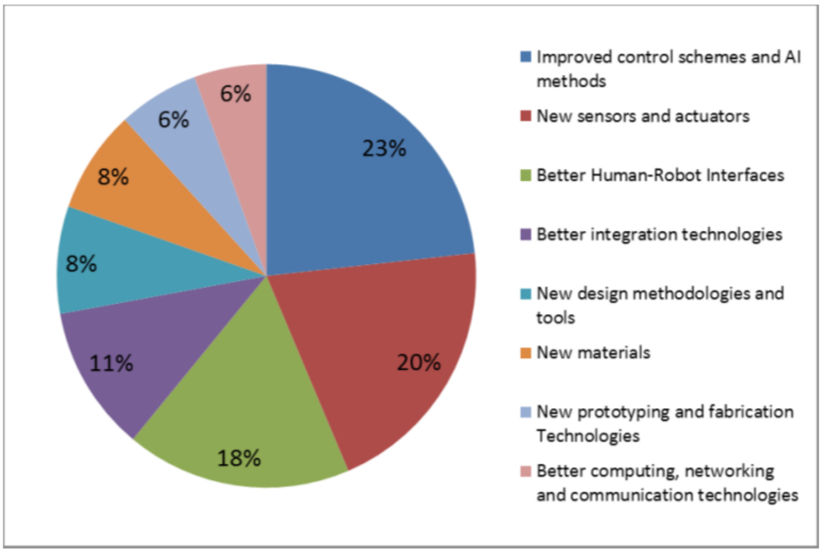
Topics only mentioned in our list:

- Language and Emotion
- Advanced Control
- Automatic path / motion planning
- Modular robotics & multi-agent systems
- Safety and Security
- Test and Validation

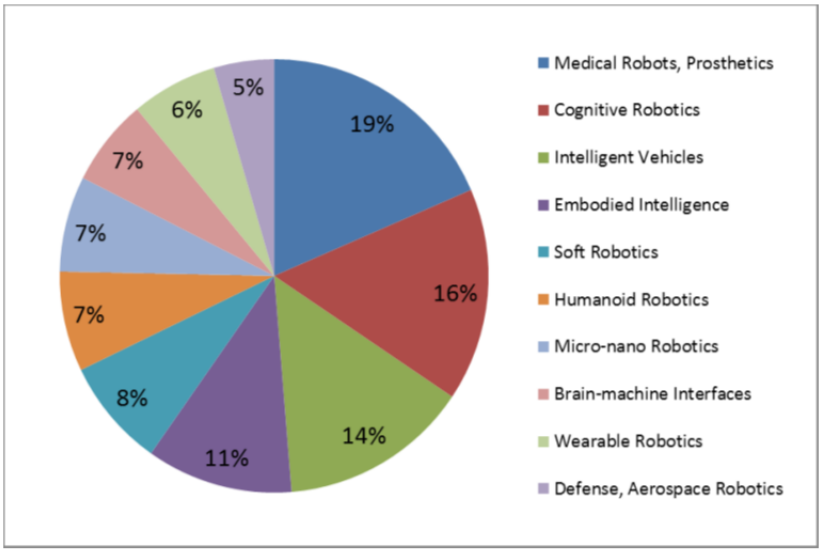
The results differ mainly due to a different focus with regard to robots in our survey. Our results echo Brooks' statement above in determining interactive capabilities (Language and Emotion, Safety and Security) more than the EUCog participants who seem more focused on the reasoning of an individual agent, though both groups also mentioned Human-Robot Interaction as one possible topic for further research. The other items in our list, which were not mentioned frequently by the EUCog members, are all connected to robot motion, except for Test and Validation which is of course needed in practical applications. The terms in our list are more strongly oriented towards the need of the market and practical applications, whereas many (but by no means all) EUCog members are rather interested in basic research.

We further compare these results to those obtained by the IROS-2012 survey: 116 forms were collected from IROS attendees. The participants could select up to three areas of research for future research for each question asked. Here we only present the results regarding the answers to two out of four questions:

“For effectively tackling such [grand societal] challenges, research should mainly focus on…”



“In the next decade robotics R&D shall focus mainly on the following grand research avenues”



The ICRA questionnaire identifies four topics, which more than 10% of the participants suggested future research should focus on. The top answer is ‘improved control schemes and AI methods’. This is related to the items ‘Advance Cognition’ and ‘Advanced Control’, which were frequently named by the participants in our study. The second most frequent response in the IROS answers relates to sensors, which were also named frequently our study. The third most frequent reply to the IROS questionnaire relates to human-machine interaction, which is also an important topic to the people who were asked by us. The final topic, which was named by more than 10% of respondents for the IROS questionnaire relates to system integration. This is a topic which the participants questioned in our study did not mention explicitly. Probably, this difference arises from the fact that IROS is a conference, which attracts system integrators and therefore this topic is assigned a high value.

Also, there is quite a lot of overlap between the 10% of research avenues, which the IROS 2012 participants named, and the topics for future research, which our participants named frequently. Medical robots and prosthetics is the most frequent answer for the IROS 2012 participants. This is hard to map onto the responses to our questions and therefore constitutes a difference. However, the other answers above 10% Embodied Intelligence, Cognitive Vehicles and Cognitive Robotics all relate to the topics Advanced Control, Advanced Cognition and Autonomy in our topic set. Therefore, a large overlap between the answers can again be shown.

In conclusion, our results could be largely confirmed, as there is a string agreement between the topics named by the EUCog members, the IROS 2012 participants and our study. Many answers related to autonomy and cognition. These are of course issues, which relate to the core interests of all three communities.

In addition to the findings reported in the preceding sections, selected results from 3 ECHORD questionnaires with a total of 100 participants (distributed on different occasions) can be found in the Appendix of this report.

An ECHORD questionnaire for Asian robotic labs was handed over to all sites that have been visited during a combined lab tour to Japan, South Korea and China in June 2012. The set of 16 questions were similar to those asked to during an earlier lab tour to North America in order to ease comparability between answers.

The questionnaire was completed by the following 15 labs:

- Japan
    - Inaba-Okada Laboratory / JSK Laboratory, University of Tokyo
    - Shimoyama-Matsumoto-Takahata Laboratory, University of Tokyo
    - Human-Robot Informatics Lab, Tohoku University
    - Uchiyama Lab, Tohoku University

- South Korea
    - Center for Intelligent Robotics, KIST
    - Telerobotics and Control Lab, KAIST
    - Biomimetic Robot Research Group, Korea Institute of Industrial Technology
    - LG Future IT R&D Lab

    - Robot / Cognitive Convergence Research Department, ETRI
    - Yujin Robot Co. Ldt.
    - Intelligent Systems Research Institute, Sung Kyun Kwan University

- China
    - Intelligent Robotics Institute of Beijing Institute of Technology
    - Tsinghua University, Beijing
    - Institute of Robotics and Intelligent Information Processing, Shanghai Jiao Tong University
    - Intelligent Robotics Institute, Kunshan Industrial Technology Research Institute (KSITRI)

Note, that all the answers were provided by at least senior scientists, e.g. by Prof. Kwon, who is chairing the Telerobotics and Control Lab at KAIST and by Prof. Matsumoto from the Department of Mechano-Informatics, University of Tokyo. For a complete list of participating labs see corresponding ECHORD deliverable. The answers to Question 3 are given below:

What are future research fields in robotics that should be worked on in collaborative effort by academia and industry?

- *Higher level generalization for variety of task execution case studied projects.*
- *Robot S/W and H/W framework making*
- *Robotic web app; Cloud robotic services*
- *Educational robots; Elderly-care robots*
- *Medical Robotics*
- *Service robots, which can take over human tasks*
- *Personal / domestic service robots; Medical service robots; Automation of labour intensive and/or hazardous tasks, including human robot cooperative manufacturing*
- *Service robotics for elderly and disabled people, medical robotics and robotics for hazardous environments*
- *Transportation system for human and physical distribution; Rescue robotics; Safe driving support; Rehabilitation; Entertainment*
- *Human Robot interaction, robot in production lines*
- *Factory Automation; Development of Industrial robot and automation system; Mechanical design and technical supports for core parts.*
- *Humanoid robots, Quadruped robots, Space robots, Medical robots, Search and rescue robots.*
- *Robotic hardware, sensors*
- *Human-robot interaction. Artificial intelligence applicable to service robotics. Robotics used in hazardous environments.*
- *Robot hands and fine operation, human cooperative teleoperation.*

There are three research areas that are mentioned repeatedly: Service robotics (5x), rescue robots and robots for hazardous environments (5x) and medical robots (5x). These fields will be considered as possible research foci in the follow-up project E++.

2.2 Topics for Industry-Academia cooperation

We are interested in current topics in robotics in the context of joint industry-academia projects. For this we analyzed “hot topics” at the International Conference on Intelligent Robots and Systems IROS 2011 and focused on the number of joint publications in order to reveal robotic fields with different amounts of contributions from I-U collaborations.

2.2.1 Analysis of conference publications

The two most important topics in terms of papers per keyword on IROS 2011 have been Motion and Path Planning and Biologically-inspired Robots. Papers tagged with these keywords comprise 15% and 14% of all 790 accepted papers. If we take a closer look at those papers that result from industry-academia cooperation, it turns out that their contribution in these two fields is well below average: Only 5 papers (4%) with keyword Motion and Path Planning are authored by an I-U cooperation and only 6 papers (5%) with keyword Biologically-inspired Robots. On average I-U collaborations contribute in the order of 8%.

Next we were interested to know those research areas that attracted a high number of I-U contributions. The following Table 1 lists all those areas by keyword with a share of joint academia-industry papers above 20%.

Keyword	# papers I-U coop.	# papers total	share
Cooperative Manipulators	2	4	50 %
Failure Detection and Recovery	1	2	50 %
Intelligent Transportation Systems	9	20	45 %
Virtual Reality and Interfaces	6	19	32 %
Space Robotics	5	17	29 %
Voice, Speech Synthesis and Recognition	5	17	29 %
Robotics in Hazardous Fields	2	7	29 %
Search and Rescue Robots	4	18	22 %
Industrial Robots	4	20	20 %
Cellular and Modular Robots	2	10	20 %
Personal Robots	2	10	20 %

Table 1: List of keywords from IROS-2011 papers with a high share of I-U collaborations.

Given an average share of only 8%, the contributions from I-U joint projects to these research fields are quite remarkable. Note that the first two entries are of limited validity due to the small amount of papers in total.

There have been many topics at IROS without any contribution from industry-academia cooperations, partly in surprising fields, e.g.:

- Aerial robotics (59 papers in total, 0 from I-U collaborations)
- Biomimetics (34 papers in total, 0 from I-U collaborations)
- Rehabilitation Robots (33 papers in total, 0 from I-U collaborations)

We then had a look in which continents the I-U joint projects are based. It revealed that most of them are from Asia, closely followed by Europe (see Figure 4). Quite a few collaboration partners are based in countries from different continents, many of them involve Europe and the US. If all intra- and inter-continent collaborations between academia and industry are summed up, Europe has the largest share of 47% of all I-U papers presented at IROS-2011.

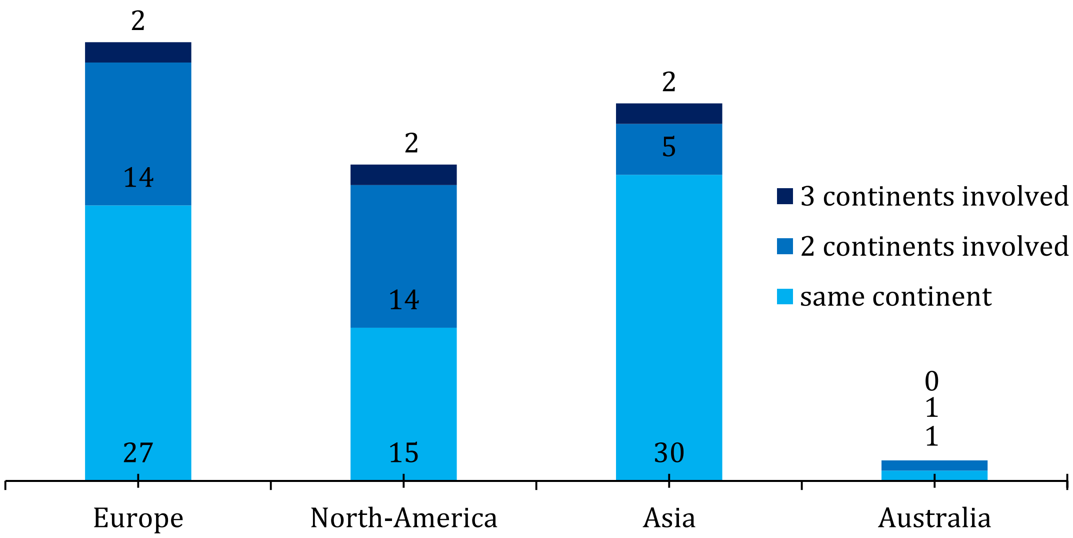


Figure 4: Amount of cross-continent collaboration as reflected in authorships of all accepted IROS-2011 papers.

Note that the “IROS 2011 keyword index” which is exploited here, contains the keywords selected by the authors during paper submission. IROS 2011 used the same list of keywords of ICRA, i.e., the one that is maintained by the RAS Conference Editorial Board and is permanently available at http://www.ieee-ras.org/ceb/areas.html.

2.2.2 Extended Analysis

In this section, the research topics currently pursued in the field of robotics will be addressed. For this purpose the most suitable method is the analysis of journal papers and conference contributions. All conference contributions that were submitted in the years 2011 and 2012 to both, ICRA and IROS, have been analysed.

These are the most pertinent venues for presenting results to the robotics community[3].

We analysed the keywords that are used by the authors for paper submission in PaperPlaza. IROS and ICRA use the same list of keywords. The RAS Conference Editorial Board is in charge of refining / updating this list for ICRAs, but this list has been very stable in the last couple of years.

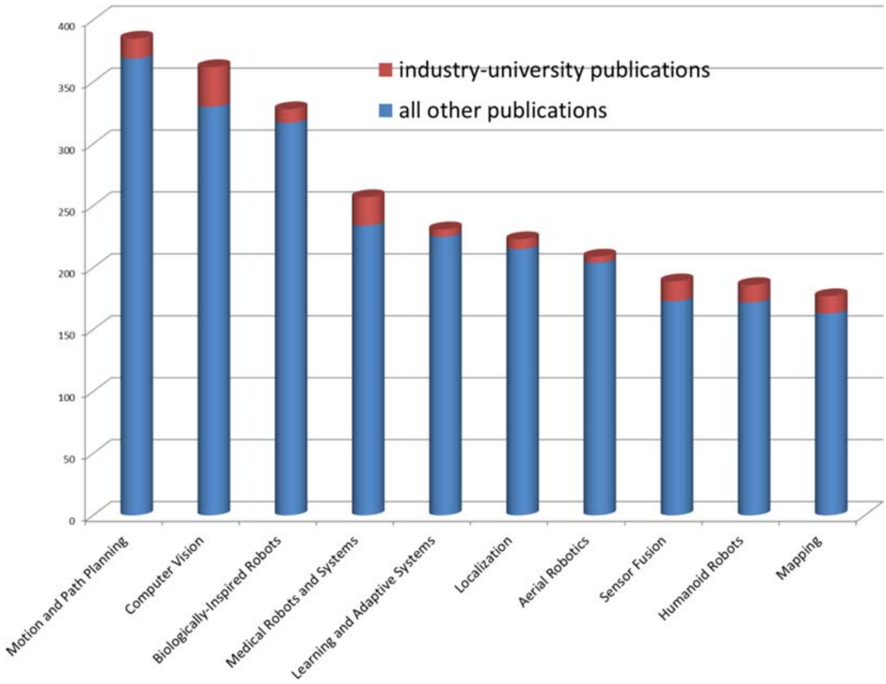


Figure 5: Most frequently used keywords from all accepted contributions to ICRA-11, ICRA-12, IROS-11 and IROS-12

Overall, there are 9726 associations with the 143 keywords, which is a number about three times higher than the number of papers since typically three keywords are assigned to each paper. Figure 5 shows the most frequently used keywords from all accepted contributions to ICRA-11, ICRA-12, IROS-11 and IROS-12.

Figure 5 displays not only the number of papers for each keyword, but differentiates between papers that resulted from an academia-industry collaboration (in red) or not (in blue) by assessing the affiliations of all authors. For a justification of this approach, see below (chapter 2.3.4). In total 594 assignments are due to industry-academia papers.

This list of top research topics is very stable across conference (IROS, ICRA) and year (2011, 2012): The 7 highest-ranked topics from the figure above are in the

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[3] See for example: http://www.ias.tu-darmstadt.de/Miscellaneous/ConferenceQuality [accessed: 3/15/2013 11:21:09 AM]

individual top 10 lists of all four conferences (with only one exception)[4].

For these 7 research topics there is a clear increase in number of academia-industry collaborations: At IROS the share increased from 5.5% to 7.3%, at ICRA it more than doubled (see Figure 6). The numbers are averages across the topics *Aerial Robotics*, *Biologically-Inspired Robots*, *Computer Vision*, *Learning and Adaptive Systems*, *Localization*, *Medical Robots and Systems*, *Motion and Path Planning*.

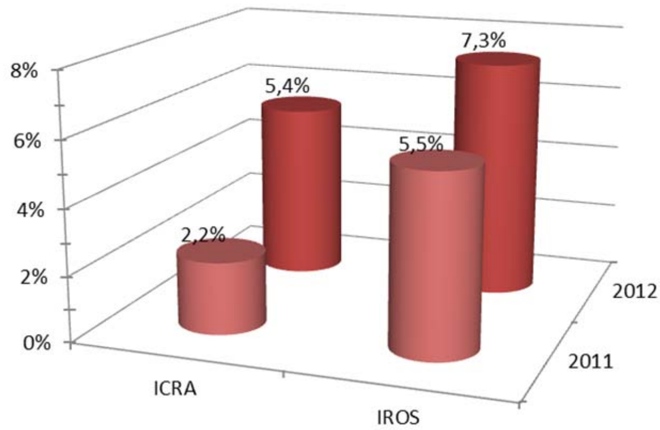

Figure 6: Number of academia-industry collaborations at ICRA and IROS 2011 and 2012.

Next we had a closer look at all topics with a high share of industry-academia collaborations. Figure 7 displays all those keywords that were attached to conference papers, whose share in industry-academia is above 10%.

[4] Topic „Learning and Adaptive Systems" was ranked only number 11 at ICRA 2011.

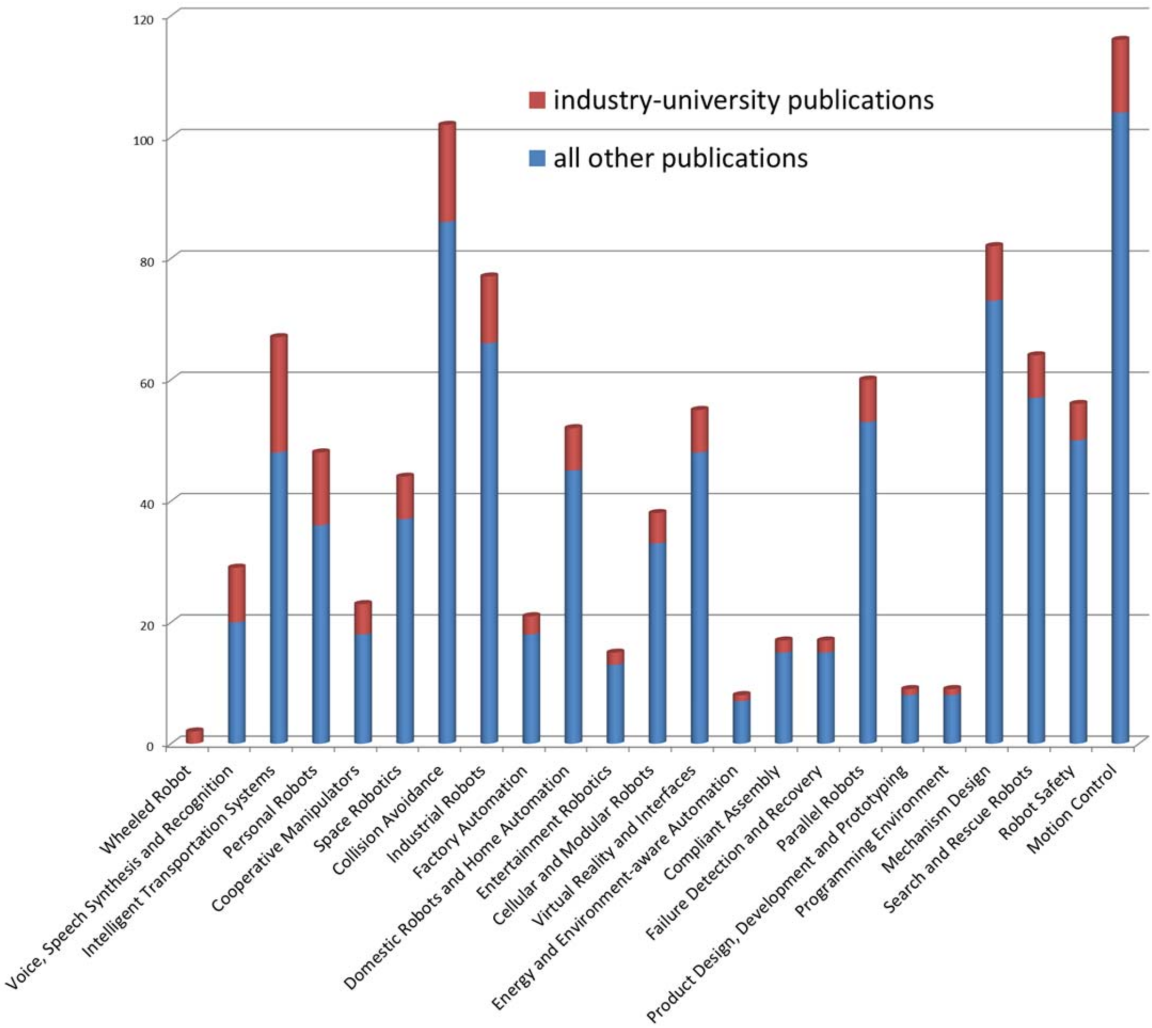

Figure 7: Keywords attached to conference papers, whose share in industry-academia is above 10%.

This list of topics is similar to that reported above which presented first results based on IROS-2011 contributions only.

2.2.3 Industry-academia joint publications

We further enlarged our analysis of joint industry-academia publications by including five top journals in robotics and extending the year analysed back to 2009. The following Table 2 gives a detailed overview on the number of I-U papers published by journal and year. In total 98 I-U papers have been published which is only a small fraction (7.25%) of all 1362 papers that have been published in these papers from 1/2009 till 12/2011.

source	year	# all papers	# I-U papers	% I-U-Papers (Journal/Year)	% I-U-Papers (Journal)
INT J ROBOT RES	2011	97	17	17,53	12,66
INT J ROBOT RES	2010	94	12	12,77	
INT J ROBOT RES	2009	91	7	7,69	
IEEE TRANS ROBOT	2011	106	5	4,72	6,07
IEEE TRANS ROBOT	2010	98	4	4,08	
IEEE TRANS ROBOT	2009	138	13	9,42	
AUTON ROBOT	2011	49	6	12,24	7,03
AUTON ROBOT	2010	52	2	3,85	
AUTON ROBOT	2009	40	2	5,00	
ROBOT AUTON SYST	2011	93	7	7,53	4,72
ROBOT AUTON SYST	2010	123	3	2,44	
ROBOT AUTON SYST	2009	119	5	4,20	
ROBOTICA	2011	93	6	6,45	5,74
ROBOTICA	2010	87	3	3,45	
ROBOTICA	2009	82	6	7,32	

Table 2: Overview on the number of I-U papers published by journal and year.

