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Analysis of the delphi query held at the workshop on “European Efforts in Strengthening the Academia-Industry Collaboration”

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1 Delphi query

1.1 Introduction.

In the context of the European Project ECHORD there is an on-going effort to characterize the robotics research activities. Partner University of Coimbra (UC) as part of the Structured Dialog task conducted this effort.

At the IROS 2011 WORKSHOP on "European Efforts in Strengthening the Academia-Industry Collaboration" we conducted a Delphi query to identify which technologies will have higher impact on the future development of robotics, and which product visions and application scenarios will have more social and economic impact in the future of our society. The aim was to identify the most relevant scenarios but also to discuss the results with the research and academia communities, in order to increase awareness about these issues.

The results show a considerable level of consensus about the majority of the research and application topics, including product visions and application scenarios, with only a few deviations that require further consideration and analysis.

Our experts pool was constituted by participants that were present at the IROS 2011 conference, which had an acceptance rate of 30%, and were interested in the mentioned workshop: a little bit more than 20 researchers.

1.2 Methodology

Following the delphi queries guidelines the experts were asked to quantify the **impact** of a list of **technologies in the future of robotics** and the **social and economic impact** of a list of **application scenarios and product visions**. The average and standard deviation from the results of the first round were presented to the experts during a second round to promote consensus.

The analysis of the final results was done considering only the results that exhibit a standard deviation below 1. In this document, the conclusions/comments are highlighted based on the most relevant topics and the less relevant topics, which are selected just by considering the topics with the top 20% and bottom 20% classification of each specific topic, respectively (see Figure 1).