For journal papers, a similar keyword analysis is complicated by the fact that no predefined list of keywords exists from which the authors can select. As a consequence a far larger set of keywords is used and they are overlapping etc. Here we would need an ontology, which is currently being worked on.

	Conferences	Journals
1.	Mechanism Design of Manipulators	Computer Vision
2.	Medical Robots and Systems	Mobile Robots
3.	Computer Vision	Medical Robots and Systems
4.	Intelligent Transportation Systems	Mobile and Distributed Robotics
5.	Collision Avoidance	Sensor Fusion
6.	Motion and Path Planning	Motion Planning
7.	Recognition	Path Planning
8.	Localization	Localization
9.	Personal Robots	Distributed Systems
10.	Distributed Robot Systems	Force Control

Table 3: The 10 most used keywords for I-U papers.

Nevertheless there is a high overlap in keywords between papers produced in collaboration between industrial partners and universities (I-U papers) published in journals and those accepted for conferences. This is illustrated in **Table 3**, which lists the 10 most often used keywords for I-U papers.

2.2.4 Methodological note

The criterion we used here to classify a publication of being an I-U publication or not was based solely on the affiliations of the contributing authors. Therefore, a publication was classified as a I-U publication, if and only if at least one of the authors' affiliation was a company and at least one an academic institution. In order to check the validity of this approach in general, we did the following cross-check: We sent an email to the corresponding authors of all papers that were accepted for the IROS conference in 2012. We asked them to indicate if their paper was the result of an I-U collaboration. 210 authors answered, which is almost one quarter of all 858 papers. Next we compared the received answers with the list of affiliations of all 210 IROS papers. It reveals that our method leads to the same result in 84% of all cases. There is a substantial share of 13% of papers which results from an I-U collaboration but which is not visible from the author list. Finally there are 6 papers (3%) which do not result from collaboration, although for some reasons the paper is authored by people from industry and people from academia.

Taken together, our method is valid for most of the IROS-2012 contributions and there is no reason to assume that this is different for the other conferences and journals we have selected.

2.3 Positioning of ECHORD

In ECHORD 51 experiments have been selected for funding from 243 submitted proposals. All these joint projects are based on scenarios and research foci relevant to both the robot manufacturers and research institutions. In this section we show how these experiments fit into commonly used categories regarding research topic, field of application and technology, and clarify to what extent ECHORD experiments address gaps known to exist in robotics.

2.3.1 Fields of activity in ECHORD

ECHORD has defined a clear thematic orientation, which is reflected in selected scenarios. Three scenarios have been identified, which are both scientifically challenging and commercially relevant. They consist of challenges, which robotics experts can easily understand and use as a basis for their own research. The scenarios, which build on each other, are *human-robot co-worker*, *hyper-flexible manufacturing cells* and *cognitive factory*. Within these scenarios, different research foci have been identified. They combine mechanical design and controller technology developed by manufacturers with the research community's expertise in sensing, cognition, and behavior control. The research foci are *human-robot interfacing & safety*, *robot hands & complex manipulation*, *mobile manipulators & cooperation* and finally *networked robots*.

The experiments in ECHORD are of different types: some are geared towards joint enabling technology development (develop new robots, components, network, etc. based on bi-directional exchange of knowledge), others towards application development (use of robots and components in new areas and scenarios) and yet other towards feasibility demonstration (show that prototypes can actually be deployed in classical industrial settings). To get a better idea where in the research landscape ECHORD's experiments are located, we have put them into commonly used categories for three domains:

- Research topic
- Application
- Technology

The resulting figures Figure 8, Figure 9Figure 10 demonstrate a broad range of fields that is covered by ECHORD's experiments.

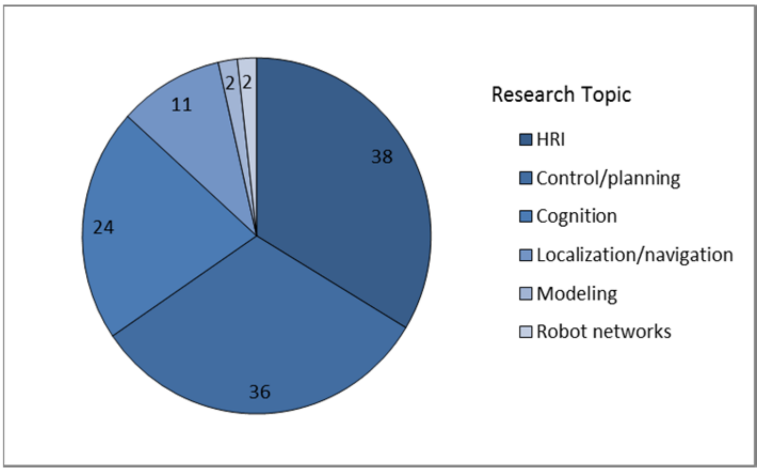

Figure 8: Research topics targeted by ECHORD's experiments. Typically two of these topics are covered by one experiment.

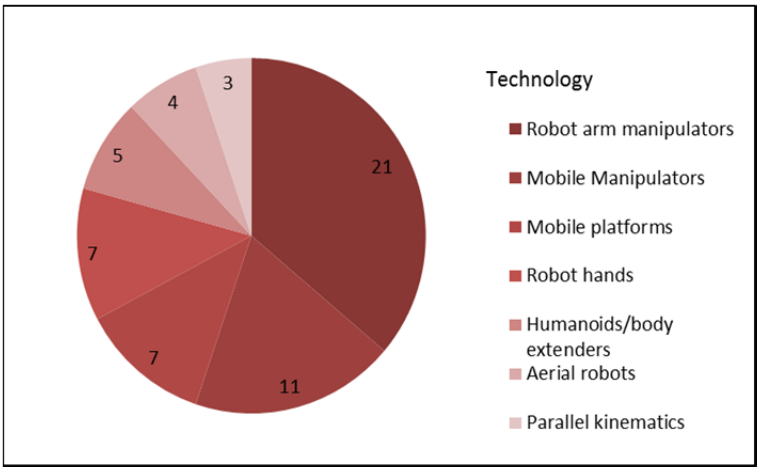

Figure 9: Classification of ECHORD's experiments based on utilized or to-be-developed technology (multiple entries possible).

The figures also reflect the influence of ECHORD's three scenarios, resulting in a majority for the application category "industrial". The bias resulting from research foci and experiment type is much less pronounced.

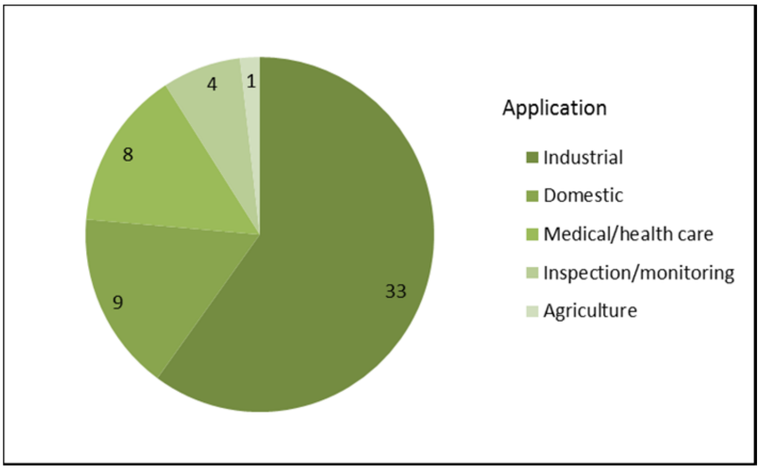

Figure 10: Application areas of ECHORD's 51 experiments.
Some projects contribute to more than one application.

An internal customer satisfaction analysis with 50 participants revealed a great contentment regarding the research fields ECHORD is targeting at. To the question "Does the scientific scope of ECHORD address the current trends and needs in industrially relevant fields?" 25 participants chose the answer "totally", the other 25 the answer "sufficiently" and nobody answered "poorly". No difference was found between participants from industry and those from academia.

2.3.2 Gaps addressed by ECHORD experiments

The gap between industry and academia in robotics that has been made explicit by the Strategic Research Agenda has triggered a recent study that aimed at identifying these I-U gaps (Guhl, Zhang, 2011). With a mixture of different methods a list of 66 gaps has been extracted and ranked with respect to relevance.

They were prioritized by assigning a score for each of the following four factors:

- Robotics as the driver of the technology
- Current situation of the gap
- Reason for the Gap
- Substitutability of the technology

The overall priority of each gap is calculated as sum of the priority scores of the individual factors. We then examined in how far ECHORD experiments target these gaps. Results are given in Table 4 demonstrating that a substantial number of identified gaps are already addressed by ECHORD, especially those with high-priority. It shows also that there are some high-ranked gaps that are not covered so far and thus might provide an interesting basis for possible follow-up projects.

Identified Gap	Priority	ECHORD
3D mapping	39	yes
Multi-robot simultaneous localisation and mapping	37.5	
Modelling of human-robot interaction	37.5	yes
Cooperative navigation and mapping	37.5	yes
Swarm intelligence	37.5	yes
Human emotion recognition	36	yes
End user focused application developing tools	36	
Auto-coding software	36	
Standardization of robot communication	36	
Safety in human robot interaction	34.5	yes
SLAM	34.5	yes
Micro grasping	34.5	
Camera based navigation / VSLAM	34.5	
Multi-modal sensing / sensor fusion	33	yes
Gesture recognition	33	yes
Neural network	33	yes
Robot kinematics/dynamics modelling	33	yes
Sensor fusion for navigation	33	yes
Collision free planning	33	yes
Force/Torque control	33	yes
Bionic locomotion devices	33	
Haptic interfaces	33	yes
Vision based human movement recognition	33	yes
Neural system interface and brain interface	33	yes
Energy source and power transmission	33	
Mobile robot deployment tools	33	yes
Integrated tool chains	33	
Dexterous hands	32	yes
Modelling of robot-environment interaction	31.5	
Distributed computing architecture	31.5	
Texture sensors	31.5	yes
Automatic obstacle avoidance and re-planning algorithm	31	yes
Distributed control for multiple robot agents	30	
Augmented reality	30	yes
Nano material	30	
Autonomous planning	30	yes
Learning from demonstration/observation	30	
Environment modelling	30	yes
Nano sensors	30	
Object recognition	30	yes
Face recognition	30	
Wireless powered robots	28.5	yes
Various control methods	28.5	
Various learning algorithms	28.5	
Majority voting sensor system	28	
Smart material actuation	27	
Micro actuators	27	yes
Knowledge based planning	27	

Self-configuration, self-calibration, self-tuning	27	
Impedance control	27	yes
Decentralized planning	27	
Biomimetic modelling	27	
Panoramic cameras	27	
Force and torque sensors	27	yes
PMD sensors	27	
Voice and language recognition	27	yes
Pneumatic artificial muscles	24	
Bio-engineered material	24	
High-density efficient batteries	24	
Solar panelled robots	24	
Cameras	24	yes
Laser sensors	24	yes
Computer networking protocols	19.5	
Field bus	19.5	
Materials for extreme environments	18	

Table 4: List of I-U gaps in robotics as compiled by Guhl, Zhang, 2011 (column 1, 2) and match with ECHORD experiments (column 3).

2.4 Research Trends

Future topics and emerging trends in robotics are covered by ECHORD deliverables as far as literature surveys are concerned and by a further deliverable based on opinions of experts that visited top-ranked labs during a North American lab tour. Here we report on special sessions at the IROS conference, mention main results from a Delphi study and point to outcomes from a recent questionnaire.

2.4.1 Conference Highlights

For the topics covered by ECHORD's structured dialogue there have been several very relevant events at IROS 2011. Most of all, two industrial forums that included representatives from robotics companies making short presentations and engaging in a moderated panel discussion among themselves and with the audience.

Forum "Robots: The New Commercial Platforms"
This forum focused on recent and emerging robotic platforms. Participants from industry discussed recent and projected advances in robotic technology with a commentary on emerging applications. The forum included presentations by several companies that are involved in ECHORD: KUKA Laboratories (experiments ERICA and Execell), Aldebaran Robotics (experiments BABIR and Graspy) and Schunk (experiments Flexprass and KANMAN). Further talks were given by Meka Robotics and ABB Research.

Forum “Robots: The Next Generation”

Here the focus was put on next generation robotic platforms, new business models for robotics and the role of open software. Talks were delivered by representatives from the US only, namely Yoshiaki Sakagami (Honda Research Institute USA), Chris Urmson (Google), Regis Vincent (SRI International) and Jan Becker (Bosch Research), who also contributed to our ECHORD workshop. Attendees discussed advances in robotic technology with an emphasis on software and applications.

Forum “Robotics: Beyond the Horizon”

In addition to the industrial forums, IROS 2011 featured a special “Blue Sky” forum on the future of robotics. Participants from academia, government, and industry present their visions for the future of the field. The forum was moderated by Hirochika Inoue, one of ECHORD’s advisory board members. Talks were given by Henrik Christensen from Georgia Tech and Juha Heikkilä from the European Commission, who both also presented at the ECHORD workshop, and by Paolo Dario from Scuola Superiore Sant'Anna, a ECHORD consortium member, amongst others.

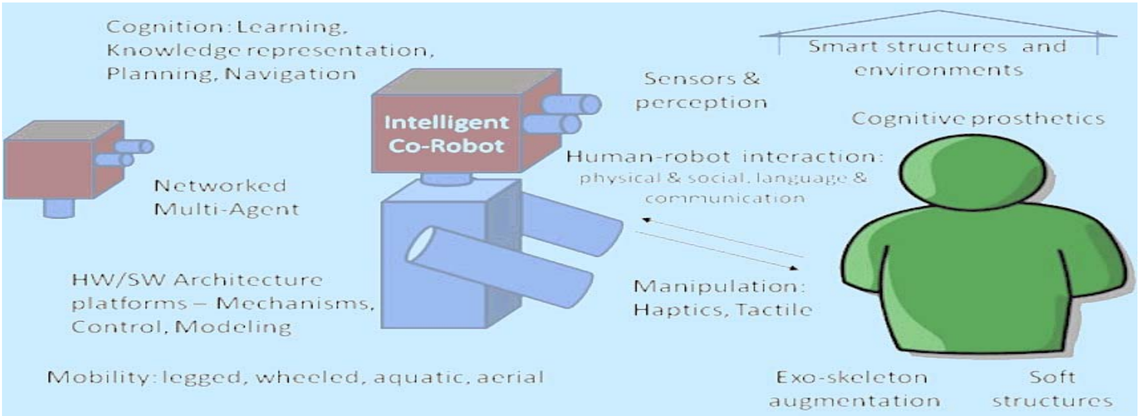

Figure 11: Topics pursued in the National Robotics Initiative (presentation slide from S. Koenig, NSF).

There have been some topics that have been raised by several speakers, including the need to combine mechatronics and cognition, the synergies to be expected from massive data, robotics and the cloud, and the importance of “co-X” (see alsoFigure 12). Two bottlenecks were mentioned, namely the investment by private companies and the government infrastructure.

A noteworthy presentation delivered by NSF revealed some details about the recently launched National Robotics Initiative (NRI) of NASA, NIH, NSF and USDA, which will spend US$ 40-50 million per year. Two presentation slides are displayed in Figure 11 and Figure 12.

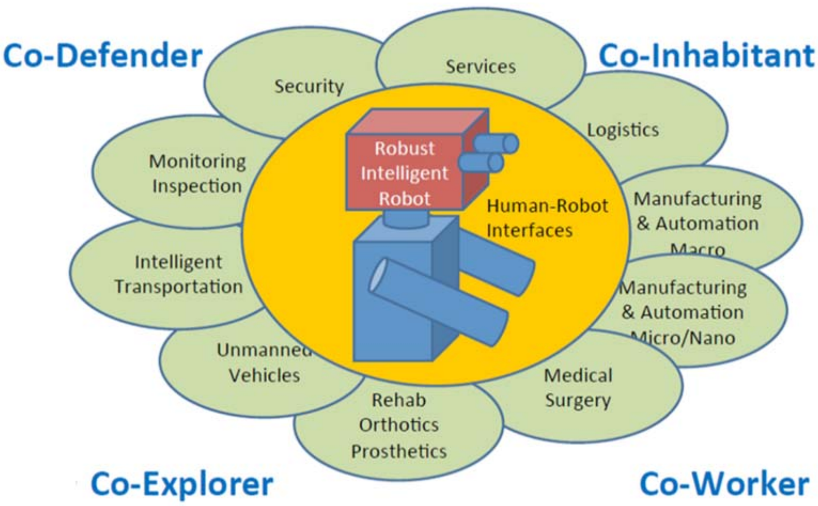

Figure 12: Presentation slide from NSF highlighting the importance of Co-X within NRI as future topic with plenty of possible applications.

2.4.2 Selected Results from Delphi study

In a Delphi study conducted by ECHORD partners at Universidade de Coimbra, participants of a special workshop dedicated to academia-industry collaborations were asked to identify technologies that will have high impact on the future development in robotics. It revealed that 3 out of 18 topics were considered extraordinary important with relatively high degree of consensus between participants:

- human-machine interfaces
- sensing / perception technologies
- safety

For the first topic, *programming-by-demonstration* is considered especially interesting, for the second the sub-topic *object recognition* and in the field of safety a very high score was obtained for sub-topics *safe robot controllers*, *predictive failure detection* and *sensors*.

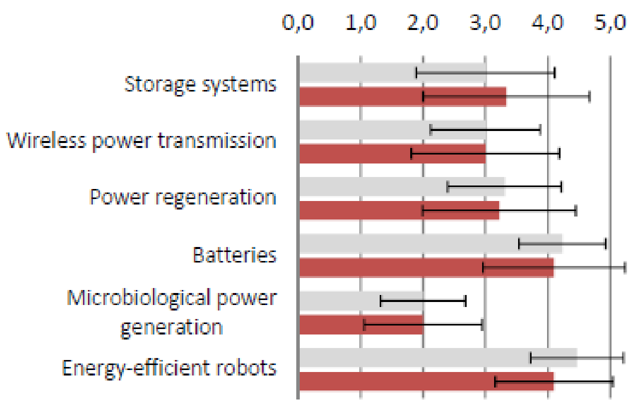

Figure 13: Exemplary results for “power management” sub-topics (red = 1st round, grey = 2nd round; 1 = lowest impact, 5 = highest impact; depicted are mean and standard deviation. From Veiga et al., 2011, p. 40).

There are also specific sub-topics that were considered to be of high importance, although the superordinate topic received less attention. For example batteries and energy-efficient robots received a very high score, as can be seen from Figure 13.

The Delphi study did not only cover a variety of research topics, but also asked for the impact of a range of upcoming and future applications. According to the participants, the highest impact of all application scenarios as defined by the SRA will result from **robotic co-workers** (see Figure 14).

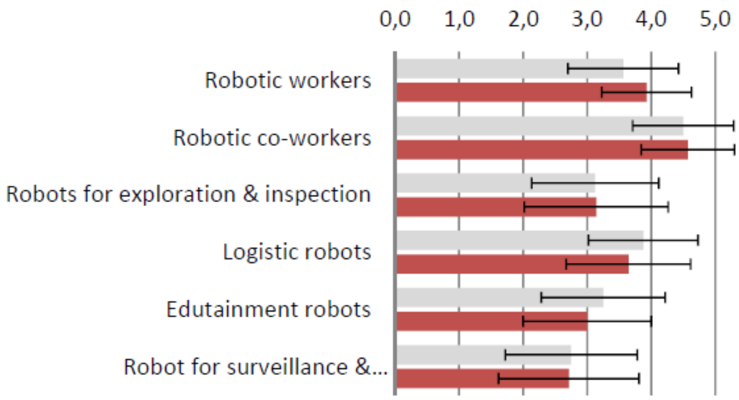

Figure 14: Results for top-level application scenarios that comprise various product visions (For legend see Figure 13. From Veiga et al., 2011, p. 41).

Taking a closer look at individual product visions, it reveals that 5 are expected to make an extraordinary economic impact. These are:

- Autonomous transport of goods
- Autonomous transport of people
- Rapidly adaptable manufacturing cell
- Robot automation for small scale manufacturing
- Robot assistant in industrial environments

For details see deliverable *Analysis of the Delphi query held at the workshop on "European Efforts in Strengthening the Academia-Industry Collaboration"* by Veiga et al. on the ECHORD webpage.

2.4.3 Differences between North America and Europe

We have developed a questionnaire about research trends and knowledge transfer that was completed by 16 participants so far. While there will be a separate publication on that, we'd like to point here to one result regarding differences seen between North America and Europe: We asked if there are differences with respect to upcoming trends and the majority answered "Yes" (see Figure 15). Interestingly, all "No" responses were made by participants from European labs. We received quite a couple of hints on the nature of these observed differences:

- *“In US more military support”*
- *“In US military applications”*
- *“US research dominated my defense application”*
- *“US more military related”*
- *“Different funding sources --> differences in research”*
- *“In EU / Asia most funding towards non-defense work”*
- *“In EU / Asia more work in humanoids, adaptive / cognitive systems”*
- *“EU: service robotics”*
- *“In EU service applications more important”*
- *“EU groups work more on "Cog. Systems" than US”*
- *“EU: more funding for HRI and cog. Robotics (might change with Nat. Robotics Initiative in the US)“*

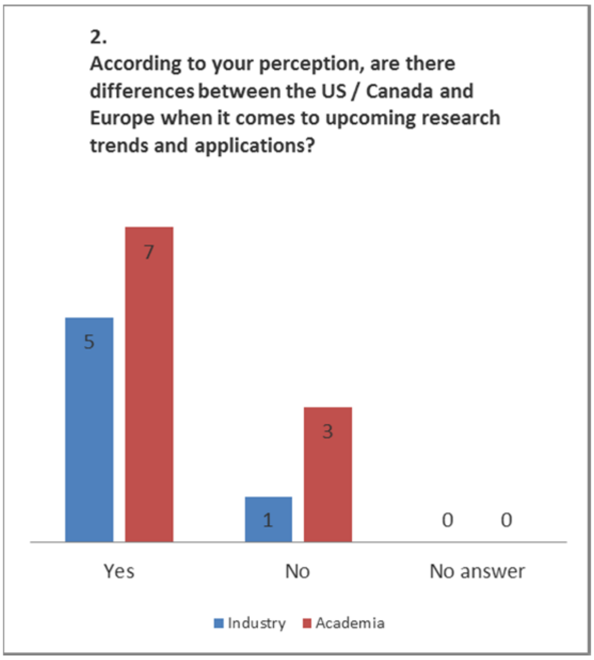

Figure 15: Answers received to question #2 (blue = participants from industry, red = participants from academia).

Survey participants also made several notes regarding the way robotic research is conducted and about the differences they have observed:

- *“US take more risks to get product on the market fast”*
- *“US more product oriented”*
- *“US more focused on applicable results”*
- *“US more industry driven”*
- *“Canada and US: more focus, short-term, especially US”*
- *“EU large, federating projects, with long-term, speculative, open-duded objects”*
- *“EU slightly higher scientific outcome”*

- *“Competitions more prevalent in EU”*
- *“EU not correctly synchronized”*
- *“EU has better organized modern robotics research”*
- *“EU / Asia more coordinated, top-down structure in research enterprise”*

3 Expert Interviews on Collaborations

Prof. Ishiguro gave the following reply to the question of how one can measure success in academia-industry collaboration: *“If you can sell many robots, that means a big success. Or, in science, if you can write a pretty good scientific paper… That is also a good success, in science. Just two simple evaluations: Science or business. We don’t need to have any other evaluation.”*

Three interviews were conducted with well-known and established experts in the field of robotics. These experts are Rodney Brooks (Heartland Robotics/MIT), Hiroshi Ishiguro (Osaka University/ATR) and Minoru Asada (Osaka University). In each we asked questions regarding the nature of industry and academia collaborations. The results showed a lot of overlap in opinions and some differences. Two of these experts are from Japan and one is from the US.

3.1 The interviewees’ background in I-U collaborations

Generally, all three interviewees had experience with industry-academia collaborations. However their experience was varied. Whereas Prof. Brooks and Prof. Ishiguro were both heads of labs at academic institutions and owners of their own company, Prof. Asada’s work is mainly within the academic realm. However all of them have experience with industry collaborations. Whereas Prof. Brooks has set up joint research facilities with big international corporations (NTT, Nokia, Quanta Computer), Prof. Ishiguro has spent time setting up collaborative projects with large and small companies (NTT, Hitachi, Toshiba, Fujitsu) and according to his interview is consulted by large companies due to his background in human-machine interaction. Prof. Asada in contrast only reported on two collaborations with industrial partners. One is within the context of student projects, which the university organized in cooperation with an industrial partner (Daiwa house) and the other is a planned collaboration with a watch making company (Citizen). All of them had extensive knowledge of the two fields with Prof. Ishiguro and Prof. Brooks having first-hand knowledge of running companies and Prof. Asada knowing about the difficulties of setting up such joint activities with industrial partners.

3.2 The nature of I-U collaboration

All of the interviewees highlighted different aspects of the nature and the reasons for such collaborative undertakings. Prof. Brooks spoke about the CEO’s of companies wanting to bring innovation into their company and seeking the advice of academic researchers. Prof. Asada emphasized the opposite view that academics seek the opportunity to verify and apply the knowledge gained through their research. Prof. Ishiguro rather suggested that both academia and industry are different ways of making use of innovative ideas.

3.3 Different approaches

The general approach to these collaborations was sketched differently by the interviewed experts. Prof. Brooks suggested that the best ways of interaction are by exchanging people for periods of at least a few months at a time or setting up joint laboratories. In this way people get to know each other and the strength of both types of organizations can be used.

Prof. Ishiguro spoke of the opportunities, which arise through dedicated research institutes which are neither part of a university nor are they actual industrial organizations. These enable a neutral ground for engaging in exchange. They do not serve the same constraints that industrial partners and universities bring into such collaborative innovation efforts.

Prof. Asada in comparison two both saw the academic side of such an undertaking firmly remaining in a university setting. From his own experience he spoke about actual collaboration between universities and companies. He saw it as more of a question of a triangle, which encompasses the industry, the government and universities. He expressed the view that the government has to encourage and facilitate the collaboration between universities and companies. He based this on his experience with trying to set up a joint research site for robotic technology research in Osaka which was heavily affected by local politics.

3.4 Problems with collaboration

There were two different points of views expressed in the interviews. Prof. Brooks spoke about the industry organization where company CEO need an active interest in the joint activities and do not just count on the involved people solving problems of innovation on command.

Prof. Ishiguro spoke of the bureaucracy involved. He particularly focused on the Japanese case in which universities are not meant to interact with business according to his perception. He therefore said that many contractual aspects of such collaborations are harder to deal with in pure university-industry joint activities.

Prof. Asada spoke about different perspectives on success. The industry is interested in short-term success, which is measured in profit whereas the academic researchers take a long term perspective. These differences make it harder from people of the two camps to collaborate because one develops things that will become more useful in the future whereas the other will need immediate tangible outcomes. Prof. Asada's suggestion was therefore for academics to develop their ideas independently and wait for industrial partners to find interest in a development as soon as the progress is sufficient for it to become an actual product for immediate profit.

To a certain extent, this agrees with Brooks' view that academic loose interest in a development as soon as it reaches a certain level of technological readiness. However Brooks did not see this as a drawback of academic work, but as a strength. In a way academics do not have to wait for the maturity of products, which is why companies come to them for innovation.

3.5 Ideas in innovation

A central theme in all interviews was ideas as the actual product of such joint ventures. What is clear is that the outputs of academics are different to those, which are expected in industrial settings. Also, in Rodney Brooks' words the reward systems are different.

Hence, the question would be what the common currency between the two types of organization is. The idea, which was pervasive, was that one is actually dealing ideas. One could read into all three interviews that ideas are formless entities, which are given form either by academics or by companies. In the one sphere the idea will turn into publishable texts which according to Prof. Ishiguro are results in their own right to which Prof. Brooks added that you cannot stop academics from publishing. Of course, no one wants academics to stop publishing. However the implication is that this is the type of outcome, which is to be expected. Brooks mentioned YARP, which is a software system, which was developed at his MIT lab. This is of course an outcome as suggested in the interview, which could have emerged from either end of the organizations. The successor of YARP in many ways is ROS, which was developed originally by a company. Therefore, one issue is the type of output, which is useful to both scenes and could have been developed by either a company or an academic institution.

However of course publications, which ultimately mean an increase of the body of human knowledge, are the type of output which is traditionally expected from academics and Prof. Ishiguro strongly suggested that prestige is a possible measure of the success of this type of output.

In either case the starting point is a useful idea or "good idea" in Prof. Asada's words. The difference between the views of the experts' interviews was in the origin and final use of ideas. Prof. Ishiguro saw ideas as the basis for both products and publications. Therefore these ideas lead to the cooperation. They only need to be communicated to the other side. Prof. Asada proposed that the media should take up a strong role in this. He expected an increase in science journalism to help in the communication between universities and the industry. He also advocated government leadership in determining the needs that both companies cater to and universities address in their research. If a solution is already being worked on by either side it needs to be communicated to the involved parties by journalists who understand science and business at the same time but can mediate between the stake holders.

Prof. Asada’s view on ideas is best explained as the outcome of academic research. The industry picks up and idea and turns it into a product. This is more unidirectional than the view Brooks expressed. In his interview he – like Asada – saw idea as the starting point for innovation. However in Asada’s interview ideas were developed by academics – though just based on his experience, he did not suggest that they cannot come from the industry – and the idea in whatever form needs to be communicated which leads to collaboration. Brooks however sees collaboration as a drive for innovation in which ideas first need to be developed. He suggested that the best way toward innovation is by joint development of ideas by companies and academic researchers (ideally in joint labs). The specific outputs then evolve from the common idea. Ishiguro in contrast sees idea as facilitators for either end. It is the reputation for idea, which makes either side interested in the other.

3.6 A summarizing overview of the interviews

	Brooks	***Ishiguro***	***Asada***
Collaboration	√	√	√
Place of cooperation	Jointly funded institute	Independent research institute	University
Problems in industry-academia collaborations	Reward system differences	Universities are not the right place for business	Government, industry and academia need to form a triangle
Active in the industry	√	√	
Ownership of a Company	√	√	
Role of ideas in innovation	Ideas are generated jointly → Starting point	Ideas are generated separately → Starting point	Ideas come from university → End point for university
People needed	People need to be exchanged (same staff in different settings)	Mix of people needed (engineers, researchers, managers)	-
Timing in academia and industry	-	Academia has time; industry needs the right timing	Academia: long-term perspective Industry: immediate profit

4 Collaboration & Knowledge Transfer

This chapter focuses on I-U partnerships and bidirectional transfer of knowledge. At the beginning a range of findings about I-U collaborations in general will be presented, then collaborations in robotics, divided into a European and a non-European perspective. Specifics of collaboration and knowledge transfer in ECHORD are explained next, followed by a larger section on future directions and possible improvements. Presented are findings from the scientific literature, insights from international workshops, results from own questionnaires and main points from discussions with high-level experts.

4.1 Current State

For a positioning of ECHORD's structured dialogue activities and in order to make suggestions on how to improve and foster I-U collaborations, we first ask about the current state in terms of best practices, different industry-academia collaboration schemes, knowledge transfer experiences from different continents and specific routes of knowledge transfer like IP rights and licensing.

4.1.1 Academia-industry collaborations in general

There is a vast literature on I-U collaborations but these studies are typically not restricted to a specific area of research, e.g. robotics. This section here therefore will only highlight some findings that are of major importance also for robotic joint projects and will give recommendations for further reading, especially on meta-studies.

A valuable source of information is a recent study by Ankrah (2007). The author provides a systematic literature review and synthesises the results of 79 separately conducted studies on I-U collaborations for technology and knowledge transfer. The meta-review provides a systematic on various organizational forms of I-U relationships and extracts factors that facilitate or impede the collaboration. These factors include those regarding capacity and resources, regarding legal issues, institutional polices and contractual mechanisms and regarding management and organisation issues. Detailed information is also given about potential benefits for industry and university. For a project like ECHORD it is of even more importance to know what the possible drawbacks that might arise from I-U projects are. Only if potential dangers are known, protective actions can be taken. Therefore a compilation of potential drawbacks for both sides is given in the following.

Potential drawbacks of I-U collaborations to university

a. Deviation from Mission or Objective
   - Threats to research autonomy or integrity or compromise of academic freedom (for commercial advantage) that may have a negative impact on culture of open science and affect future direction of university programs or teaching.
   - Confidentiality agreements/proprietary issues may block the dissemination of knowledge.
   - Could result in the abandonment of long-term basic research in favor of results-oriented, short-term, applied research and technology transfer
   - Concern that the end result of collaboration could be short-term contracts in which industry would require 'quick and dirty' solutions to problems, with university departments acting as extensions to the research activities of firms.

b. Quality Issues
   - Potential diversion of energy and commitment of individual staff who are involved in interaction with industry, away from core activities, with negative effects on the curriculum.
   - Could affect types of research questions addressed and reduce the quantity and quality of basic research.

c. Conflicts
   - Potential conflicts of interest.
   - Conflicts between researchers and company over the release of adverse results/Damage in professional relationships among the researchers.
   - Biased reporting by researchers sponsored by companies in favor of positive experimental results relating to company products.

d. Risks
   - Dilemma of either publishing results for short-term revenue and academic recognition or withholding them until they are patented, with the risk of the technology becoming obsolete.
   - Risks that academic-industry relationships pose to human subjects of research.

Potential drawbacks of I-U collaborations to industry

a. Detraction from Objective
   - Slow academic bureaucracies may stifle technology commercialization, depress the firm's performance and delay the fulfillment of the firm's objectives.
   - Diversion away from the 'bottom-line' issues of industry like return on capital investment.

- Collaboration may be costly due to increase in administrative overheads, as industry may have to develop specific managerial and administrative competencies, which may be a time-consuming process.

b. Quality Issues
   - Low intellectual level of some contract work.
   - Results in theoretical and impracticable solutions since University staff are too theoretical and not very practical whereas industry's focus is much more problem centered on critical situations requiring immediate attention.

c. Conflicts
   - Disharmony and discord during R&D development.
   - Intellectual property disputes and patenting disagreement.

d. Risks
   - Diminished control or leakage of proprietary information, allowing competitors to imitate the innovation quickly.
   - High failure rate of collaborations.
   - Financial risk to industry.
   - Risk of incomplete transfer or non-performance of technology.
   - Market risk where there is uncertainty of the success of the product launched in the market.

Each identified potential disadvantage is based on up to 27 references (see Ankrah, 2007). A recurring issue is that of patents and intellectual property rights (see "conflicts" and "risks" above). This is in line with a study from 2002, which analysed factors for successful I-U cooperations in the US (Santoro, Betts, 2002).

Issue	Prevailing University Position	When Firm Should Accept	When Firm Should Develop More Creative Approaches
Exclusivity of IPR and patents.	Firms usually not given exclusive rights.	1) When a socially constructed technology infrastructure is required. 2) When the technology is ancillary or enabling to an existing dominant design.	When the technology is central or core to the firm's business, products or services, and to defend against the introduction of next generations by the firm's competitors.
Time period of license.	Can vary substantially. 3–5 years not uncommon, often without options to renew.	Under most conditions.	If time to market takes several years and technology has limited shelf life.
Revenue sharing of patents.	1%–3% of sales.	As long as consistent with prevailing industry norm.	If current industry norm is significantly higher.

Figure 16: Guidelines for intellectual property rights, patent ownership and licensing agreements (Santoro, Betts, 2002, p. 45).

It revealed that the university's posture on intellectual property rights, patents and licensing is **the most important factor** to industrial firms. This result is based on data obtained from R&D managers and technology executives at over 200 firms in 20 different industrial sectors. These companies were selected by approaching the NSF-supported IUCRCs (Industry-University Cooperative Research Centers) and ERCs (Engineering Research Centers), which have the explicit mission to foster I-U collaborations. To pro-actively deal with this issue, basic guidelines for potential industry partners are given in Figure 16.

Since the handling of IPR, patent ownership and licensing varies to a great extent between universities, Figure 16 gives an overview as it relates to exclusivity, timing and revenue sharing. It also makes suggestions for the reaction of the potential industrial partner and thus provides guidelines for this key factor in the establishment of collaborations that are beneficial for all parties involved.

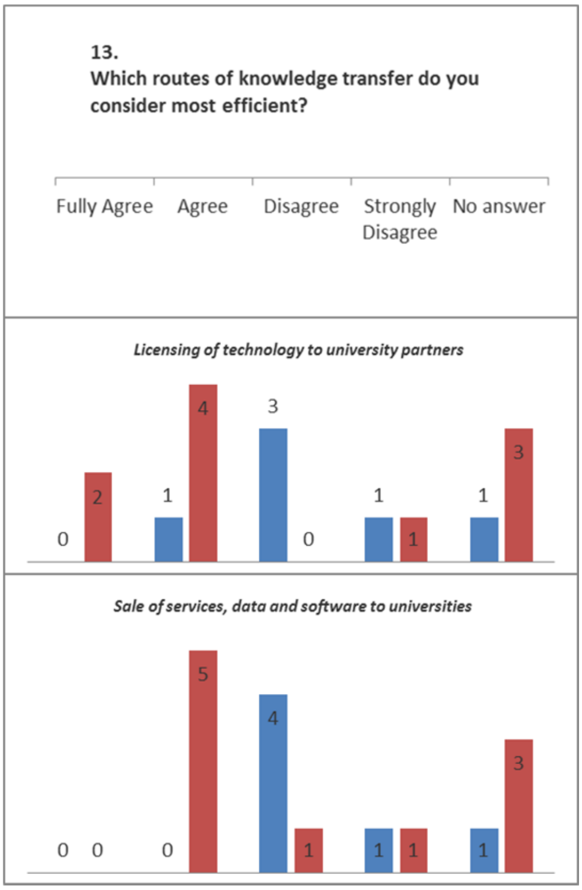

Figure 17: Assessment of 2 out of 11 options in question #13 (blue = participants from industry, red = participants from academia).

This topic was also one of the most controversial ones when we asked in a recent survey about the most efficient routes of knowledge transfer. The questionnaire was sent to robotic industry and university labs and there was by-and-large agreement on means like exchange of personnel, formation of spin-offs, presentations etc. There were two routes of knowledge transfer with quite contradictory assessments from academia and university, one being "sale of services / data and software to universities”, the other “licensing of technology to university partners”. Preliminary results with limited number of respondents are shown in Figure 17.

Reaching consensus over IP rights thus is an important, and often lengthy, precursor to I-U collaborations. Other studies like Pertuzé et al. (2010) concentrate on the management practices that came after the company reached an agreement over IP with the university. They identified key factors that are most important for the success of I-U projects (see below), but during the interview process some companies shared their impressions also with respect to IP. The authors could observe variations in terms of the importance of IP depending on the industry, and also on the characteristics of the project. If the industry is taken as the unit of analysis, they could clearly distinguish certain patterns: For the pharmaceutical industry, for example, owning IP was important. This affected the choice of university partner, as some universities are also quite stringent with respect to owning IP. For other industries, however, IP was not a major concern, as they protect their knowledge assets through other mechanisms (e.g. secrecy, lead time, etc.) If they looked at the different projects, however, they could see more variability in terms of IP. In general terms, when the purpose of the project was to learn, explore, or hire students, companies were flexible with respect to owning IP. One project manager, for example, mentioned that IP was not really an issue because more than the results of the research, he was interested in hiring the PhD student after graduation. On the other hand, when the collaboration sought to solve an immediate company problem, IP became a more pressing issue (Personal communication with the team at MIT).

Main finding of the study is that there is an outcome-impact gap in that promising outcomes of joint projects often fail to translate into tangible impacts for the industry partner. Seven best practices for overcoming this gap have been identified on the basis of more than 100 collaborations (see Figure 18).

The study was based on the responses provided by company project managers from the aerospace, information technology, materials, consumer electronics, automotive, and other industries. University researchers were not interviewed, but certain guidelines for university researchers can be inferred from the responded results, especially:

- University researchers (including students) should be aware of the project's strategic context.
- University researchers should visit the company, as face-to-face communications were found important.
- University researchers should make efforts to meet with different stakeholders in the organization (e.g. sales, operations, and marketing people). This will allow a better appreciation of the project's strategic context, and also a better understanding of the company's internal practices.
- Positive correlations were found between the experience of the university researcher in collaborating with industry, and the outcomes and impacts of the project (from a personal communication with the author).

THE SEVEN KEYSTO COLLABORATION SUCCESS

1. Define the project's strategic context as part of the selection process.
- Use your company research portfolio to determine collaboration opportunities.
- Define specific collaboration outputs that can provide value to the company.
- Identify internal users of this output at the working level; executive champions are not a substitute for this requirement.

2. Select boundary-spanning project managers with three key attributes:
- In-depth knowledge of the technology needs in the field
- The inclination to network across functional and organizational boundaries
- The ability to make connections between research and opportunities for product applications

3. Share with the university team the vision of how the collaboration can help the company.
- Select researchers who will understand company practices and technology goals.
- Ensure that the university team appreciates the project's strategic context.

4. Invest in long-term relationships.
- Plan multiyear collaboration time frames.
- Cultivate relationships with target university researchers, even if research is not directly supported.

5. Establish strong communication linkage with the university team.
- Conduct face-to-face meetings on a regular basis.
- Develop an overall communication routine to supplement the meetings.
- Encourage extended personnel exchange, both company to university and university to company.

6. Build broad awareness of the project within the company.
- Promote university team interactions with different functional areas within the company.
- Promote feedback to the university team on project alignment with company needs.

7. Support the work internally both *during* the contract and *after*, until the research can be exploited.
- Provide appropriate internal support for technical and management oversight.
- Include accountability for company uptake of research results as part of the project manager role.

Figure 18: Key factors for successful I/U Collaborations (Pertuzé et al., 2010, p.85).

On the other hand side, several factors often thought to be important to I-U collaborations were found to have **little effect** on the impact of the project.

These are:

- Presence of an executive "champion"
- Geographic proximity
- Overall project cost
- Type of research (basic, applied or advanced development)
- Location of project manager.

A study by Perkmann, Walsh (2007) analysed the role of practices such as collaborative research, university-industry research centres, contract research and academic consulting. The evidence they collected suggests that such university-industry relationships are widely practiced whereby differences exist across industries and scientific disciplines.

While most existing research focuses on the effects of university-industry links on innovation-specific variables, such as patents or firm innovativeness, the organisation and management of collaborative relationships seems to be under-researched.

Characteristics of collaborative relationships between universities and industry are therefore explored, but we narrow this down to the following overview of relevant studies of research partnership (Table 5).

Type of partnership	Object of analysis	Countries	Authors
Collaborative research	EU framework programmes	EU	Caloghirou et al. 2001
	Collaborative Research and Development Agreements (CRADAs)	US	Ham and Mowery 1998
	Research joint ventures (broadly speaking)	US	Link et al. 2002
	Case study of ATP-funded project	US	Link 1998
	Collaboration strategies of firms	EU	Fontana et al. 2006
University-industry research centres	Engineering Research Centres	US	Feller et al. 2002
	Industry-University Cooperative Research Centers	US	Adams et al. 2001
	SEMATECH, case study	US	Rea *et al.* 1997
Several types	Study of 46 collaborations several European countries and in the US	EU, US	Carayol 2003
	University-industry partnerships	US	Cohen *et al.* 1994

Table 5: Studies of research partnerships (Perkmann, Walsh, 2007, p.269).

All further references can be found in reference list. There is one study with special focus on European framework programs, but the reported data are somewhat outdated (Caloghirou et. al, 2001) and therefore results are not reported here. The literature in general is quite multitudinous, including publications that are not of sufficient quality (e.g. Iqbal et al., 2011), but also very valuable sources like the PhD thesis by Butcher (2005), which includes a comprehensive literature review and in-depth discussion on how to measure the effectiveness of I-U collaborations.

With the focus on collaborations in the field of robotics, we will for the remainder of this section mainly report on results from our workshop held at the IEEE/RSJ International Conference on Intelligent Robots and Systems IROS-2011 in San Francisco. The overall goal of this workshop has been the exchange of experiences on how to strengthen I-U collaborations. For this, the potential benefits of collaboration have been worked out and the different approaches from Europe, North America and Australia have been discussed.

4.1.2 Collaborations in European robotics

In Europe there have been several efforts in recent years to foster I-U collaborations in robotics, including the European Robotics Network EURON, the European Robotics Technology Platform EUROP, the Coordination Action for Robotics in Europe CARE and the European Robotics Coordination Action euRobotics. As one example, steps taken by euRobotics have been the identification of gaps of understanding (see section 2.3.2), the maintenance and implementation of the Strategic Research Agenda, the training for industry and the fostering of entrepreneurship. Insights from presentations given at the euRobotics / ECHORD workshop will be summarized next.

KUKA-DLR lightweight robot

A well-known success story is the technology transfer between DLR and KUKA that lead to the LWR. It started with an initial transfer of technology, patent and know-how for the first DLR-KUKA robot and was followed by continuous support in the development of next models and transfer of new results through a strategic partnership. Lessons learned from this cooperation include:

- Intensive and exclusive collaboration
- Need to transfer people
- Strong patents
- Spin-out of required technologies not in the focus of industrial partner
- Continuing interest of academic partner
- Building the market / integration into product line

EFFIROB study

Further insights come from a study conducted at Fraunhofer IPA (Germany) on “Profitability analysis of new service robotic applications and their means for robotic development”. The lessons learned from this EFFIROB study are:

- Need to carefully evaluate market and development costs
- EFFIROB tool/methodology can be used by:
- Academia to convince industry
- Industry to calculate cost of Service Robots
- Consortia to evaluate the commercialization potential for research

- Funding agencies to evaluate where to set long term focus
- “Economy of scale” has less leverage often quoted
- Sometimes robotics needs new business models

A direct impact of the study on I-U collaborations is seen for academia as a tool to convince industry about economic feasibility of SR solutions and for industry as a tool to estimate costs for a service robotic development.

FP7 / National funding

- Calls partially based on roadmaps from industry and academia
- Frequent consultations of representatives from both communities
- Encouragement of industrial participation often with end user

So far we asked what we can learn from I-U robotic collaborations of other continents in order to foster European I-U projects, but we can also ask what we can learn from successful European I-U projects in areas other than robotics. In the document at hand we will now take a look at collaborations outside Europe.

4.1.3 Collaborations in robotics outside Europe

First we turn to the US and summarize the point of view from representatives of two well-known companies, namely Jan Becker from BOSCH Research and Technology Center North America and Brian Gerkey of Willow Garage.

Lessons learned at BOSCH

BOSCH tries to overcome the gap between the industrial requirements of **quality, reliability and reusability** and the current success measures for academia, i.e., **productivity** (total number of papers) and **impact** (citations of papers). The approach taken by the ROS / PR2 Beta Program is as follows:

- Academia and industry in one program
- Common basis is open source repository
- Requirement to open source commitments
- Request to open source code related to publications
- Establishing standard for academia
- Quantitative software metrics

As a result, there was an increased exchange of code and high interaction between sites. So far people at BOSCH are content regarding repeatability of results and reusability of algorithms (basically through standardization), but quality and reliability can still be improved. As conclusion, I-U collaboration based on open source collaboration can be of great help in bridging the gap between industry and academia.