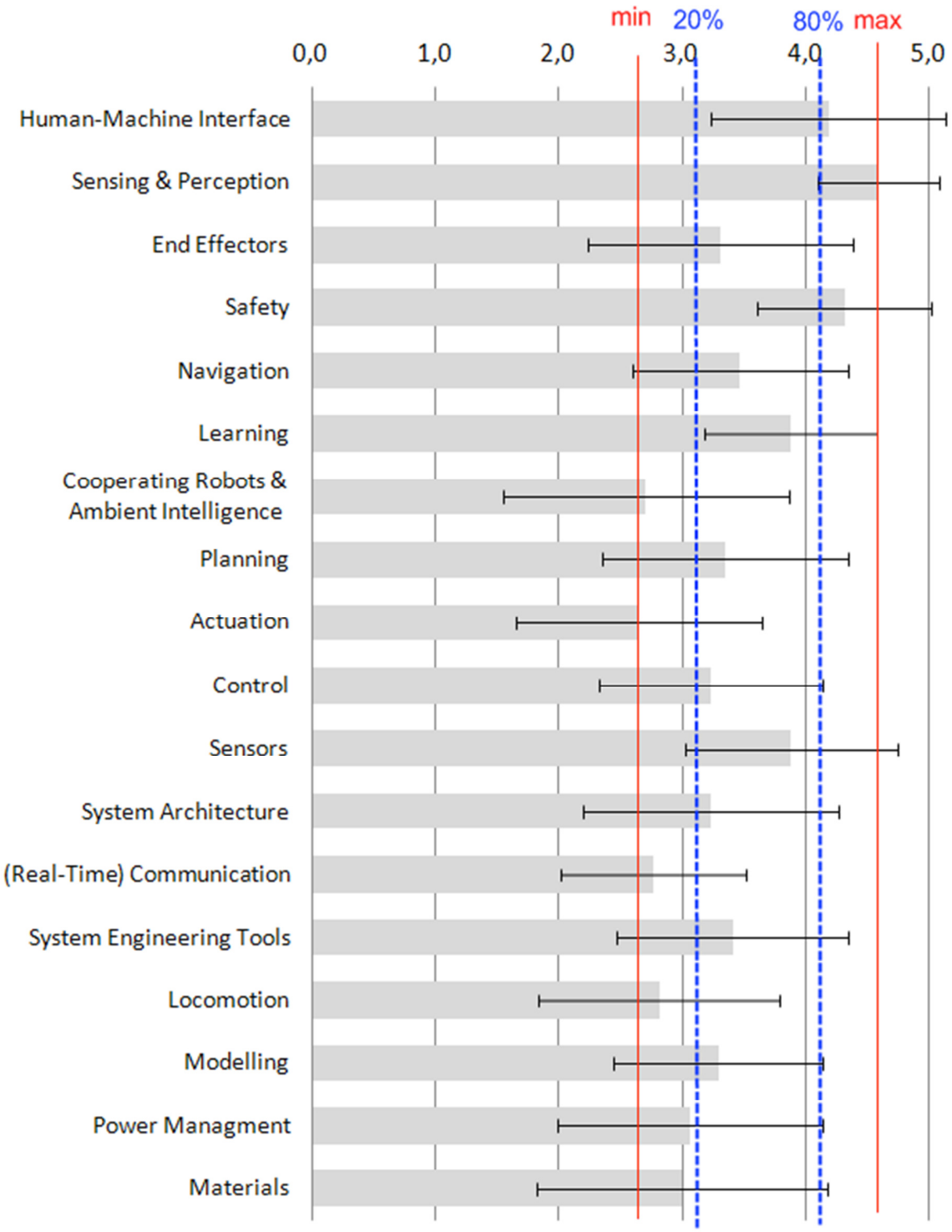

Figure 1. Technologies delphi query results

2 Results

2.1 Technologies

The results show (see annex 3) that the group of experts consider that in terms of the fundamental domains, the ones that have more impact in the future of robotics are **Sensing & Perception and Safety, Human-Machine Interface** subtopic is also rated with a high note but the level of consensus is less significant.

On the other hand, the group of experts have chosen the following topics as the less important (with a classification that fall in the bottom 20%): **Locomotion** and **Real Time communication** and **Actuation**. The developments on **Power Management** are also rated as low impact but with a surprisingly high uncertainty**.**

Please also notice that the topics **Cooperating Robots & Ambient intelligence** and the topic **Materials** didn't generated the required consensus and therefore were not included in this analysis.

2.1.1 Human Machine interface subtopics

The **HMI** sub-topics (annex 3, figure 1.2) that gathered consensus within the experts as the most relevant in the future of robotics were: **Programming-by-demonstration, 3D PMD cameras, Gesture Recognition, Force controlled HMI and Cognitive HMI.**

The topics that were considered less relevant (annex 3, figure 1.2) were **Co-transport, and Neural system interfaces.**

2.1.2 Sensing & percetpion

The only **Sensing & perception** subtopic that fell in the top 20% of the classification (annex 3, figure 1.3) was the **Object recognition.**

The topic that was considered less relevant (annex 3, figure 1.3) with high degree of certainty (consensus) (bottom 20%) was the **Smell recognition.**

It should be noticed that the classifications of these sub-topics clearly separates them from the rest of the group. In the case of the object recognition this fact might be attributed to the broad coverage of the sub-topic, but in the case of the smell recognition this clearly shows a trend.

It should be noticed that in this topic the average classification of the sub-technologies is 2,9, which is far bellow the classification of the technology (Sensing & Perception)

(see **Figure 1**). This result needs further investigation and may indicate that current research trends aren't inline with the expectations of the experts.

2.1.3 End Effectors.

The classification for sub-topics of the technology **End-Effectors** show high disparity of results (see annex 3, figure 1.4), which indicates that no consensus was reached, with maybe the exception of the expected low level impact of the **prosthesis** sub-topic.

Nevertheless, the average impact of the subtopics matches the result of the technology End-Effectors.

2.1.4 Safety

The results (see annex 3, figure 1.5) from the query show that **safety** is one of the topics with more impact in the future development of robotics. Concerning sub-topics of this technology, the most relevant and consensual were the **Predictive failure detection** and the development of safety **Sensors.** Although with a higher standard deviation the development of a **Safe Robot Controller** also gathered a high number of votes. On the other hand the **Safe Zones** technology (somehow strange result since **Safe Zones** are a current trend in industrial systems) and the **Majority voting** technique were pointed as the less relevant.

2.1.5 Navigation

Among the **Navigation** sub-topics (see annex 3, figure 1.6) the **SLAM** sub-topic was consensually (0.7 standard deviation) considered with a higher impact in the future of robotics. Interesting results also for the technologies **Collision Avoidance** and, **Mapping** and **Localisation,** which is inline with current research trends. On the other hand **Piloting** was consistently classified as the less relevant sub-technology.

2.1.6 Learning

The input from the experts regarding the **Learning** sub-topics (see annex 3, figure 1.7) was very consistent classifying the topics **Life Long learning** and **Learning by observation** as the most relevant topics. **Object recognition** was also considered relevant, although in this case with a worse consensus (but still valid). The worst subtopic was **Learning Teamwork**.

The average classification of the **Learning** sub-topics was 3,3 and the technology itself was classified as 3,9, which shows the consistency of the results and the importance attributed to this technology.

2.1.7 Cooperating robots & ambient intelligence

Cooperative manipulation and **Collaboration** were the technology sub-topics (see annex 3, figure 1.8) that gathered significant consensus as relevant for the future of robotics.

The subtopics **RFID, ZigBee, Middleware for physical multi-agent systems** were consensually classified with low impact in the future of robotics. In our point-of-view this is a strange result considering the actual high interest in these sub-technologies from application engineers and product developers.