Lessons learned at Willow Garage

- Industry hat: transfer technology to academia by:
  - Build hardware with industrial methods & to industrial standards
  - Mentor interns and host visiting scholars, e.g. value of unit testing etc.
- University hat: transfer technology to industry:
  - Develop and distribute robust implementations of important algorithms for use in commercial products
  - Commercialize technology through spin-offs, keep competitive advantage through first entry and choosing what to keep secrete
- Mixed I-U hat: transfer technology to both communities:
  - Develop, distribute and support open source software platforms
  - Create a community for academic and industry partners alike
- Create an environment for people to work with (like, e.g., Android)

In the course of the National Robotics Initiative a new robotics network, called Robotics-VO, is currently built (see Figure 19). It aims at coordinating various initiatives in the US robotic community. According to official information they plan to start January 2012[5].

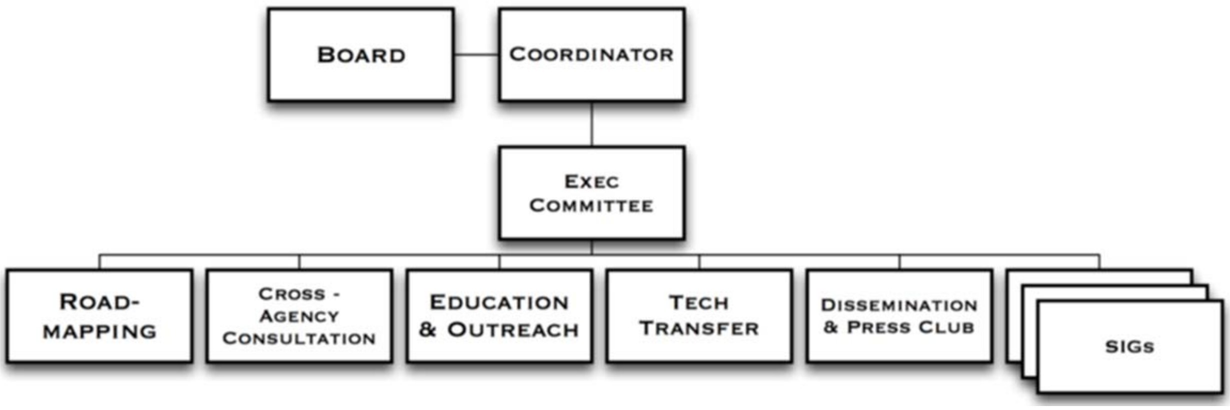

Figure 19: Organizational structure of the Robotics Virtual Organization. From a presentation by H. Christensen.

Lessons learned from US universities

- Communicate in the language of those you want to address! (show that you can address an important problem)
- Of utmost importance in the US are: money, jobs and security
- Develop products that people care about!
- Try to find a model that suits stakeholders!

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[5] See http://www.robotics-vo.org

- Constraints of market are relevant to research
- Make technology accessible to people! (also to uneducated ones)
- National Robotics Week great for society support
- Robotics business competition
- Set up pipeline so that the right people talk to each other!

Complementary results regarding I-U collaborations in the US are documented in the deliverable associated with the ECHORD North American lab tour that took place in September 2011. Topics covered in this deliverable include first-hand information about cooperation modes, commercial activities, spin-offs and, once more, IP handling.

Lessons learned in Australia

A slightly different stance is taking from the perspective of I-U cooperations in Australia (see also section 4.4.4). The following key points and requirements have been mentioned as lessons for making innovation happen (Figure 20 from a slide by A. Zelinsky):

1. It's all about the people and building the best teams
2. Great outcomes start with excellent focused science and technology
3. Strong unencumbered and sufficiently mature IP builds advantage
4. Working with standards organisations e.g. IEEE and ISO where possible
5. Be resourced for success with smart money and realistic market valuation
6. Orchestrating collaboration with innovation and industry partners
7. Know your global competitive advantage and how to maintain it
8. A living business plan that captures your winning strategy
9. Brilliant execution of great plans is mandatory
10. Embracing risk and not fearing failure with a "whatever it takes" attitude

Figure 20: Ten lessons for successful I-U projects.

It was stressed that it is of utmost importance for a joint project to address an unmet business need, possibly starting in a niche or new markets and later license if markets are established. Where possible, it should be aimed at non-exclusive licenses.

4.2 Structured Dialog in ECHORD

Knowledge transfer has top priority in ECHORD, a fact that is expressed in the very structure of ECHORD as demonstrated in each individual experiment and in the existence of an own pillar dedicated to the topic of "structured dialog". This makes ECHORD quite exceptional, also confirmed in a recent query among roboticists in industry and academia, in which nobody was aware of a "similar project like ECHORD".

In a recent discussion round with ECHORD experiments that were presented at IROS-2011, the following points were commented as “lessons learned” from the experimenters’ point of view:

- Consider the market and potential products
- Consider the timeline and industrial requirements
- Geographical closeness is an advantage (but see study by Pertuzé et al., 2010)
- Keep the company involved at all times
- Reduce HW dependence by using HW that is specified by industry
- Make technology accessible to industry e.g. SW tool
- Set up strategic partnerships
- Industry may not see all benefits that robotics has to offer
- Overcome barrier between company and academic R&D
- Help those in the industry to think “outside the box”.

Specific means have been implemented to foster knowledge transfer within ECHORD, e.g., a mind map as a tool for inter-experiment communication, also meetings like the last European Robotics Forum in Vasteras (2011) and dedicated ECHORD workshop (as in San Francisco 2011). In addition, the communication between partners within experiments is ensured via the bi-monthly monitoring procedure.

There is also a bunch of methods to strengthen knowledge transfer outwards ECHORD, for example a brochure was compiled with all 51 ECHORD experiments as a showcase of exemplary industry-academia collaborations. Furthermore, a special catalogue has been developed that contains a comprehensive overview of European robotic products (nearly 300 items), based on robotic equipment information gathered from a large number of companies and institutions.

As another tool, we built a list of potential cooperation partners in Europe by evaluating all ECHORD proposals that did not receive funding but were rated above quality threshold.

4.3 Technology transfer’s obstacles and chances

Academia-industry technology transfer projects face their own challenges. We have previously already worked towards looking at these in detail. For potential drawbacks of I-U collaborations to both university and industry see deliverable D4.5-2011 (pp. 19-21). Here we are going to focus on looking at a few issues, which were reported by the participants who filled in the aforementioned Asian Lab Tour questionnaire (see last sections in chapter 2.1).

Before we look at those results, we will present another quote from the interview with Hiroshi Ishiguro. He had a critical view on academia-industry collaborations:

"Obviously, a university is not the ideal place for doing some practical work. […] Still a lot of people think that a university professor cannot have a private company or something. But China is different."

Rodney Brooks mentioned a certain kind of obstacle, which relates to the way in which such collaborations are set up. He suggested that sometimes the matter of who takes the initiative within such projects can be crucial:

"The biggest problem really is… Well here's a generic problem that I've see happen many times: The CEO level of the company says "I want to bring innovation into my company by working with academia". Goes and signs a deal with some academic group. And then the CEO hands it down two levels in the company. And now it's someone's assignment: "Oh, I'm supposed to get innovation from…" […] So, I've seen that really fail. Within the company, the CEO says "Yes we're gonna do this", they really have to cultivate some group which is really going to do it. And some I've seen do it well, and others have done it very badly."

The Asia Lab Tour questionnaire asked a specific question which related to the main obstacles. Below are the question and frequent replies the participants provided grouped by topics:

What are the main obstacles in collaborative projects with academia and industry?

Several participants mention the gap that exists between academia and industry:

- *The discrepancy in the value being pursued by academia and industry: difference in evaluation/promotion criteria (e.g. university often cares about papers while industry cares about implementation)*
- *The gap between the need of industry and the technological results of academia.*
- *The gap between making a product and research*
- *There is a lack of a long-term mutually beneficial mechanism*
- *The academia pursues novelty of the approach and methods etc. The industry pursues the usability to solve the problem no matter how they develop.*

A recurring issue is also IP rights and patents:

- *One obstacle to make delay the start-up of the collaborative research is making the final contract on handling the department of IP through the division of Cooperate Relations of University and Company*
- *Patent transfer fee evaluations.*

Several comments can be subsumed under the heading TRL:

- *Difference of viewpoint in needed technologies for commercialization*
- *Technical level at the transferring stage is too premature to apply it to commercial robot; In some cases, license is way too high*
- *Lab research results transfer to industrial applications welcomed by market*
- *Finance*

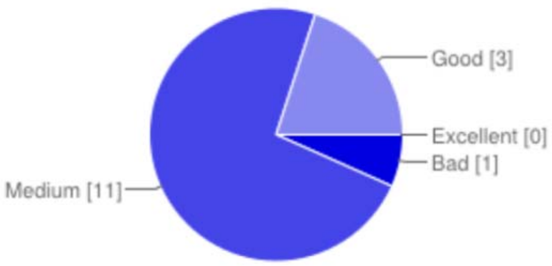
- *Difference view of technological completeness*
- *Some innovative technologies in academia are not very suitable for industrial application*

Further responses include:

- *Inadequate communication and coordination among participators.*
- *Economic conditions*
- *Lack of proper applications of robot in the real world*
- *Immaturity of robot technology*
- *Encounter to good partner and budget*

Recurrent themes with the replies which people have to the question on obstacles are therefore a gap between industry and academia research (see section 2.3.2), the problem of IP rights and patents and TRL, a topic which we plan to address in a later report.

How is the quality of know how transfer between academia and industry?



Bad	**1**	7%
Medium	**11**	73%
Good	**3**	20%
Excellent	**0**	0%

The results show that there is large room for improvements, also from the Asian perspective.

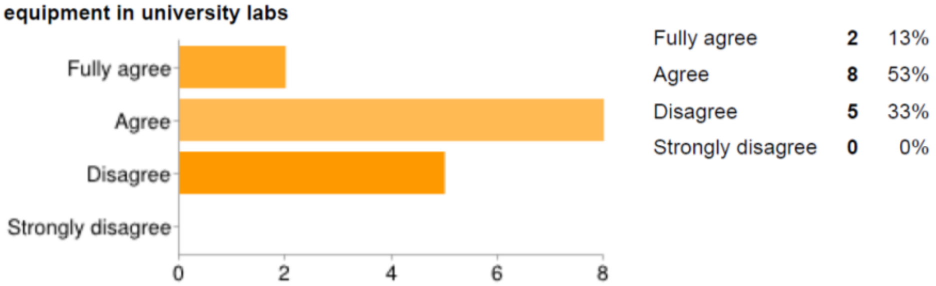
The three experts who were interviewed were asked about ways in which one can stimulate academia-industry collaborations. The following sections reports on the answers they gave by quoting their answers verbatim. We use their views as an indicator as all of the experts have different backgrounds in such collaborations.

- *"I mentioned a triangle – the industry, the government and the university or academia. There are still large gaps between these. Therefore, we need a guy to connect these. This is a kind of gatekeeper or producer. He or she should know the demand and need and then determine what kind of product has a big potential. He or she should not be a researcher but someone with a sense of the market." (Prof. Asada)*
- *"The most important thing is to have the kind of person. […] The role of my student was technology transfer. […] We need to have that kind of person. The students will be that kind of person." (Prof. Ishiguro)*
- *"You can view the different reward systems of industry and academia also as strength! Because then the innovations are different in the two places, and so,*

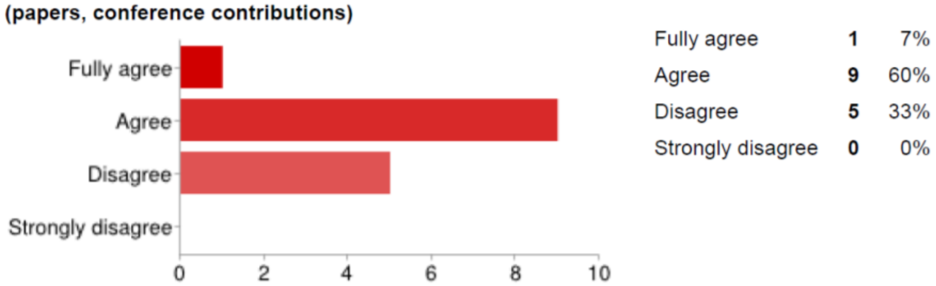
how do you get the best from both. You can't view either as a subset of the other. I think that's a mistake sometimes people make." (Prof. Brooks)

- *"I would propose that we start a good collaboration with some immediate application to the real world and then gradually introduce it to the market. By collaboration, I mean university and industry again. I suppose the government's role is to lead this kind of collaboration." (Prof. Asada)*
- *"I think the only way technology transfer can happen is by people … by people moving back and forth. At MIT we had a lot of collaboration with large companies and small. And it was only satisfying and successful when people really knew people in the other organization and moved back and forth. Sometimes six months at a time, or even a year at a time. […] And the companies and the academics have to be willing to make that investment. So, there's got to be payoff. No one wants to make that big an investment if it is not about some real value out of it. … But it really has to be people." (Prof. Brooks)*

6. Which routes of knowledge transfer do you consider most efficient? - Use of industrial equipment in university labs

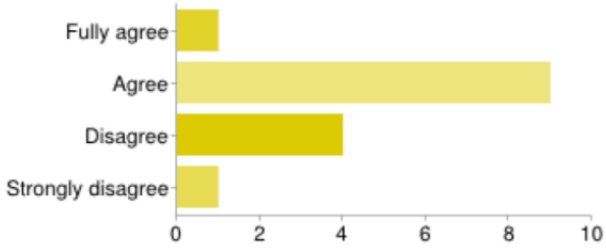


6. Which routes of knowledge transfer do you consider most efficient? - Presentations (papers, conference contributions)



Different views are taken from industry (they all agree) and from academia (who are responsible for all disagreeing answers).

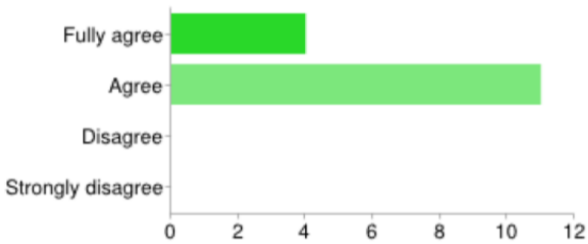
6. Which routes of knowledge transfer do you consider most efficient? - Free dissemination of research outputs



Fully agree	1	7%
Agree	9	60%
Disagree	4	27%
Strongly disagree	1	7%

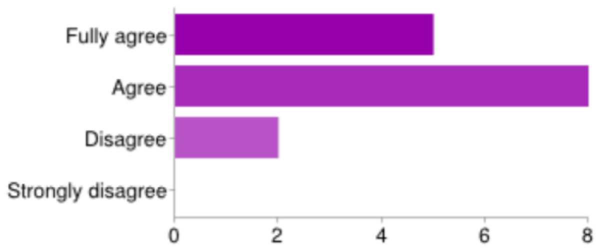
There is even more discrepancy in these answers. It follows the pattern observed for the previous question and both extreme points (fully agree and strongly disagree) are made by participants from academia. Overall it has the weakest support from all 11 options that have been offered here.

6. Which routes of knowledge transfer do you consider most efficient? - Research collaborations



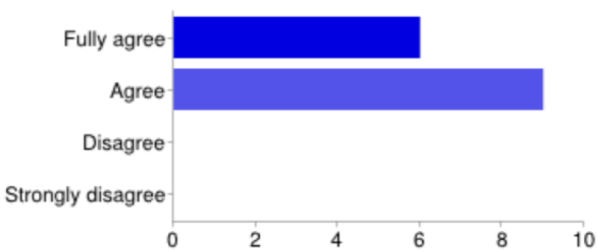
Fully agree	4	27%
Agree	11	73%
Disagree	0	0%
Strongly disagree	0	0%

6. Which routes of knowledge transfer do you consider most efficient? - Contract research on behalf of the industry



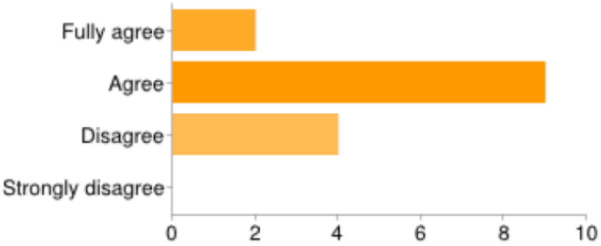
Fully agree	5	33%
Agree	8	53%
Disagree	2	13%
Strongly disagree	0	0%

6. Which routes of knowledge transfer do you consider most efficient? - Licensing of technology to university partners



Fully agree	6	40%
Agree	9	60%
Disagree	0	0%
Strongly disagree	0	0%

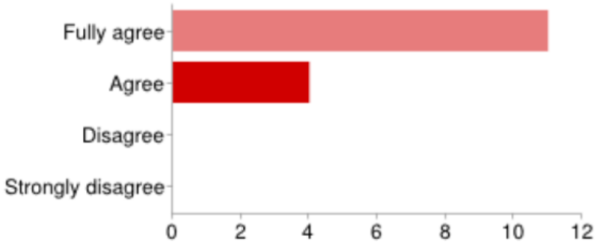
6. Which routes of knowledge transfer do you consider most efficient? - Sale of services, data and software to universities



Fully agree	**2**	13%
Agree	**9**	60%
Disagree	**4**	27%
Strongly disagree	**0**	0%

The answers here are quite inhomogeneous and follow once more the pattern that all participants who disagreed are from academia and all participants from industry agreed.

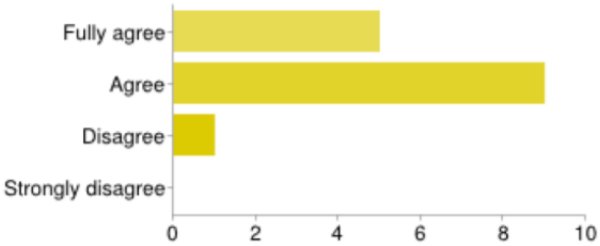
6. Which routes of knowledge transfer do you consider most efficient? - Formation of ventures and spin-off companies together with university or public sector partners



Fully agree	**11**	73%
Agree	**4**	27%
Disagree	**0**	0%
Strongly disagree	**0**	0%

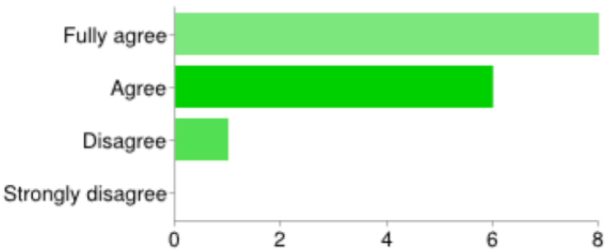
The joint formation of companies is considered the most efficient way of tech transfer.

6. Which routes of knowledge transfer do you consider most efficient? - Joint projects based on public funding

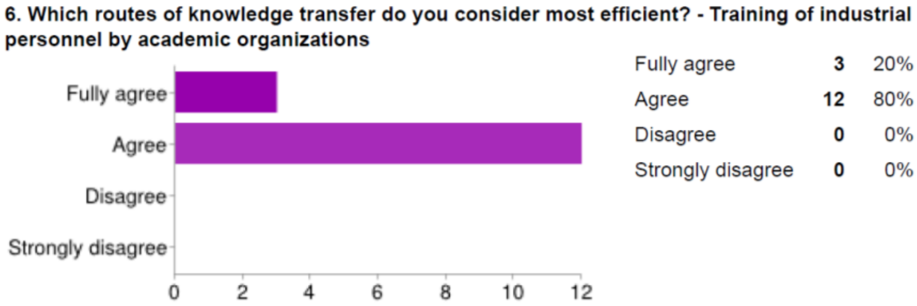


Fully agree	**5**	33%
Agree	**9**	60%
Disagree	**1**	7%
Strongly disagree	**0**	0%

6. Which routes of knowledge transfer do you consider most efficient? - Recruitment of personnel from universities or public organizations (internships, PhD students etc.)



Fully agree	**8**	53%
Agree	**6**	40%
Disagree	**1**	7%
Strongly disagree	**0**	0%

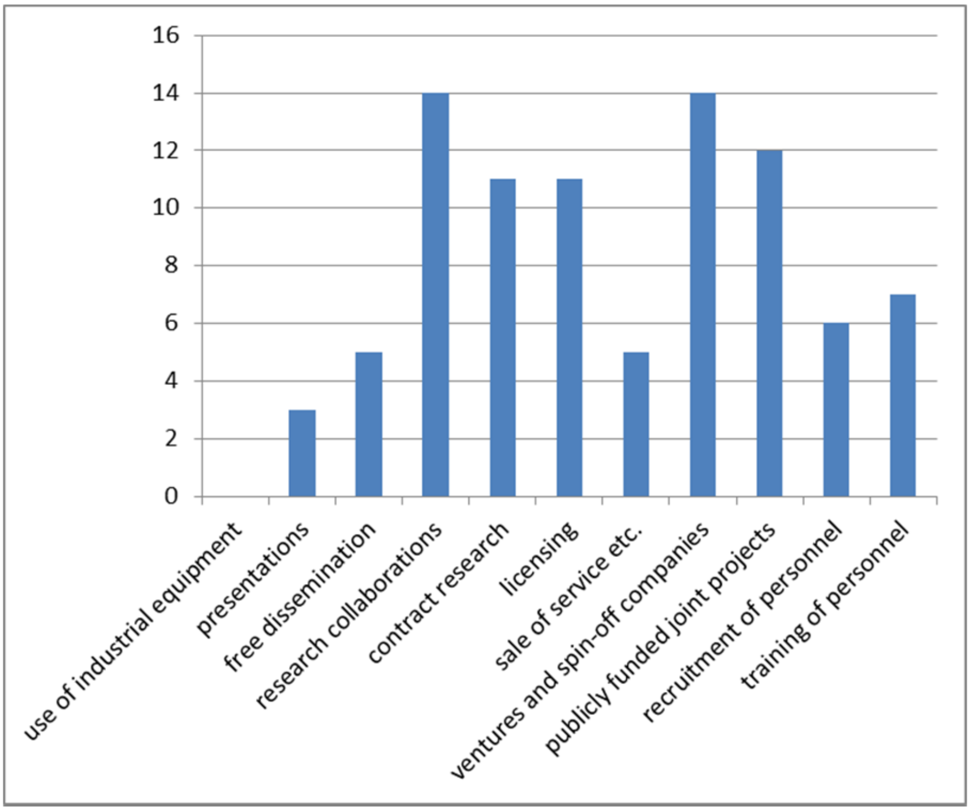


Are there other routes of knowledge transfer?

The only response here was "Joint to apply projects by government".

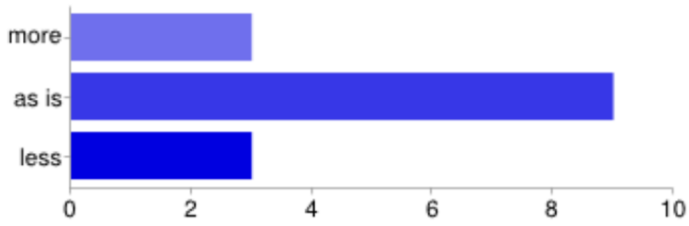
The next question deals with various measures that are potentially suitable to improve the knowledge transfer between industry and academia. The participants were asked to express their opinion for a set of 11 individual measures, if they should be employed more, less or as is. The following figure summarizes the results on a scale between zero (= mean of all responses equals to "as is") and 14 (= one participant voted for "as is", the remaining 14 for "more"). All mean values are positive, since there was for no measure a majority that voted for "less".

As a result, there is a wide range of mean values and a strong emphasis on those measures that aim for a collaborative effort, be it research collaborations, publicly funded joint project or even spin-off companies and ventures.



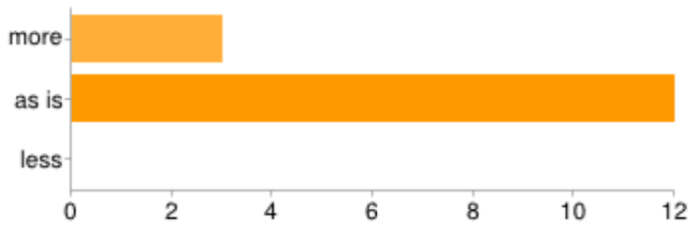
In the following the responses to the individual questions are provided. Note, that the use of industrial equipment is seen quite controversial. There is regularity, namely that all participants that wished to employ this measure more are from academia.

7. In your opinion, what should be done to improve knowledge transfer? - use of industrial equipment



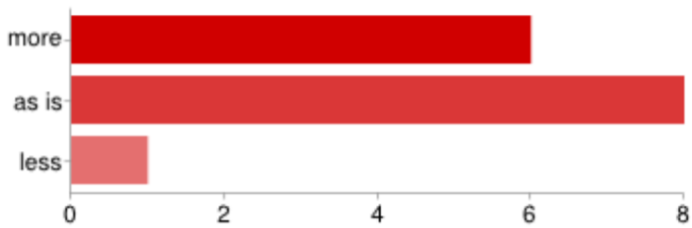
more	**3**	20%
as is	**9**	60%
less	**3**	20%

7. In your opinion, what should be done to improve knowledge transfer? - presentations



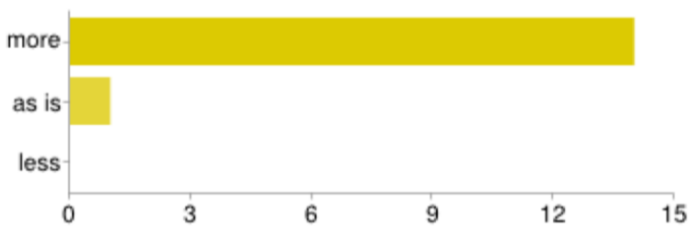
more	**3**	20%
as is	**12**	80%
less	**0**	0%

7. In your opinion, what should be done to improve knowledge transfer? - free dissemination



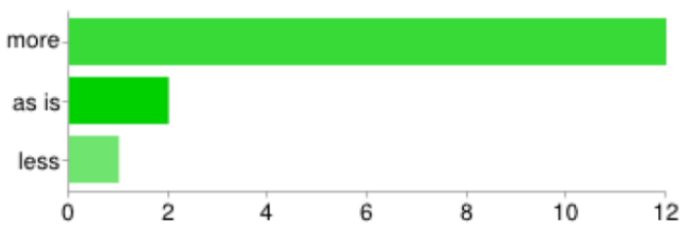
more	**6**	40%
as is	**8**	53%
less	**1**	7%

7. In your opinion, what should be done to improve knowledge transfer? - research collaborations



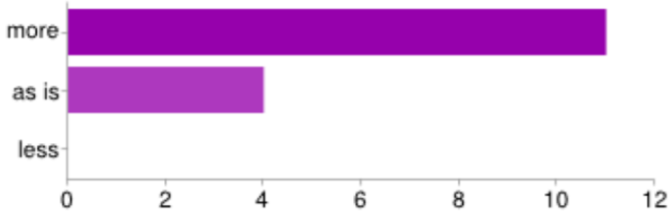
more	**14**	93%
as is	**1**	7%
less	**0**	0%

7. In your opinion, what should be done to improve knowledge transfer? - contract research



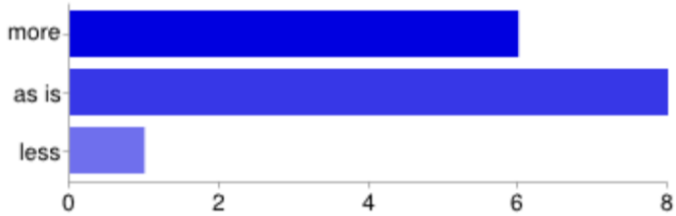
more	**12**	80%
as is	**2**	13%
less	**1**	7%

7. In your opinion, what should be done to improve knowledge transfer? - licensing



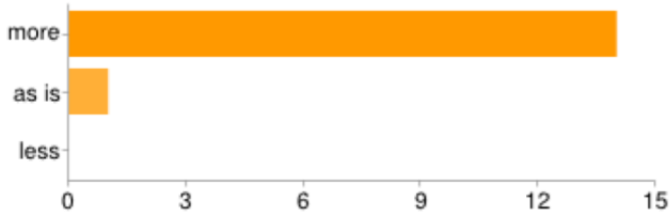
more	**11**	73%
as is	**4**	27%
less	**0**	0%

7. In your opinion, what should be done to improve knowledge transfer? - sale of service etc.



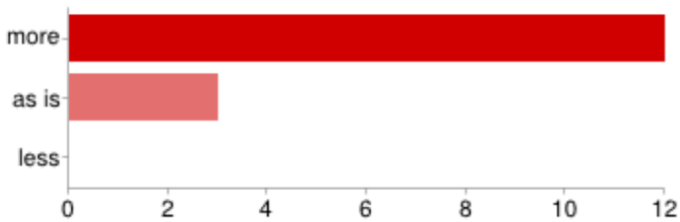
more	**6**	40%
as is	**8**	53%
less	**1**	7%

7. In your opinion, what should be done to improve knowledge transfer? - ventures and spin-off companies



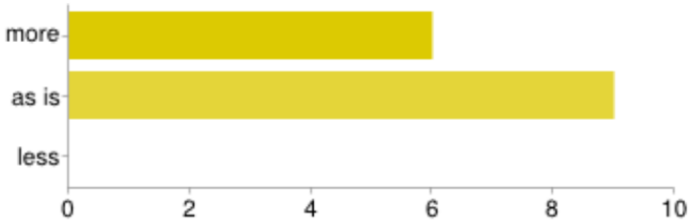
more	**14**	93%
as is	**1**	7%
less	**0**	0%

7. In your opinion, what should be done to improve knowledge transfer? - publicly funded joint projects

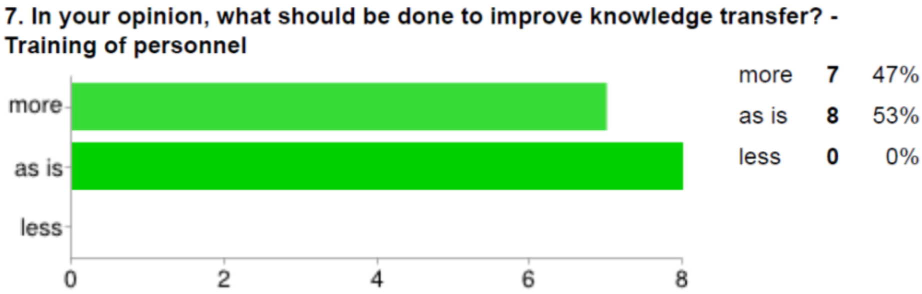


more	**12**	80%
as is	**3**	20%
less	**0**	0%

7. In your opinion, what should be done to improve knowledge transfer? - recruitment of personnel



more	**6**	40%
as is	**9**	60%
less	**0**	0%



For this part of the questionnaire, we had a closer look at the answers of some tightly related questions. For example, only 20% felt that we should have more presentations in order to improve knowledge transfer (question 7) and 33% expressed their disagreement that presentations are an efficient route of knowledge transfer at all (question 6).

Do you have other suggestions to improve the knowledge transfer?

"A better mechanism to match the technology available and the demand by industry may be of help."

Questions 6 and 7 provided the same set of options to be rated, so we can directly compare the answers from both questions. The result of this analysis is shown in Figure 21, which plots results from question 6 on the abscissa and results from question 7 on the ordinate by using a Likert scale with arbitrary units.

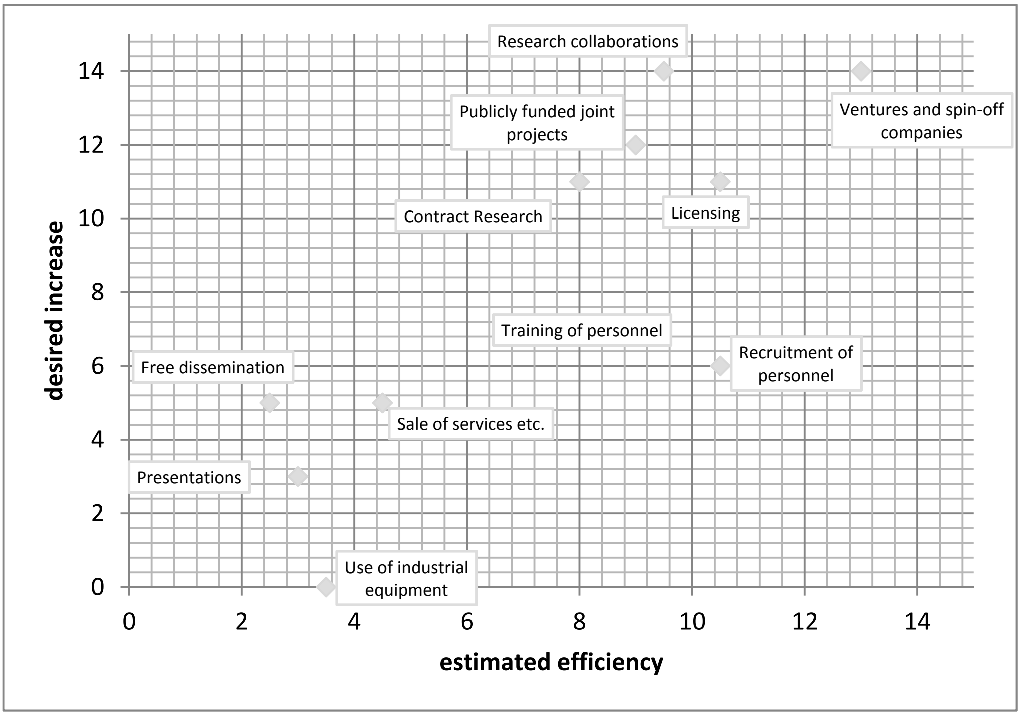


Figure 21: Results from question 6 on the abscissa and results from question 7 on the ordinate, using a Likert scale with arbitrary units.

It is apparent that there is a good correlations between the two sets of answers, but there are also noteworthy deviations: ”Free dissemination” was rated rather low with respect to efficiency and it received also only moderate values for desired increase. Rougly the same value for increase was given to “recruitment of personnel” which received a much higher rating in the estimated efficiency. From this we can conclude that the measure of recruitment should not be employed more, not because it is not efficient, but because there is already enough activity going on. If we finally look at “research collaborations”, we observe about the same high value for efficiency, but also a high rating regarding desired increase, meaning, that there is a large agreement that this measure is both, very important and not enough employed.

4.4 Future Directions

There are plenty potential benefits of close collaboration between academia and industry in robotics (for I-U cooperations in general see Ankrah, 2007) like, e.g., a better understanding of the needs of industry as well as a better understanding of the offerings from academia. This may result in:

- More industrially relevant research
- More money for research via I-U technology transfer
- More advanced products via I-U technology transfer
- Less duplication of work
- More spin-offs and start-ups.

When we asked various stakeholders about the quality of knowledge transfer today, answers were not too pessimistic, but clearly indicate that there is quite some room for improvements (see Figure 22).

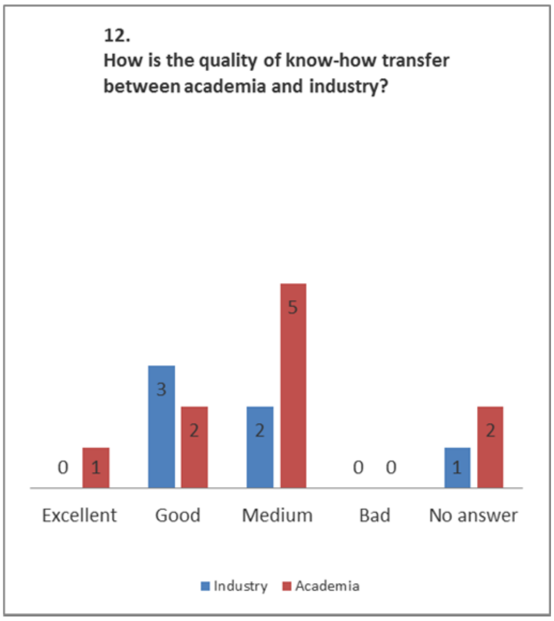


Figure 22: Responses to question #12 (blue = participants from industry, red = participants from academia). Numbers refer to absolute number of participants (as by now).

In the following we will therefore summarize ideas and suggestions put forward in workshops, special sessions, ECHORD meetings and conversations with leading researchers in the field on how to overcome obstacles etc. We will start by a general discussion and then turn to European and several extra-European points of view.

4.4.1 General discussion

On the joint euRobotics / ECHORD workshop at IROS 2011 we organized a moderated discussion that was guided by questions like

- What can be done to improve I-U collaboration?
- What is best practice?
- How can funding support this process?
- At which Technology Readiness Level should technology transfer happen?

In the following an overview will be given in a bullet-point style (based on notes taken by T. Guhl). It contains interesting ideas, but points also to open issues and raises new questions.

How to get industry and academia to work together

- US government (project offices) compiled a list of gaps to then pass on to academia

How to allow academia to evaluate their results in a context that the industry understands (see below)

- Common projects (e.g. ECHORD, funded research, etc.)
  - Length of projects:
    Short: validate technology quicker, good if proposal is less work, but not long enough to really create value (as in new technology)
    Long: team might change too much
    Start with a short project (e.g. intern) with a focus and then build a longer project on that (maybe 10% turn into long projects)

How to facilitate

- Getting academia to do something short-term if you have money is normally easy
- Dating agency – key: to increase success rate and decrease overhead of taking part
- If academia offers to write the proposal then industry is often willing to be part

How to improve I-U understanding

- Industry may not be so willing to put their topics onto the academics agenda as they would reveal their course
- Understanding of what is realistic for how much money if the collaboration starts

- Industry needs to participate in research to a certain extend to understand academia (and vice versa)
- „Yellow pages of robotics“ → find the experts on both sides
    - How to build yellow pages
        - From conference proceedings, but understanding needed to evaluate quality
        - Hard to capture all relevant topics and people
        - Give the experts a platform to provide information about them and their technologies / content
    - Problems with yellow pages:
        - May help industry to find a set of experts, but how to identify the most suitable ones?
        - Even with yellow pages you need the network
- Discuss to understand the positions in the context of a technology or problem
- Improve understanding of each other's problems via media
- Communicate from industry towards academia
    - Communicate (product) visions and the related needs
    - Challenges set by industry (e.g. navigate in environment X)
    - Establish repository of industrially relevant datasets
- Communicate from academia towards industry
    - Industrial training, e.g., academia teaches how to use results
    - Tell industry what you have to offer

How to help start-ups

- Help for start-ups focused on robotics
- Find the person on the technical team who has or is happy to develop the business sense
- Ensure the start-up is user focused (internal and external users)
- Build up tool box for people "to pick up things from", if they have an idea
- VC with a focus on robotics (e.g. from within the "mother ship")
- Get VC to give talks to those most likely to start companies
- How to facilitate "buying the bits you need" → need for standardization

How funding can support this process

- Design calls
    - to stimulate cooperation and communication
    - aim for mixed projects (industry and academia collaborate)
    - content industrially relevant
    - involve end users / consider exploitation strategy
- ECHORD style experiments
- Try to close the gap between academic research (Technology Readiness Level i) and industrial development (Technology Readiness Level i+x).

We also asked the participant of our survey what from their point of view should be done in order to improve knowledge transfer (Figure 23). It was a multiple choice question with eleven pre-defined answers and the task was to score the different measures by choosing between “more”, “less” and “as is”. Responses were very similar between participants from industry and academia for all but two options: “licensing” was evaluated quite differently in that roboticists from academia wished to focus more on licensing (or keep it as is) whereas potential collaboration partners from industry opted for less licensing (or as is). The same was true for the option “sale of service”.

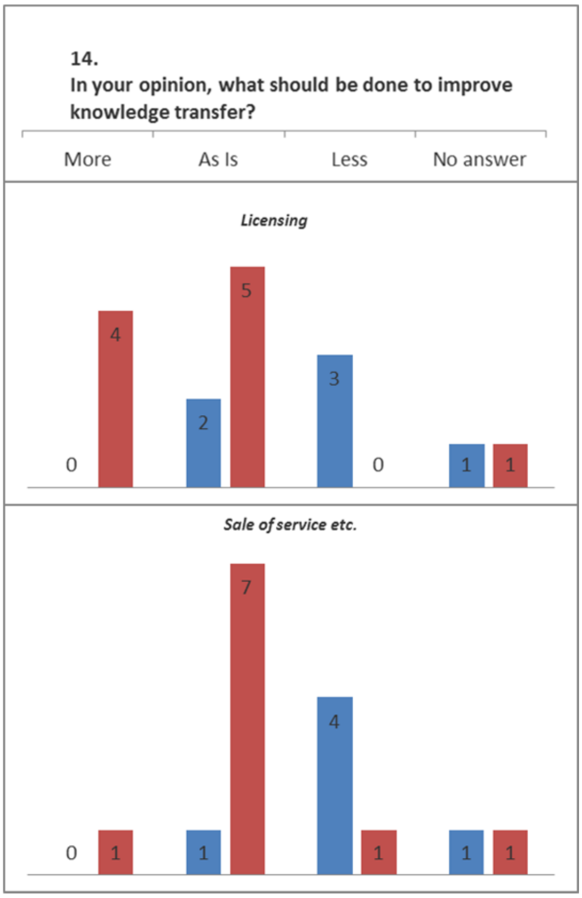


Figure 23: Assessment of 2 out of 11 options from question #14, blue = participants from industry, red = participants from academia.

4.4.2 European perspective

At the occasion of the EU Innovation Convention 2011 in Brussels a session was organized by LERU (League of European Research Universities) about “Universities, governments and industry: successful partnerships for a competitive Europe”. Speakers from industry (H. Hofstraat, Vice President, Philips Research), university (P. Van Dun, Director of Leuven Research & Development, K.U. Leuven) and the EC (J.-C. Burgelman, DG Research and Innovation) debated on how to ensure successful partnerships for innovation and the relation of innovation to basic science and fundamental research. The discussion focused on specific aspects of the crucial role of universities in the innovation cycle. Their case is summarized in the following:

- Fundamental research lays the foundation for the discovery of new knowledge and creation of innovative products and services
  - Fundamental research is exploratory, curiosity driven and can lead to transformational societal impact
  - A culture of intellectual discovery is essential for effective exploitation of serendipitous discovery
  - Fundamental research provides the basis of a knowledge economy and delivers an economic return
- Innovation is a complex process, not a linear progression of basic science into new products
  - Innovation is as important for basic research as it is for applied research and development
  - Cross disciplinary research can provide rich opportunities for innovation as well as discovery and invention
  - Innovation requires iterative cycles of incremental advancement
- Public investment in research is essential. It requires patience, persistence and a long-term vision
  - Research is uncertain – the outcomes cannot easily be predicted
  - There can be associated economic benefits from the activity of basic research even before the ultimate goals of research are realized
  - The process of long term fundamental research has potential for shorter term economic benefit through associated innovation

In the context of ECHORD we are interested in the question what we can learn from European collaborations in research areas other than robotics. For this, we took advantage from the fact that the innovation convention showcased 49 joint projects from fields as diverse as energy, transport, environment protection, safety and the elderly, amongst others.

4.4.3 US perspective

For an US perspective on possible improvements in I-U knowledge transfer, major findings of the experts from a North American lab tour are summarized below.

- The time window for service robotics in industry is now open – all major laboratories are working on different kinds of applications
- Platforms (= robots systems) are being used that make it possible to concentrate on application development – not on classical robot development
- The US is pushing very hard to bring technology forward – through DARPA and the National Robotics Initiative
- The US is becoming aware of its leading role in manufacturing and will invest heavily into its Advanced Manufacturing Program (US$ 2 billon)

- The „classical“ areas (elderly care, medical robotics, exoskeletons, etc.) may not perceived be as spectacular any more, but they are also pursued with high pressure
- Europe will need to find an answer to this rising competition!

Six US and one Canadian top-level university lab were visited, several industrial labs and the NASA Jet Propulsion Laboratory. A detailed report on the tour is available on the ECHORD website[6].

4.4.4 Australian perspective

During a recent advisory board meeting we received additional input on how to foster I-U collaborations from an Australian perspective. Alex Zelinsky, who is the Group Executive for Information Sciences at CSIRO (Australia) and member of the Australian Government’s Information Technology Industry Innovation Council, shared his experience on successful collaborations (Figure 24). He made a strong case for market pull as opposed to technology push. He gave examples from the work with farmers that have the problem of big water holes.

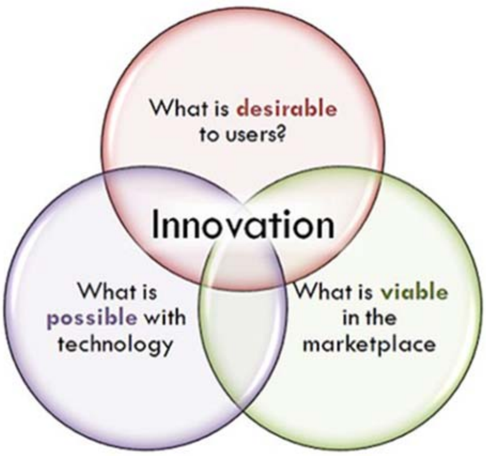


Figure 24: Prerequisites to make innovation happen
(from a slide by A. Zelinsky, IROS-11 workshop).

Also fish farming needs to be automated, since very soon twice as much food is needed in the world. He pointed out that we as roboticists must find these problems ourselves, e.g. by looking at non-traditional areas (the “problem transfer”). According to him, it should also be stressed when talking about structured dialog with industry that “industry” encompasses more than only the engineering industry, since it includes people who have not been exposed to robotics before. Potential end users have to be proactively identified.

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[6] http://echord.info/wikis/website/cc-publications

4.4.5 Asian perspective

Also a member of ECHORD's advisory board, Hirochika Inoue from Tokyo University (Japan) argued that the notion of technical transfer from academia to industry is wrong, because industry will take the initiative to go into new technology (see also above). He verified ECHORD's approach to focus on SMEs. His advice is to give small companies a chance to try at least, since big companies use government money to survive. Grow up small companies - do more, even though the quality of the product might not be so good. From his perspective, the telepresence business model is important, in some new area maybe food industry is important, but each country's policy is different.

5 Analysis of ECHORD cooperations

The European case for collaboration is especially interesting, as the partners in academia-industry collaborations do not necessarily have to be located in the same country. In the ECHORD project partners in experiments often came from more than one country. This poses physical boundaries to face-to-face interaction. Therefore, we will look at the effects of proximity on our ECHORD experiments.

5.1 Distance as possible factor for success

The distance between project partners as a possible factor for successful collaborations is a topic that is controversially discussed in the literature. This topic was also raised by some of our partners on ECHORD workshops (see e.g. p. 75) and we want to contribute to this discussion by using the data available from ECHORD experiments.

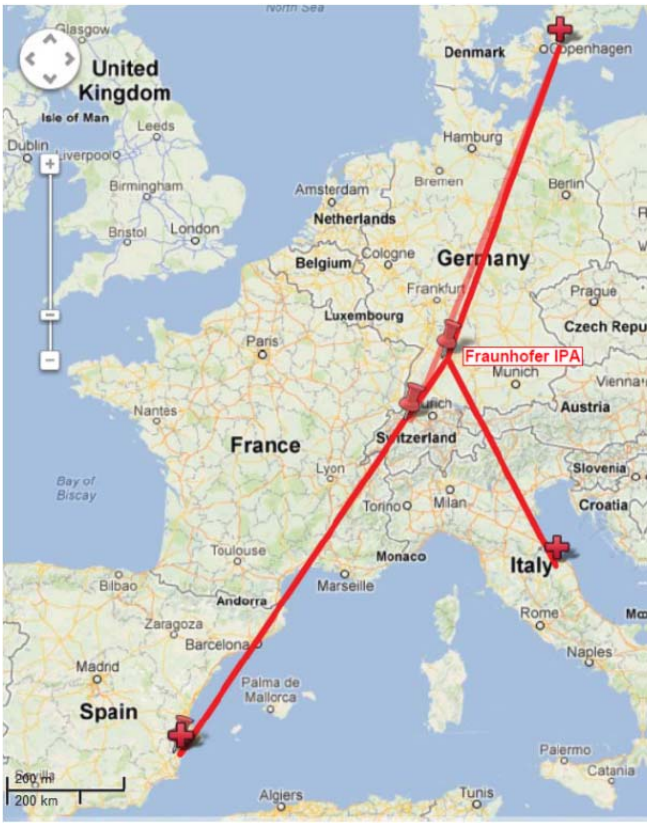
In order to assess if distance between partners is correlated with the success of the project, we need both, a distance metric and a success metric. At present it is too early to assess the success of the ECHORD experiments in a uniform manner, because the majority of them is either under final evaluation or even still running. To avoid delays, we have therefore started to collect and analyse data on distance between project partners.

The majority (>90%) of ECHORD experiments has 2-3 partners, but there are also four experiments with a single formal partner (these are: HYROPA, MoFTaG, PsyIntEC, RIVERWATCH) and one experiment with four partners (PRADA). In each experiment there is one partner that acts as the coordinator of this experiment and this is usually the one which plays the major role in terms of person months, budget etc. To treat all experiments equally and also to take into account the communication structure that seems to be most relevant, we decided to take the average of the distances between the coordinator of the experiment to all its partners. The resulting distances are illustrated in Figure 25.

Figure 25: Geographical distances between the four ECHORD experiments with a single formal partner (HYROPA, MoFTaG, PsyIntEC, RIVERWATCH) and the one experiment with four partners (PRADA).

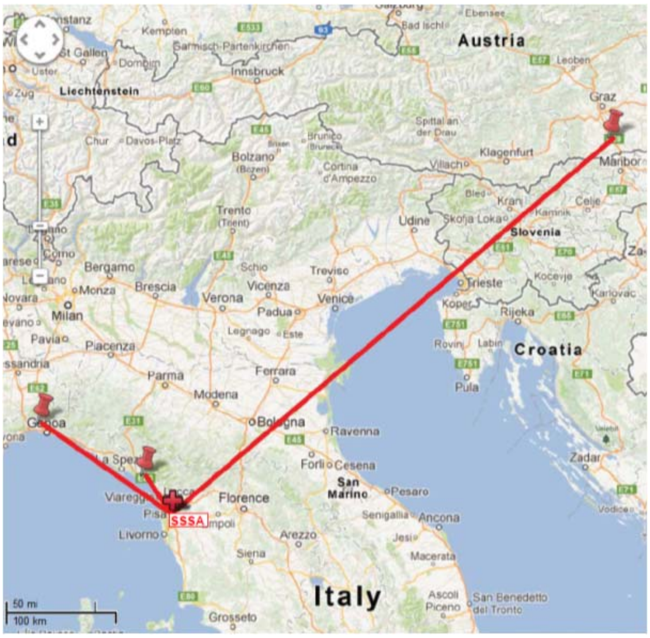
As soon as a substantial part of all 51 experiments has come to an end and is evaluated, we are able to check for correlations between success and partner distance. In the meantime, we selected four experiment partners for further analysis, because they are involved in three or even four ECHORD experiments. These are Fraunhofer IPA, Fraunhofer IFF, Skybotix and SSSA. Since they are involved in several experiments it is possible to make a direct comparison with one and the same experiment partner. The data that will be used for the correlational analysis are given below.

- Distance from **Fraunhofer IPA** (Stuttgart, Germany) to experiment partners:
    - 661 km (to Angeli di Rosora, Italy)
      Experiment INTERAID, no further partners
    - 825 km (to Lund, Sweden),
      Experiment MONROE, one additional partner
    - 1405 km (to Elche, Spain),
      Experiment HERMES, one additional partner



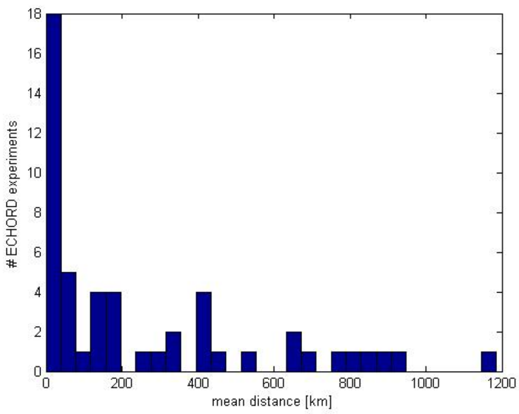
- Distance from **Skybotix** (Zurich, Switzerland) to experiment partners:
  - 136 km (to Bellinzona within the same country),
    Experiment REMAV, one additional partner
  - 434 km (to Nice, France),
    Experiment TUAV, no further partners
  - 1246 km (to Madrid, Spain),
    Experiment OMNIWORKS, one additional partner

- Distance from **SSSA** (Pisa, Italy) to experiment partners:
  - 1 km (within the same city),
    Experiment HUROBIN, no further partners
  - 59 km (to Massa within the same country),
    Experiment SPRAYBOT, no further partners
  - 147 km (to Genova, within the same country),
    Experiment TESBE, no further partners
  - 530 km (to Leibnitz, Austria),
    Experiment ATROMOBILE, no further partners



- Distance from **Fraunhofer** IFF (Magdeburg, Germany) to experiment partners:
  - 0 km,
    Experiment HYROPA, no partner involved
  - 5 km (within the same city),
    Experiment BRACOG, no further partners
  - 347 km (to Cologne within the same country),
    Experiment ALEXA, no further partners
  - 423 km (to Augsburg within the same country),
    Experiment EXECELL, no further partners

The upcoming analysis will have to show if further parameters are to be considered, e.g., the number of countries involved. The overall distribution of mean distances spans a huge range, from several meters to more than 1,000 km beeline. Figure 26 depicts a complete histogram, while Figure 27 focuses on small-distance experiments.



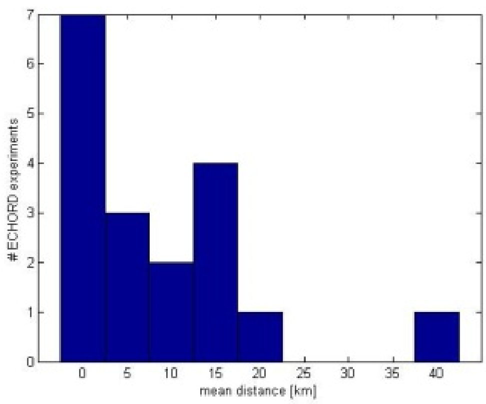
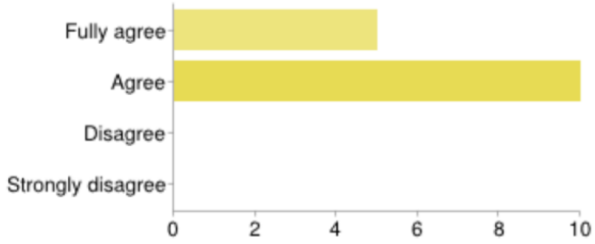


Figure 26 (left): Mean distances between partners (complete histogram).
Figure 27 (right): Mean distances between partners (small-distance experiments).

5.2 Measuring success

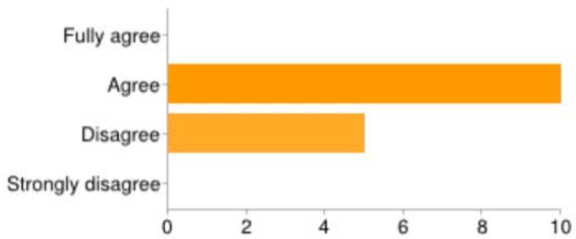
In their interviews, both Prof. Ishiguro and Prof. Asada noted that one can only measure success in an industrial setting in actual sales. The industrial partners measure their success and sales and they will therefore decide their involvement and the success according to this measure. Academic success was harder to pin down. Generally, Hiroshi Ishiguro spoke of the need for external evaluation in case of academics. Brooks in contrast commented on the good relationships between academics and industrial environments, which show the potential for successful collaboration. As part of the ECHORD questionnaire for Asian robotic labs (see last sections in chapter 2.1) we also asked a set of questions on how to measure success:

2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Patents granted



Fully agree	**5**	33%
Agree	**10**	67%
Disagree	**0**	0%
Strongly disagree	**0**	0%

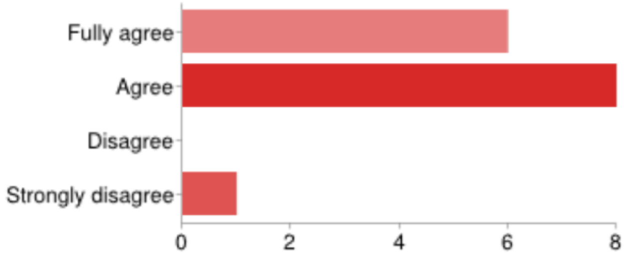
2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Publications (papers, conference contributions)



Fully agree	**0**	0%
Agree	**10**	67%
Disagree	**5**	33%
Strongly disagree	**0**	0%

The answers here are quite uneven. It is interesting to note that all participants who disagreed are from academia. All participants from industry agreed, which is rather surprising. Taken together, publications are considered to be the least suitable method from the 11 options that we have provided.

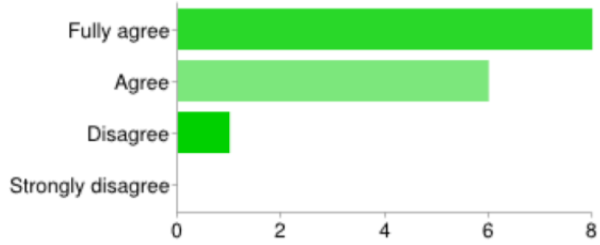
2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Patent applications



Fully agree	**6**	40%
Agree	**8**	53%
Disagree	**0**	0%
Strongly disagree	**1**	7%

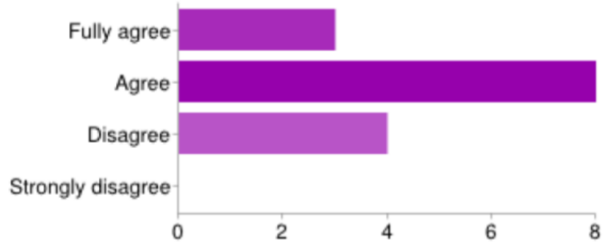
One of the respondents made a clear distinction between patent application and granted patent: The one that has ticked “strongly disagree” here, chose “fully agree” as answer to the next part of the question:

2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Having found a partner to develop / manufacture a product



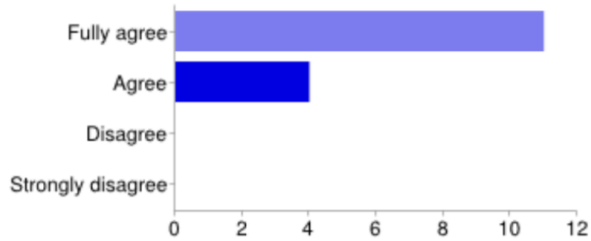
Fully agree	8	53%
Agree	6	40%
Disagree	1	7%
Strongly disagree	0	0%

2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Long-lasting cooperations with specific non-industrial labs



Fully agree	3	20%
Agree	8	53%
Disagree	4	27%
Strongly disagree	0	0%

2. In your opinion, are the following methods suitable for measuring the success of the knowledge transfer between industry and academia? - Prototypes sustainably used in a realistic environment, where applicable



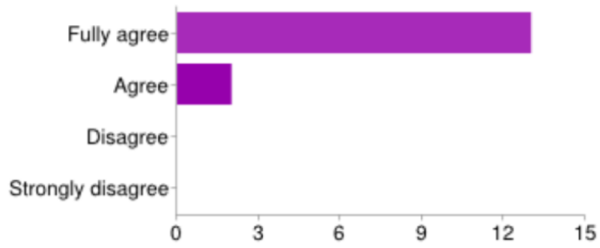
Fully agree	11	73%
Agree	4	27%
Disagree	0	0%
Strongly disagree	0	0%

This method is considered to be most suitable one.

Are there other methods?

- *Sales statistics of products*
- *Number of products based on the technology*
- *Prepayment of fees paid by industry*
- *Exhibitions in which both industrial and academic organizations participate.*
- *Develop a product which is welcomed by market*

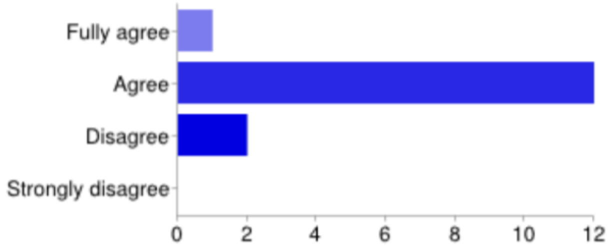
8. In your opinion, are the following methods suitable for measuring the success of a robotics research project? - Prototypes sustainably used in a realistic environment, where applicable



Fully agree	**13**	87%
Agree	**2**	13%
Disagree	**0**	0%
Strongly disagree	**0**	0%

This option received the strongest support amongst all 5 suggested methods.

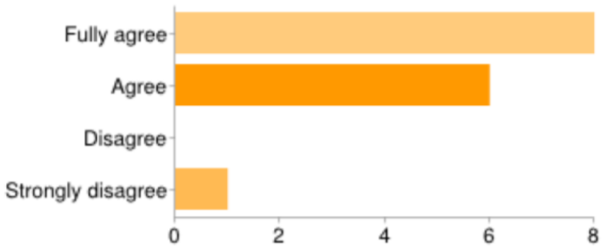
8. In your opinion, are the following methods suitable for measuring the success of a robotics research project? - Publications with high impact



Fully agree	**1**	7%
Agree	**12**	80%
Disagree	**2**	13%
Strongly disagree	**0**	0%

“Publications” received the weakest support amongst all methods, although there is still substantial agreement that it is an important method for measuring success.

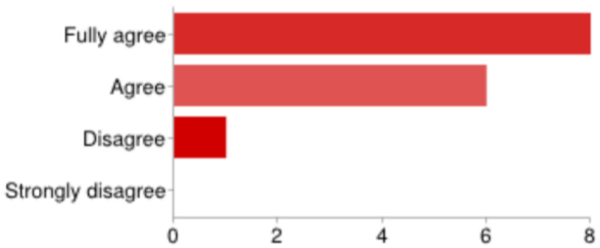
8. In your opinion, are the following methods suitable for measuring the success of a robotics research project? - Patent applications



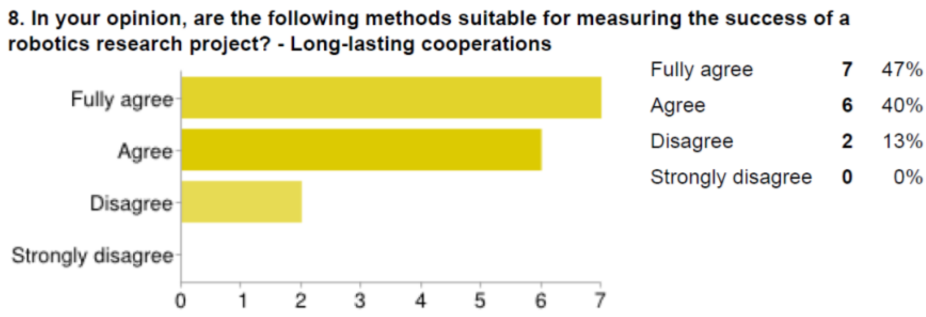
Fully agree	**8**	53%
Agree	**6**	40%
Disagree	**0**	0%
Strongly disagree	**1**	7%

As in question 2, one of the respondents made a clear distinction between patent application and granted patent: The one that has ticked “strongly disagree” here, chose “fully agree” as answer to the next part of the question:

8. In your opinion, are the following methods suitable for measuring the success of a robotics research project? - Patents granted



Fully agree	**8**	53%
Agree	**6**	40%
Disagree	**1**	7%
Strongly disagree	**0**	0%



In question 8 we asked if publications are a suitable method to measure the success of a robotics research project and question 2 if they are a suitable method to measure the success of technology transfer between academia and industry. The results we obtained show that most participants (80%) agreed on the former question, but only 66% for the latter. If we further compare answers to these closely related questions, we get the following scatter plot (Figure 28) with results from question 2 on the abscissa and from questions 8 on the ordinate (arbitrary units).

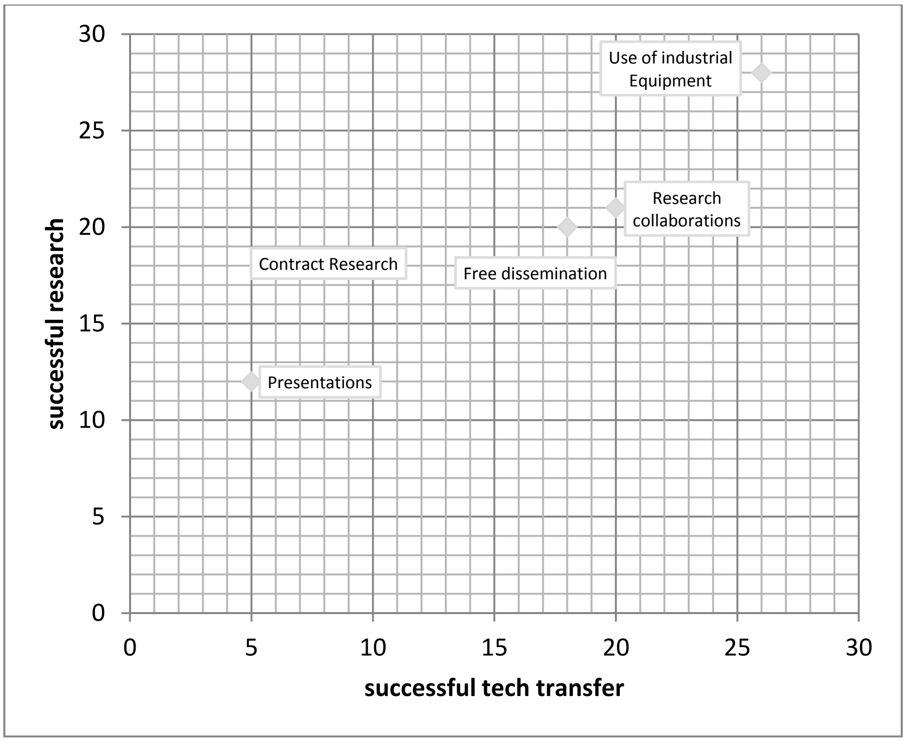


Figure 28: Results from question 2 on the abscissa and from questions 8 on the ordinate (arbitrary units).

What are measures of success for ECHORD-like projects?

Apart from the abovementioned measures there could be other means of measuring success. Below is a bullet list of verbatim answers that participants in ECHORD experiments gave with respect to what they considered good measures of success in ECHORD-like projects.

- *Both, industry and academic partners say, "I would do it again, it was valuable to cooperate"*
- *Res. institutes see a gap, do not know what to get out of academia, measure by asking*
- *More clear measure of collaboration*
- *Academia not able in some cases to transfer without company, as not interested in creating products, but that is the ultimate success, clearly defining the limits of academic work*
- *Clear answers of the questions raised during the set-up phase of the experiment*
- *Influence to turn-over 2 years after the project, exploitation plan after the project*
- *For academics, after on-going collaboration, sometimes publications only possible afterwards*
- *Are partners willing to exchange staff within and after the project*
- *Successful follow-up projects*
- *Testing alternatives if the original approach didn't work, maybe too expensive*
- *Best output would be to find the way to identify the projects*
- *Robots for green-houses failed, but raised discussion, scientific success, but product failure*
- *Awareness of potential technology in the wider community.*

For results on a related discussion see also chapter 6.1.

5.3 Proximity in Industry-Academia Collaborations: ECHORD

Academia-industry partnerships form one element of the National Innovation Systems (Arundel & Geuna, 2001). These are the *"flows of technology and information among people, enterprises and institutions [which] are key to the innovative process on the national level"* (OECD, 1997). However, within a European context they have to be contrasted with innovation systems, which are more general flows of technology and information among people.

Especially in the recent European Union context the term 'National Innovation System' needs to be re-examined in a transnational context. One needs to look at what impact transnational European projects have on sharing knowledge and advancing technology. The research and development (R&D) activities, which are funded by public investment through European Union grants, need to be inspected as a means of improving the innovation systems with the EU.

One of the ancillary questions is whether investment of public money is worth the costs if the effect is dwarfed by the barrier that may arise from the distances between collaboration partners on the European continent. The distances may be physical but these kinds of collaboration also face political, economic, cultural and linguistic barriers.

It has often been proposed (Arundel & Geuna, 2001) that innovation systems are comprised of codified knowledge which is being shared and tacit knowledge – also named spill overs - which is harder to share. Johnson et al. (2002) also say that the distinction between codified and tacit knowledge often coincides with the distinction between knowing what (knowledge about the world) and know-how (competence). The latter is crucial for technology transfer were the relevant aspect is the transfer of competencies together with concepts of procedures.

In this context one has to think about the feasibility of sharing tacit knowledge amongst project partners, which are operating within a dispersed network spread over geographically long distances.

In the pertinent literature on knowledge sharing in academia-industry collaborations the role of geographical proximity is discussed controversially (Biggiero & Sammarra, 2010; Cunningham & Werker, 2012; Ponds, van Oort, & Frenken, 2007; Rosa & Mohnen, 2008). Some argue that tacit knowledge is harder to share in contexts where physical proximity is high. Others argue that proximity effects are counteracted by modern information technology.

5.4 Theoretical and Empirical Background

The measures that (Arundel & Geuna, 2001) describe from their literature review for successful knowledge transfer include: scientific papers, citations of published papers, patents registered, patent citations and product announcements. For all these different effects are discussed with reference to the pertinent literature. For example, one can correlate the numbers of patents applied for or the number of product announcements – which in this case serve as a proxy for innovative output - with the explanatory variables private and public spending (on the R&D tasks). This yields results, which show a positive effect of public investment on the innovation potential of R&D activities. Using patents as a measure is however noted to be problematic (Johnson et al., 2002) for various reasons (they cannot be used for inferences regarding the knowledge flow between industry and academia).

Generally, all the measures listed above are codified knowledge and it is harder to tackle the issues connected to tacit knowledge. This is almost a definitional point. The main correlate of successful transfer in R&D from academia to industry is probably products, which emerge from collaborations. However often these become available after the project ends and are therefore not useful as an indicator for the monitoring of on-going knowledge transfer initiatives. Therefore, it is easier to track the project progress and the output as codified knowledge during a project's run time.

5.5 The ECHORD Project Data

Out of the 51 ECHORD subprojects 17 (27.45%) are of the category joint enabling technology, 20 (39.21%) are aimed at application development and 14 (33.33%) are feasibility studies (Figure 29). However, these categories should not been seen as mutually exclusive. The applied nature of the project is underlined by the foci of these activity types.

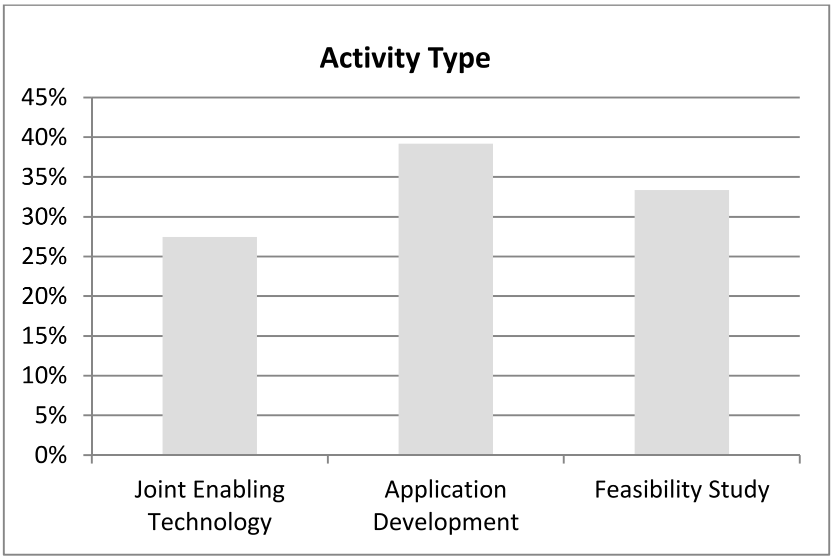


Figure 29: Distribution of activity types of ECHORD projects.

For the analysis of distances in ECHORD experiments we decided to take the mean over the distances between experiment coordinator and remaining experiment partners. To check whether this method is justified we had a look at the distribution of financial resources between experiment partners. It reveals that in most ECHORD experiments the coordinator has indeed the highest total costs (>80% according to the experiment proposal) and receives the highest total funding (>76% according to prepayments).

For the purpose of examining proximity effects the final reports of the 33 experiments which have ended so far (February 2013) have been examined in more detail and the reporting done by the experiments every two months while they were running.

The experiments report on a bimonthly basis on their activities and the moderator judges their progress via a traffic light system. A green traffic light means that there are no deviations from the experiment plan. A yellow traffic light means that there are possible delays. A red traffic light judges the experiment to be delayed. This information has been used to generate a second measure of success for the Experiment.

Additionally, the information extracted from the final reports relates to their dissemination activities. The information is of course self-reported and should be taken as such. The categories of dissemination activities are divers: websites, talks, student activities, conference presentation, paper (conference or workshop), conference poster, organization (e.g. workshop), tutorial, public event/trade fair, media and TV, competition, journal paper, journal special issue, YouTube video, other. These are all methods the project chose to employ to communicate the knowledge gain throughout the runtime of their individual experiments.

What we wanted to investigate here is whether a long distance between two or more experimenting partners shows a detrimental effect on the experiment outcome. Therefore, we employ two measures regarding proximity effects:

- Number of dissemination activities
- A measure of conforming to the proposed to the time plan

Both of these types of measures can be seen as operationalization of progress within an experiment's execution. One measures the codification of knowledge in the various formats listed above. The other tries to grasp the progress at run time.

5.6 Results

The experiments reported on fifteen different dissemination types (including the category other). The distribution of activities among all experiments is shown in the following Table 6.

Website	3
Talks	2
Student Activity	53
Conference Presentation	93
Paper (Conference/Workshop)	17
Conference Poster	16
Organization (e.g. Workshop)	8
Tutorial	2
Public Event/ Fair	31
Media and TV	3
Competition	1
Journal Paper	28
Journal Special Issue	2
YouTube	34
Other	11

Table 6: Distribution of activities among all ECHORD experiments.

Out of these, only conference and journal publications count as peer reviewed scientific publications. Therefore, one has two different values. These measure overall dissemination activities and specifically scientific published articles and conference papers.

Published papers: 47
Overall Dissemination: 304

The literature predicts that in such situation where the direct face-to-face communication of knowledge is harder, more knowledge needs to be codified. This means that each partner in projects with little physical proximity will need to find means for communicating their results to the other partner more than projects which have a direct physical proximity. This leads to the hypothesis in this specific case that an ECHORD experiment in which the partners are further apart within Europe with respect to their physical locations will be more active with regard to communicating their results. This is can be tested on the data at hand. The result is a positive correlation both with respect to the overall dissemination activities as well as the scientific publications. The distribution plot below shows the distances of experimenting partners plotted against the number of dissemination activities.

There is a significant positive correlation for the general dissemination activities with distances of the experiment partners ($r(31)=0.6$, $p < .05$; Figure 30). Further, there is a positive correlation between physical distance and the scientific publications ($r(31)=0.49$, $p < .05$).

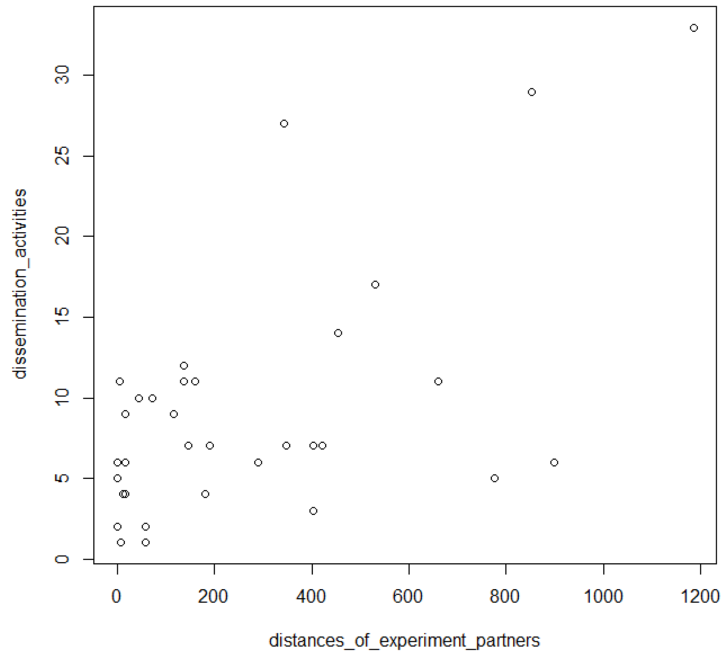


Figure 30: Correlation of general dissemination activities and distances of experiment partners.

This suggests that the physical distance of partners involved in a project influences the amount of knowledge dissemination they pursue. As predicated by the literature (Johnson et al., 2002), the ECHORD experiments have a higher dissemination rate when the partners are physically further apart. There is also a week correlation between the outputs the experiments generate with a country barrier. The tests regarding the physical distance correlating with the traffic lights, no significant results were found. There were no correlations regarding the raw number or percentage of green, yellow or red traffic lights given to a project at run time. This suggests that delays or progress on time did not hinge on physical proximity.

5.7 Conclusions

This study of dissemination and delays in the experiments shows that the projects actually do collaborate well even when they are not physically collocated in the same area. The statistical analysis suggests that the experiments which are further apart actually do produce more codified knowledge. We can therefore concluded based on the analysis of the data that there are no negative outcomes as no effects regarding delays or deviations from the experiment schedule could be found. There is a significant effect on the project output. The further apart the experimenting partners are the more dissemination activities they report on in their final reports. Therefore, the only effect that can be reported is a positive effect for long distance collaborations within the ECHORD project.

6 Workshop Results

Several major workshops have been organized by the ECHORD team at TUM. One took place in Odense, Denmark, at the occasion of the European Robotics Forum. It was entitled “Best Practice for Knowledge Transfer and Industry-Academia Collaboration in European Robotics” and was scheduled for March, 6, 2012. During the IEEE International Conference on Robotics and Automation ICRA a full-day workshop was held with the title "Industry-Academia collaboration in the ECHORD project: a bridge for European robotics innovation". The workshop took place in St. Paul, MN, USA on May 18, 2012. A third workshop was organized for the IEEE/RSJ International Conference on Intelligent Robots and Systems IROS in Vilamoura, Portugal on Oct. 11, 2012: "ECHORD – scientific results and tech transfer opportunities". We will briefly report on these selected workshops in chronological order.

6.1 Workshop at ERF

The European Robotics Forum has taken place from 5-7 March 2012 and was hosted by the Danish Technological Institute (DTI). More than 300 robotics researchers from industry and academia, as well as entrepreneurs and public investors discussed latest developments, research challenges and business opportunities for European robotics. The 2012 theme of the European Robotics Forum was “European Robotics towards new horizons”. The ECHORD session started with a presentation of some facts and findings from the structured dialogue. We then discussed with the audience selected topics about knowledge transfer and I-U collaborations, such as:

- The output-outcome paradox
- Does geographic proximity matter?
- "Teams build only on CEO level will not work!"

- What is the optimal run-time for initial I-U projects?
- Patents - different views from academia and universities
- What are the measures of success for ECHORD-like projects?
- "There should be an impact beyond economics!"
- Pros and Cons of standardization in service robotics
- Is open source vs. IP protection an issue?
- Which type of funding would you like to see?
- "The time frame of the project, not the amount of funding is important!"

For each of these topics we asked the ECHORD experiments to report their experiences so far, partly with contributions from both, academic and industrial partners. There was also the chance to discuss best practices and specific ECHORD-related topics like:

- What do you plan as follow-up after your ECHORD experiment has ended?
- What topics would be hot for the successor of ECHORD?

The agenda was as follows:

8:30	Welcome address and introduction to the WS format, short presentation on the current results of the structured dialog
9:00	Discussion of statements and questions related to knowledge transfer and I-U collaboration, these theses will be announced in advance. The discussion is led by introductory short presentations for each of those theses, ideally by ECHORD experiment partners present at the forum with focus on knowledge transfer, if possible, 2 statements, one by an academic and one by an industrial partner of the same experiment
10:30	Coffee break
11:00	Continuation of the discussion of theses
12:00	General discussion about the best practices for tech transfer and an outlook on how this can be supported by the Commission or by other national or European initiatives/funding schemes, etc.
12:25	Wrap-up and conclusion
12:30	End of the workshop

In the following, summaries of all discussions are given, grouped by topic:

The output-outcome paradox

- In ECHORD-like projects, which start immediately, there is not much time to discuss the strategy
- What are suitable measures?
- Follow-up research in HRI

- Importance of negative results (advantage for short-running projects)

Does geographic proximity matter?

- Projects with standard platforms might reduce the need to meet physically
- More frequent meetings necessary for separated SW/HW development
- It all depends on the scenario, e.g., testing would benefit from short distance
- Skype, video conferences etc. help a lot
- Advantage in ECHORD: partners are allowed to be located nearby
- number of partners matters

“Teams build only on CEO level will not work!”

- Support from CEO is needed (e.g. as first contact in rather small companies), sometimes too far off; big companies: often informed only at the end
- Employees are essential
- How did industry-academia project start?
    - Group discussion
    - Group leader is important
- Depends a lot of the size of the company, on company structure, type of action, type of CEO
- Push it down to operational level
- Project has to be part of roadmap (support by CEO)
- All levels are needed!
- Better rephrase to “Teams built only on one level will not work”

What is the optimal run-time for initial I-U projects?

- 12-18 months is good, less partners, precise common goal, concrete application based on technology available, open controller enables academic or end-user, using robot in a special way, which is not possible with standard roots
- 12m or shorter ok for academia to test whether idea is useful, in cooperation to see whether useful in industry, than longer projects to make it real
- Often after 3 y project is over, PhD leaves, no follow-up, tracked projects would be helpful for transfer
- Pre-projects as pre-condition for larger projects
- Not only PhD students, but also senior researchers

Patents - different views from academia and universities

- Patents vs. software and source code transfer, this stays at university, question addressed in CA and individual agreements
- For industry to keep in the consortium, often blocked by legal departments of university
- IP belongs to people in Sweden, picking up software written by someone else
- Companies sit on patents
- SMEs do often not like to patent their developments

What are the measures of success for ECHORD-like projects?

- Both, industry and academic partners say, “I would do it again, it was valuable to cooperate”
- Research institutes see the gap, do not know what to get out of academia, measure by asking
- More clear measure of collaboration
- Academia not able in some cases to transfer without company, as not interested in creating products, but that is the ultimate success, clearly defining the limits of academic work
- Clear answers of the questions raised during the set-up phase of the experiment
- Influence to turn-over 2 years after the project, exploitation plan after the project
- For academics, after ongoing collaboration, sometimes publications only possible afterwards
- Are partners willing to exchange staff within or after the project
- Successful follow-up projects
- Testing alternatives if the original approach didn’t work, maybe too expensive
- Best output would be to find the way to identify the projects,
- Robots for green-houses failed, but raised discussion, scientific success, but product failure
- Awareness of potential of technology in a wider community

"There should be an impact beyond economics!”

- Public awareness of the potential of technology
- Personal relationships, employment of partner (e.g. post-doc)
- Internships, master’s theses, etc. maybe through a project
- Increase in knowledge, but how to spread?
- Contribution to improving safety and usability, marketing success
- Input to standardization (for longer projects)
- Approach of ECHORD as model for other areas?
- Raised international visibility of European Robotics
- New sectors aware to stakeholders
- Additional discussion: Education
- Influence younger people, e.g. for their career, competitions
- Farmers: milking robot economically not feasible
- Customer’s benefit
- Awareness!!! In the general public, finally economic impact

Pros and Cons of standardization in service robotics

- Industrial standards to be able to be connected, for home environments to connect to mart homes
- If company big enough, everything is internal, for SME, you may need to exactly define your application based on standards

- Easier to create products, you cannot live on your own, components, connections, software interfaces
- Dangerous to standardize too soon, developing areas, more for mature areas, but rival standards
- Standards of semantics, re-use of models and algorithms

Is open source vs. IP protection an issue?

- Software developed by academic partner fits only on the industries' system, not usable otherwise, useless for others even if open source, but general ideal maybe relevant for others
- Separation academic/industrial software, translation needs effort, e.g. prototype in Matlab, etc. (certification!)
- More a problem of transfer than open source

Robotics R&D based on Technological Readiness Levels?

- Awareness of the concept among the WS participants: ~50%, active usage: close to 0%
- Anchor technological gaps using TRL, these gaps can be used for creating calls
- TRL is used only in specific sectors (such as aerospace), useful in others?
- Good for handling expectations
- HR-collaborations apply TRL, for safety aspect
- Clear map of where we are in HR-collaborations
- Define actions
- Similar to 5 category model of Claus Risager, which is easier to understand
- Used for evaluation of products? Alternatives?
- Component supplier: quality gates, sometimes same research already done, product available, re-invention is a waste of money

"The time frame of the project, not the amount of funding is important!"

- Preparation + project phase!!
- 3 phases: check of idea (<=18 months), actual R&D (3-4 years, depending), transfer phase (duration? 2-4 years or shorter?)
- Refined to make the time shorter
- Buffer to cover phases without payment easier in universities

6.2 Workshop at IROS

The pool of ECHORD experiments is a good source to exemplarily point out ideas and first results in different industrial relevant scenarios: "human-robot co-worker", "hyper-flexible manufacturing cells", and the "cognitive factory". Within these scenarios, the different research foci like "human-robot interfacing & safety", "robot hands & complex manipulation", "mobile manipulators & cooperation" and "networked robots" allow to categorize the work and to streamline the “structured dialog”. For the IROS-2012 workshop, a selection of successful experiments was given the opportunity to present their results and discuss them with the participants. The main focus of these presentations and discussions was on the practical use of the scientific work and knowledge transfer aspects and a special focus on the Technological Readiness Level (see below).

We were especially interested to hear how our ECHORD experiments relate to so-called "Technology Readiness Levels" (TRLs). These were developed by NASA in the 1980s and are a measure to assess the maturity of evolving technologies. We asked all presenting experiments to rate their experiment along this scale

6.3 Workshop at ICRA

The goal of the workshop at ICRA was to strengthen the exchange of knowledge and experience between scientists and practitioners and to inspire the robotics community to form new types of cooperation. The important collaboration between European robot manufacturers and research institutions in ECHORD has already resulted in significant innovations in many facets of the robotic field. The workshop was therefore composed of two parts:

- A presentation session where an overview of the ECHORD experiments was given by the coordinating partners. Then selected speakers from ECHORD as well as invited speakers presented their work in 20 min. time slots.
- An open discussion session about innovative solutions inside and outside ECHORD, future impacts, new applications, limitations and possible improvements, as well as safety concepts.

In the following we will focus on those parts that are most relevant for the structured dialog, i.e., the overview presentation given by Christophe Simler and the general discussion at the end of the workshop. The workshop proceedings that resulted from a call for papers for this ECHORD workshop can be found on the ECHORD website[7].

The talk was on upcoming scientific robotic trends and emerging applications and resulted from an extensive literature survey. An overview is given topic-wise:

Autonomy

- In a few years: semi-autonomous systems improved and extended to many fields for large scale applications (prototypes)
  - o Different functions: assistant, rehabilitation and social robots

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[7] http://echord.info/file/Documents/WP4-monitoring/T4-4-structured-dialogue/Workshops/ICRA2012/proceedings.pdf

  - Optimal level of autonomy will be determined for each field
  - Interaction with “intelligent spaces” and home controllers
- Later: fully autonomous systems and cognitive teams. Human-like robots
- Applications involving humans and safety are particularly difficult: surgery, search and rescue, service robotics → delay in autonomy with respect to other fields.

Bio-inspiration

- Algorithms: based on advanced neural models from neuroscience analyses, adaptive robot behaviour
- Mechanical designs, actuators and sensors: humanoids, robot hands, insect multi-legs, soft-compliant actuation systems using pneumatics or artificial muscles, multimodal perception, tactile skin

User interface, human robot interaction

- Adaptive: situation understanding, personalized behaviour – observation, learning user features
- Easy-to-use, natural, intuitive, interactive, human-like and friendly: multimodal perception and feedback
  Typical application fields: medical/health care and domestic service
- Tactile feedback, virtual/augmented reality
  Typical application fields: surgery, therapy, manipulation, medical, hazardous field
- Higher level of abstraction (task level), decomposition into subtasks

Vision and 3D geometrical sensors

- Human recognition: persons, actions, situations
- Scene processing: better situation understanding
- Temporal, 3D and contextual information
- Reliable patterns – occlusion and invariance
- Probabilistic kernel classifiers (RVMs)
- Probabilistic SLAM with severely underdetermined data set, outdoor SLAM
- Efficient and accurate knowledge representation of the environment
- Semantic level of information

Force/tactile sensors

- Guiding, body extenders, coded touch instruction transmission, teaching by touching, exchange objects, dance or transportation with robots, touch therapy, surgery, manipulation, grasping, exploration
- Integration – end effectors – humanoid legs - robot hand fingers
- Force feedback visualized in surgery
- Force feedback for reliable force control (grasping, manipulation, leg locomotion and stability)
- Improved to enable complex grasping and manipulation with robot hands. Soft artificial skins with highly distributed tactile sensors

- Suitable processing techniques of their data and extraction of dynamic information

Audio sensors, robot language and emotion

- Improvement of speech recognition algorithms
- Add language ability using sophisticated brain models
- Integration of voice tone, emotion and motivation
- Knowledge transfer between robotics and neuroscience
  Typical application fields: service and rehabilitation robotics.

Physiological signals

- Control the physical HRI during robotic therapy administration of stroke patients
- Health status monitoring in smart home

Brain machine interfaces

- Help paralyzed people to perform daily tasks with a robotic arm
- Adaptation of manipulator´s technology
- Improvement of brain signal extraction, processing and connection to the robot
- Tactile feedbacks for efficient manipulation
- Impedance control and decoding from the brain of the intended mechanical impedance
- Decoding high level tasks from the brain, more autonomous robotic systems, finding the optimal level of autonomy

Development environment

- Easy integration of commercial industrial automation and new perception technologies will be provided by the extension of ROS (robot operating system)

Simulation environment

- Medical/health care, surgery and in domestic/personal service. Handicapped patients using BMI to control a robot will use simulations to select or reject a planned task

Control

- Bio-inspired controllers – neural models – adaptive learning
- Automatic grasping of unknown objects
- Approach human-like manipulation. Progress of tactile sensors integrated into robot hands
- Underactuation of robot hands
- Locomotion strategies using recent CPGs models and complex neural mechanisms.
- Knowledge transfer with neuroscience
- Reliable controller for legged robotic locomotion
- Adaptive impedance control on end effectors, legs and fingers of robot hands

- “Soft actuation” systems
- Better artificial muscle control

Automatic path/motion planning

- Optimal paths with geometrical and differential constraints
- Efficient motion planning with uncertainty in perception
- Better information space representations
- Dynamic environments
- Semantic information for path planning
- Planning toward non-stationary goals
- Humanoids
    - Reaching and SLAM with moving obstacles
    - Locomotion and planning under uncertainty
    - Better trade-off between exploration and exploitation

Modular robotics and multi-agent systems

- Autonomous robot teams; self-operations on team members
- Self-organizing teams; learning new behaviours; self-coordinated; propagating information
- High-secured wireless network; share knowledge; decentralize components; remote control
- Efficient, collision-free and fault-tolerant traffic control strategies applied on AGV systems in automatic warehouses
- Teams of robot tractors using sensor networks

Advanced cognition

- Using behavioural systems; dynamic changes
- Easy robot behaviour teaching with interactions, even for ordinary people
- Improvement of reinforcement learning and programming by demonstration
- Deeper exploitation of the temporal dimension of sensory information
- Language; voice tone, emotion; knowledge transfer
- In addition to cognition, use of internal robotics

Safety and Security

- Safety measures adapted to human robot collaboration
- Intensive use of sensors to ensure human safety
- Reliable human risk estimators and safety action models
- Use of tactile sensors for collision detection
- Methods recovering from collisions, consideration of temporal persistent physical interactions
- Robustness against attacks from the network
- Safety and dependability metrics to successfully introduce robots in everyday environments

Test and Validation

- Large-scale completion and standardization of tests for robotic systems
- Formal methods of verification and synthesis of autonomous systems
- Approximate verifications with reachable sets for dynamic hybrid systems
- Reach-avoid sets with environment sensing and obstacle avoidance

In the open discussion, the increasing importance of safety in robotics, particularly in service robotics and industry was mentioned several times. It was asked if projects like ECHORD should handle the safety aspects in more detail first before the beginning of the experiments. There was also a discussion about possible improvements of robotic operating systems: integration of commercial industrial controllers with state of the art algorithms (in ROS). However, companies typically do not appreciate freeware competitors. In the discussion that followed, it was suggested that these companies should actively participate in the elaboration of freeware, since freeware will be improved in any case. ROS, on the other hand, suffers from not being real time, it will probably be extended. Next, the discussion turned to the use of mobile manipulators, different types and features of robotic systems and the topic of intelligent homes. It turned out, that there is still no consensus about what is really important in smart homes. It was noted that in many applications it is not essential to find an optimal path for a robot; instead, a feasible path is sufficient and should be learned by demonstration.

7 Summary

The current report aimed at outlining how progress in robotic technology can be facilitated via successful technology transfer through academia-industry collaborations within a European context. For this purpose we looked at current research topics and future trends. We showed a convergence between several questionnaires which had been disseminated in different contexts but which showed a high level of similarity in their results. The differences were small details that had to do with the focus of the community creating the questionnaire.

The expert interviews with Rodney Brooks, Hiroshi Ishiguro and Minuro Asada revealed a critical but positive outlook on academia-industry collaboration. The experts expressed different views depending on their own involvement in academia-industry collaborations. However, all of them had a keen interested in such collaborations but generally thought that the different needs of industry and academia do challenge such work. Especially, the fact that academia is looking for long-term impact whereas the industry requires short-term success.

The points raised by the experts lead to an analysis of the obstacles researchers see for such collaborative projects while at the same time providing some answers in the section four. During the Asian Lab Tour of some of the ECHORD project members, a questionnaire was distributed. The replies indicated three main obstacles, which also agreed with our expert interview opinions: a gap between industry and academia research, the problem of IP rights and patents and TRL (technology readiness level). Chances in technology transfer were viewed positively by most participants. The joint formation of companies was named as the most efficient way of technology transfer.

One question, which also needed to be addressed, is how one can measure success in such collaborations. As the experts pointed out success is measured differently in academia than it is in the profit-oriented industry. A further point, which was addressed in this technical report, was the question of whether the physical distance between collaboration partners actually matters. This is relevant in the European context, more than in projects that are located within the same national boundaries. The result is positive as distance has no negative impact but will lead to more codified outputs where it is higher. Therefore, one can conclude that actually it is productive to connect partners throughout Europe in ECHORD-like projects.

8 Appendix

8.1 Interview with Prof. Brooks

The Interview with Rodney Brooks took place in Eskilstuna (Sweden) during the Robotics Innovation Challenge on February 9, 2012.

Florian Röhrbein (FR): *What are future research fields in robotics that should be worked in collaborative effort by both academia and industry? Are there specific fields where you think they are especially suited for this sort of collaboration?*

Rodney Brooks (RB): *Well, in general I think there can be collaborations across as long as the expectations are right on both sides. Academia should only be involved if you're not too close to product.*

FR: *So you mean, in terms of technical readiness level it would be like a six or even less?*

RB: *Less, yes. By the time it gets to six I think academics have lost interest.*

FR: *Yeah, surely that's a problem. Also, what you talked about in the morning about the different reward systems – I mean this is one of the problems.*

RB: *Yeah. … Or you can view it as strength! Because then the innovations are different in the two places, and so, how do you get the best from both. You can't view either as a subset of the other. I think that's a mistake sometimes people make.*

FR: *M-hm. Let me put the question maybe this way: From the one perspective, are there platforms or tools developed by companies that should be used more in robotics research … more in universities? Is there anything people have overseen?*

RB: *To me it's interesting that ROS, the robot operating system is now pervasive. One of the systems out of my lab, YARP started to get used by the RoboCub people. But now, ROS has taken over. But that's probably good, that that be that.*

FR: *But are there other tools that are …*

RB: *In ROS then you get a lot of tools, a lot of tools go into that: kinematic tools, dynamic tools, all sorts of tools that then become accessible, and easily moved around. So I think that it's not ROS itself that becomes important. Now there's a place where people can out stuff as a repository, and so those tools start to become more universally used and, people grab them, and use them themselves. I think it's like Open GL and those sorts of things made graphics much easier, I think the same sort of thing is happening with robots there. But maybe you have something in mind about tools, I'm just not picking up on.*

FR: *If we think about topics, emerging topics, are there some that you feel that researchers should more focus on those in order to ease future collaborations with* *partners from industry?*

RB: *I see, you have a particular agenda here, don't you? So, here's my overall take on industry … well, depends what you mean by industry. Do you mean industrial robots, or, you know like the KUKAs, and the …*

FR: *Yeah, but I mean, there are also all these many small and medium scale enterprises which do a lot of interesting things …*

RB: *Like, Schunk, you mean …*

FR: *Yeah, or even smaller ones, like Skybotix, or many Swedish companies also… So, are there some hot topics where it might make sense to push a bit guys from academia to, in order to have more joint projects?*

RB: *I'm not sure I can answer your questions directly, but let me give you some opinions. I think that in industrial robots and manufacturing in general we haven't really seen the impact of information technology in the same way we've seen it in the office and information spaces. It's been very slow to be adopted. And I think … too much … when information technology or computation is brought into manufacturing; it's brought in more like it was with mainframes. So, imagine if, in order to use this device, you had to program it in COBOL…. Totally useless! But I think that's sort of the level we are with trying to bring new technologies to manufacturing. It's about how to get them to be achieved and not making them how to be simple to be used. And it's the simplicity of use which then leads to high adoption and high rate of adoption. So, I think we haven't seen that penetration. So, how to make the things easy for ordinary people to use, instead of making the people adapt to the technologies … in industry. These things have been to be people centric. Adapt them to people. Not the other way around. So that's where I think the big payoff is going to be.*

FR: *This brings me to the topic of knowledge transfer. I would like to ask you which routes would you consider most efficient. I mean, in the talk you already said that going to the institutional licensing offices, like hoping … But I mean there's lots of other possibilities, like in exchange of personnel, or…*

RB: *Oh, absolutely! I think the only way it can happen is by people … by people moving back and forth.*

FR: *Ah, interesting!*

RB: *I haven't seen … You know I ran - not just in robotics - I ran the computer science an AI lab at MIT and had 839 people involved in that. And we had a lot of collaboration with large companies and small. And it was only satisfying and successful when people really knew people in the other organization and moved back and forth. Academics where spending time at the company and people from the company where spending time … you know … Sometimes six months at a time, or even a year at a time. Really going back and forth.*

FR: *Yeah, just wanted to ask about the time scale in terms of …*

RB: *Yeah, it's not like a one day visit.*

FR: *… and also not weeks but …*

RB: *Months, many months! And the companies and the academics have to be willing to make that investment. So, there's got to be payoff. No one wants to make that big an investment if it is not about some real value out of it. … But it really has to be people.*

FR: *Okay, so this exchange is very important. Are there other things that you would consider best practice concerning facilitating this cooperation between industry and academia?*

RB: *Well, I've been involved in many, many interactions, at very large scale. To me, the things that have been most successful have been when we've set up joint lab. We've done that with Nokia, we've done that with Quanta Computer, with NTT, from Japan. And, in each case, the thing that set up, the people from the company and the people from university are equals. It's not "We're the people with the money, we pay you", or "We're the people with the ideas". It's really a very equal basis, on all aspects of it. To me that was the most successful, way of working.*

FR: *So this could also be one way to improve knowledge transfer. Are there other things, maybe like, free dissemination, or contract research, or use of industrial equipment? What would you think should be done to make some improvements here?*

RB: *Well, contract, yes… But… you can't change the fundamentals of either side…*

FR: *Like different reward systems, or communication…*

RB: *Yeah, I mean, you can't stop academics publishing…*

FR: *… or having many ideas, or like to have…*

RB: *Yeah, I mean, so you've got to play to that strength, in some way. You can't change that and get the benefits. What was the question again? I lost focus…*

FR: *So, this was about what can be done in general to improve knowledge transfer. Or the other way around: What do you think are the main obstacles in collaborative projects between academia and industry and what would be means to overcome these obstacles? Maybe also on an institutional basis, or are there regulations that have to be changed, or…?*

RB: *Well, I don't know about the German case, right…*

FR: *No, in general…*

RB: *The biggest problem really is… Well here's a generic problem that I've see* *happen many times: The CEO level of the company says "I want to bring innovation into my company by working with academia". Goes and signs a deal with some academic group. And then the CEO hands it down two levels in the company. And now it's someone's assignment: "Oh, I'm supposed to get innovation from…". That goes against what I tell them to…*

FR: *And then it doesn't work anymore.*

RB: *It doesn't work at all. You've got to have someone who really understands what is wanted and is part of their mission and not get it handed off to people…*

FR: … *and really wants to do it…*

RB: *Yeah. So, I've seen that really fail. Within the company, the CEO says "Yes we're gonna do this", they really have to cultivate some group which is really going to do it. And some I've seen do it well, and others have done it very badly.*

FR: *Is this somehow collated with the size of the company? Like, for small companies it might be easier, because they don't have that many levels involved?*

RB: *Maybe, but even there, there can be problems. Even in a small 50-person company I've seen it… not quite working. Surprisingly, one place I've seen it work very well recently is John Deere, which is a very large company. But, the last CEO, Bob Lane, and the current CEO, Sam Allen, keep saying it, keep showing up at the places, keep talking … They keep pushing it. And everyone in the company sees "Oh, this is important. He really means it." But he's got to mean it by participating, at some level. So, they're running along to demonstrate they're on board.*

FR: *Okay, one final question, more about upcoming research trends and robotic applications. Do you think there are differences between North America and Europe and Asia, when it comes to upcoming trends?*

RB: *The most important thing is that it's cross-disciplinary, and I think Japan has a large failure on that, because robotics tends to be in mechanical engineering departments, and the departments are so strong in academia they don't have computer scientists working on robotics, they don' have electrical engineers working on robotics. It's mechanical engineers. And I think they fail. I think the places that do better are where the boundaries between the departments - maybe with a lab structure across multiple departments - are much more flexible. And that's where it works well. That's not necessarily just by country, it's also by institution. Some institutions are much better at having the cross-disciplinary work.*

FR: *Would you also see a difference there between Europe and North America?*

RB: *Well, there are differences between different places in North America. Very much so. So, some are too department driven, and others, like MIT, is very much a lab culture which… I had faculty from six departments in my labs.… So, it depends on the universities.*

8.2 Interview with Prof. Ishiguro

The interview with Hiroshi Ishiguro was conducted at the CITEC Summer School 2012 at the Center of Excellence “Cognitive Interaction Technology” at Bielefeld University (Germany) on the 28th of August 2012. The interviewer was Sascha Griffiths from TUM.

Sascha Griffiths (SG): I*’m going to ask some questions on collaboration between academia and industry. If you are involved in industry-academia-cooperations, in which areas do you prefer to cooperate?*

Hiroshi Ishiguro (HI): *My cooperation with industry is a very long. In 2000 I started my venture company, the venture company using my patents. They are essentially developing the robot - a small human-like robot. In RoboCup our team was champion, in collaboration with my venture companies. There we have many good engineers, they build pretty good robots. We got the championship four times. We were so strong that the people hated us, so finally we stopped to attend. I’m always working with big enterprises, like Toshiba, NTT, Fujitsu, Hitachi. They are building big systems. For the venture company, the market is smaller. We can develop kind of a toy-like robot, a very simple robot; we don’t need to have a big market. But on the other hand, to change this world, we need to work with big enterprises, and we need to develop more of a general, powerful, robot, like Honda’s Asimo. In Japan, nobody studies human-robot-interaction, but I have studied it, therefore all the enterprises are coming to ask my opinion, and we are always running small collaborations. The rest happens in the university. ATR, which is running a big project supported by the government – its members consist of big enterprises. ATR is a leader – very big with the government projects. There are two things: I have the university operations and the ATR operations - and the university is kind of an incubator. At Universities it’s easy to work with venture companies. We can start something new, once we have good ideas. And then we negotiate with the government about running a much bigger project at ATR. And ATR isn’t a university; it’s a research institute, kind of a private organization. Therefore it’s easier to collaborate with other private organizations, like big enterprises. The companies don’t trust universities so much, because a university cannot take any responsibility. A university is kind of a collection of amateur people, with so many students. But ATR is different. Everybody is a professional. We can make any contract.*

SG: *How would you measure a successful collaboration between a university and industry? For example, do you measure it in patents, or in publications, or is it just the length of time …?*

HI: *No, the most important thing is to have a real product. That is a goal for the companies. Otherwise, everything is an error. To have a big success it usually takes a long time. Of course it’s better to submit more patents or journal papers, to share the know-how… - there are many ways.*

The most important thing is to evaluate ourselves. We can evaluate ourselves. Because this is a serious game. This is not the university, the paper writing game. What we are doing with the big enterprises, that is a very serious game. We don't need to have any evaluation by others. We don't need to have any external evaluation. Internal evaluation is enough. Because we are spending our own money. Universities are using government money, therefore they need to have external evaluations. Because the university is using other people's money. That is the difference. We don't need to have any external evaluation.

SG: *What are the main obstacles when you have academia-and-industry collaborations? Where are problems that arise?*

HI: *Well, we cannot have pure collaborations. When we want to do some real business we should leave the university. Universities are quite a unique organization. It depends on what you want to do. I'm quite okay. I have two organizations. ATR, it's a research institute. If I cannot do it at the university, I just do it at ATR. And ATR is a private research institute, and I don't have any problems with that. There I don't see any difficulties. So, my recommendation is to just have two types of appointments. Obviously, a university is not the ideal place for doing some practical work.*

SG: *So you would say that an institute, a specialized institute that is independent of universities, is a better platform to exchange knowledge between industry and academia?*

HI: *Yes. It's quite important to have that kind of operation.*

SG: *Especially thinking of Asia, do you think there is a very active collaboration between industry and academia, or would you like to see more of it? Do you think it's especially good in Asia?*

HI: *The situation in Japan is quite strange. We have many good big enterprises in Japan. They don't spend any money for Japanese universities. We are getting a little money, but, you know… The difference is: they are spending a lot of money on US universities. Their excuse is that they are paying a lot of taxes in Japan. I'm working at a national university - that means I am using their tax money. But I don't think so! In Japan we have a very different situation. Probably in the US, they have a more natural situation. They are always working with the…, they're gathering a lot of money from the companies. The universities are supported by many companies.*

SG: *So you think that collaboration between industry and academia is better in North America?*

HI: *Yes, definitely the US is the best for that kind of activity.*

SG: *Do you know anything about Europe - How the collaboration works there?*

HI: *I'm not sure. But I guess you are doing very well, right? Your universities are growing and they keep growing. Just this afternoon I saw the new building. You have* *a large overall construction… And you are getting a lot of money. You got another five years extension. I think that you are doing well. In Japan it's a different. Here you have a lot of good collaboration with industry, I think. It's a better tradition, right? Your universities are very traditional, and you are always working with industry. But Japan is different. Many people think universities should be independent from industry, traditionally. In Japan universities are kind of a different world which is independent from economics. Studying something should be different from earning money. That's what the fundamental idea is. But probably in Germany you have different ideas. You have a very long history, and so does the US. But in Japan it's different, because of our history. Usually, the school was in a temple. A temple was independent from business stuff. Still a lot of people think that a university professor cannot have a private company or something. But China is different.*

SG: *In your opinion, how could you improve knowledge transfer between academia and industry? Especially thinking of Japan, but also in other countries. How could you improve the collaboration?*

HI: *The most important thing is to have the kind of person. I started my venture company with three people. Myself, and the president, and my student - he wanted to start a venture company. But he definitely could not be president, because a president should be good for the management. We met pretty good people, who wanted to be president. So, the role of my student was technology transfer. Because… we worked together a couple of years. He was the best student at Osaka University. I recommended he should get a PhD, but he said he could get a PhD anytime. But for the venture company, the timing is quite important. So he said he was going to do something for the venture company. We need to have that kind of person. The students will be that kind of person. And you get it in engineering or …*

SG: *Final question: How do you measure the success of a robotics research project?*

HI: *Well, if you can sell many robots, that means a big success.*

SG: *So the sales, the real numbers are important.*

HI: *Right, yes. Otherwise we cannot evaluate. Or, in science, if you can write a pretty good scientific paper… That is also a good success, in science. Just two simple evaluations: Science or business. We don't need to have any other evaluation. If you want to have some evaluation … Well, the people want to have kind of a good evaluation, therefore we have so many details about an evaluation, usually it is kind of a fake, or it is just for … Well, we have to survive. We need to get better operations. They probably know we are building many systems to evaluate each other, but basically we don't need to do that, right? If you do good things, if you find very important things, you will have a good reputation in science, and then you can get the Nobel honors, right? And if you develop something very useful, robots, then someone will sell the robot.*

8.3 Interview with Prof. Asada

Minoru Asada was interviewed by Sascha Griffiths from TUM at the IEEE International Conference on Development and Learning and Epigenetic Robotics ICDL-EpiRob 2012 in San Diego (USA) on November 9, 2012.

Sascha Griffiths (SG): *Have you got any connection to the industry? Do you collaborate with industrial partners?*

Minoru Asada (MA): *So far I have not got a direct connection to the industry from the point of my own research, but our department has as curriculum with project-based learning with companies. In that case we had two companies: One is the Daiwa House – it's a house company. The research topic is the design of an intelligent room. So that you can show the air conditioning, or the lighting, or sensing, the humidity, and so on –*

SG: *So, all this ambient intelligence work?*

MA: *So, to do that, we add some kind of face recognition, and recognition of facial expressions, lots of gesture recognition, lots of voice recognition, and so on. So, that's kind of a mixture of that and ambient intelligence, and so on. That's the first one.*
The second one is Citizen, a clock company. The topic is some new application of something like a clock. So, we started to design some kind of device - this kind of size [points at his watch] - that measures the temperature, or the rhythm of the place, or the health maintenance, and so on. And also some kind of interaction, between the user and this device, to tell something, to get information, and so on. So, it is like a clock, but there is some interaction. The ideas for some functions are for mobile phones, and so on. So they just know: "Please call me", or something.

Of course to realize the product, especially in the case of the Daiwa house, not only do they know the curriculum of the government. But we also are doing some joint research with them. I myself am the PI and also Hiroshi [Ishiguro], especially, contributed. So it's kind of some joint research. Also, myself, and Hiroshi, and also one other group professor. The other professor does the lighting control, depending on the gesture recognition, detection of a face, or the voice, and so on. So, maybe in a couple of years we will try to realize that as a real project. Not as an entire house but in the obvious situations or some kind of daily life application. In case of Citizen - I'm not sure when we can realize it as a real product. Maybe in a few years.

SG: *I am wondering… we are looking at how we can decrease the time it takes for something to be developed in the lab to go actually on the shelf, to be sold. What do you think, how do we make that time frame smaller in which something is invented in the lab, and everyone goes "Hey, cool that that works!"…?*

MA: *My idea is that I have my own research: the very fundamental research issue, development, cognition, and so on. It is very far away from the real application, it* *seems. Actually I don't think so. Suppose that the main goal is to reveal the mystery of human development and the cognitive functions, and how the baby can remember something. There's some step which involves many processes. And to do this research we have to design some kind of materials, or some equipment, or a robot, and so on. And suppose that the kind of the spinoff of this technology can lead other applications. For example, very soft skin with sensors can also be applied to non-humanoid robots, like some furniture, or walls, for the home of senior people, to avoid them getting hurt or something. So, that's an idea. That's a fundamental idea of my own research.*

Closing those gaps is still very far away. There will be a development in the technologies and these technologies can be applied to the other situations. In order to apply these kinds of spin-offs to the other situations we need some teams. There are many gaps between even the best ideas and actual implementations. To fill those gaps, we have a strong team. In our case this is a collaboration between researchers and industry teams. That's the case for the Daiwa house. So we have three professors in Berlin, the researchers in the Daiwa house and also students. The total is more than ten people. These people work with effort to realize this as an actual product.

The joint research will expire next March. Last month we have shown intermediate results to the president of the Daiwa house institute. Probably we will continue the joint research but much more oriented towards an actual product. Otherwise we cannot survive. Actually, we have a test home in the university. There we have some real experiment with naïve subjects to gather data and impressions.

SG: *Is the robotics industry in Japan bigger than in Europe?*

MA: *We Japanese robot researchers are very proud of our advanced technology. However we are lacking the integration with the real things. For example, a typical situation of this was the Fukushima power plant. Many Japanese people expected the Japanese robots to be there and to do rescue and other operations. But actually that did not happen. The US robot was deployed there for the operation. Many Japanese people are very disappointed about this and they are very passionate about that.*

One other point is that we have very advanced technology but we are lacking a real – let's say – verification. For example, 10 – 20 years ago we had a joint research project in Japan on this kind of situation. The government spent a lot of money. Companies and researchers designed a robot for such situations. The ministry then decided that such a situation would not happen and that the robot was supposed to focus on inspection only. Therefore, they designed such a robot for the rescue operation but only once. After that they put it in storage and no one used it. That's a big issue.

So, one of the ideas of the RoboCup is that the real implementation for competition for the public. For the researcher, this is a very good chance to show their achievements. For the audience, it is also a good chance to realize what advance technology is. So, we have advanced technology in Japan but we are not good at integrating it in *real situations. My idea is to have a site for the real robot experiments like a new town. There was supposed to be a new town in Osaka but last year there were elections for the mayor in Osaka and the new mayor changed everything. He gave no support to us. There was also the earthquake and big Japanese industry suffered huge losses. For example, Panasonic had a group for robot research in a hospital application but they reduced the funding due to the lack of money. These two things, the earthquake and the new mayor made me give up on such a site for robot experiments. But I suppose that we need such a site for robot experiments because maybe the robot industry is not established enough, yet.*

In Europe, Paulo Dario has proposed RCC – a robot companion for citizens. By the way, this is actually the same acronym as my robot city core (RCC) - but anyway. He is inspired by Japanese robotics but he started to set up these big robot projects which not only involve the industry but also research and education. If he received the funding for the RCC, that is going to be a big movement.

In Japan we have that advanced technology but not a good connection between researchers, the government and the industry. Usually, these should form a triangle. And these entities should cooperate with each other. That's the ideal situation. But now the government in Japan is just focused on the disaster situation. The industry on the other hand is weakened. Therefore, researchers are losing the connection to the government and the industry. That's the current situation but it also depends on which industry one looks at. The robot industry in Japan right now is going through a very hard time. It is supposed to only focus on the disaster situation and lacks fundamental research. For fundamental research we need a long term perspective.

SG: *In the wake of the earthquake a lot of companies cut their budget for R&D activities. Would you say that this would be a good time for universities and the industry to move closer together in Japan?*

MA: *As I mentioned, right now Japanese companies cannot afford these kinds of operations. They are focused on the profit. They have suffered from the deficit and are continuously cutting their expenses. Therefore, it is actually not a good time for industry and university connections. I would proposal that we focus on topics and issues which will make companies realize that there is some immediate profit to be made. If a research, professor or university has a good idea for a device or some material which is immediately applicable to the industry, then it might work. But except for such cases, it is very difficult right now.*

SG: *If someone has a good idea which should make it into the industry, how should researchers communicate such results?*

MA: *The issue is that Japan is an aging society. In a couple of years one third of the population will be over 65. I suppose 65 is still young [laughs]. The robot applications for the aging society are a social demand. There's a big potential. Therefore, the government, the industry and universities have a chance to collaborate. For the aging* *society there are various kinds of applications, not only the physical assistance but also mental assistance. Therefore, we need to focus on these topics.*

My parents are 90 and 92. My father has an assistance level of 5 which is actually high for Japan. He goes to a place where he gets help. He needs assistance. We need to focus on one topic at a time and develop devices that assist senior people with their lives. But we have that social demand to help senior people.

Safety is a top priority. The physical contact with senior people needs to be improved. We need time to do research and real experiments.

Another issue is entertainment. The origin of the robot is a clockwork-doll. Robots can also be appliances such as door stoppers – any kind of everyday device. The shape is similar to us but it does something strange. That is kind of fun. In that case you don't need physical interaction or it is not always necessary.

These applications – both for the senior citizens and in entertainment – are both far away but they can share some technology. Therefore, a person dealing with fundamental research issues can apply it to different areas. But the industry needs immediate profit. So they just focus on chosen topics.

SG: *The industry measures success in profit and researchers measure theirs in publications and citations. When these two worlds meet, how would you measure the success of such industry-academia collaboration?*

MA: *That is a big issue. Even if the media coverage is high it does not guarantee the success of a product. The typical example of this is a car. So, if an automobile company shows a design for a future car and many people say that it is good, the company will introduce it to the market only to realize that it is "good" but not bought. It's just to look at. One has to be careful as media coverage does not guarantee success on the market.*

Therefore, I would propose that we start a good collaboration with some immediate application to the real world and then gradually introduce it to the market. By collaboration, I mean university and industry again. I suppose the government's role is to lead this kind of collaboration.

SG: *How can one increase industry-academia collaboration and how does one overcome the current problems?*

MA: *I mentioned a triangle – the industry, the government and the university or academia. There are still large gaps between these. Therefore, we need a guy to connect these. This is a kind of gatekeeper or producer. He or she should know the demand and need and then determine what kind of product has a big potential. He or she should not be a researcher but someone with a sense of the market.*

In Japan we lack the general scientist to promote research. In the US there are general scientists who are science journalists. These people are necessary. But in Japan *science journalists can't afford a life. I suppose that we need these kinds of people to bridge the gap between industry and university. But in japan we don't have that job category and there is no salary for them. But we need people who are not researchers and not in the industry but have a sense of both.*

SG: *So, media and science journalists could be the driving force?*

MA: *I am getting used to media coverage and interviews. So, I can be that kind of generalist, too. But I only have two connections, the Daiwa house and Citizen. But I can make suggestions for the future.*

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