2.1.8 Planning

The analysis of the classification of the **Planning** sub-topics (see annex 3, figure 1.9) show that **Cognitive** techniques and **Task Planning** were consensually elected the most promising sub-topics of the technology **Planning**. On the other hand **symbolic planning** was considered the topic with the less impact.

2.1.9 Actuation

The results show (see annex 3, figure 1.10) that experts strongly agreed that **Compliant manipulators** is the most relevant sub-technology for the **Actuation** of future robots. On the other side a big group of sub-topics was classified with low impact: **Passive compliant manipulators, AC/DC motors**, **Linear actuators**, **Ball and socket joints**, **Gears**, **Drives**, **Piezoelectric actuation**. Although with a higher uncertainties **Pneumatic Muscles**, **Electro-active polymers, Shape memory alloy** and **Micro actuators** were also classified as low impact technologies.

2.1.10 Control

The results of the query for the **control** technology sub-topics (see annex 3, figure 1.11) show a low level of agreement among the participants. Nevertheless, 3 technologies excel from the rest due to the low impact results: **Underwater vehicle control, Dynamic walking and Aerial Vehicle control.** On the positive side the most relevant technology was the **Impedance control.**

The average result of the sub-topics is consistent with the **Control classification** (see **Figure 1**).

2.1.11 Sensors

The impact of the sub-topics within the technology **Sensor** group was classified very consistently (see annex 3, figure 1.12) showing the consensus of the experts in this topic. **Smart sensors** and **3D Vision systems** expected impact is very high and distant from the other sub-topics. On the other side of the scale, **Nanosensors**, **Ultrasound (sensors)**, **Radar (sensors)**, **Feet sensors** and **Audio Sensors** were classified by the group of experts as low impact technology sub-topics.

It is important to notice that the **Sensor** sub-topics (average 2,9) were classified significantly below the value (3.9) obtained by the **Sensor** topic itself (see **Figure 1**). This requires further investigation and may indicate that current research trends aren't inline with the expectations of the experts.

2.1.12 System Architecture

In the **system architecture** technology the sub-topics classifications (see annex 3, figure 1.13) are fairly even and the experts opinion consistent. The topic with the highest relevance is the **Plug-n-Play** and the worst impact is **Grid Technologies**.

2.1.13 (Real-time) communications

The results of the query regarding the impact of (**Real Time) Communications** sub-topics show a good consensus (see annex 3, figure 1.14), namely for the topic with the most relevant impact (**High speed Networking*).*** With the lowest impact in the future of robotics the experts agreed on: **USB**, **ZigBee**, **Bluetooth**, **Microwave** and **Laser**/**Fiber**. Again, this seems to be a strange result if we take in consideration the high actual interest in these topics from application engineers and product developers.

2.1.14 System Engineering

System Engineering Tools that target developments in **Robot Programming** were voted as the sub-topics with more relevant impact in the future of robotics (see annex 3, figure 1.15). In the opinion of the experts **Product Data Management** tools will have the lowest impact.

2.1.15 Locomotion

In general, (see annex 3, figure 1.16), the consulted experts agreed that **Locomotion** is a topic with low impact (see **Figure 1**) and the classifications of the correspondent sub-topics confirm this fact.

Among **Locomotion** sub-topic only **Wheels** is considered relevant. On the other hand

the **Propeller**, **Waterjet, Flapping Wings, Snake Movements, Climbing Feets** were classified as low impact technology sub-topics.

2.1.16 Modelling

The **modelling** sub-topics (see annex 3, figure 1.17) show very consistent classifications, with a minimum of 3,4 for the **Standards and Representation** and a maximum of 3,9 for the sub-topics **Adaptive Realtime Modelling** and **Modelling tools.**

2.1.17 Power management

The experts classifications (see annex 3, figure 1.18) for the **Power management** technology sub-topics were very consistent, and resulted in electing the sub-topics **Batteries** and the **Energy efficient robots** as the sub-topics with the most relevant impact. **Microbiological power generation** was the technology classified with the less impact.

2.1.18 Materials

The results for the **Materials** sub-topics (see annex 3, figure 1.19) show a medium/low level of consensus. Nevertheless, it is possible to say that **Biodegrading** materials won't have significant impact in the future of robotics and **Carbon Fiber** is the most promising material. It should be noticed that both **shape memory alloys** and the **Biomimetic materials** were excluded from this evaluation due to the high standard deviation of the results.

2.2 Application Scenarios and Product Visions

The experts that participated in the delphi query agreed (see annex 3, figure 2.1) that the scenario **Robotic Co-Workers** is the one with the higher potential impact in the future, along with **Robotic workers**, and that the development of **Robots for surveillance and intervention** is the robotic application scenario with less impact in the future.

2.2.1 Robotic workers

Among the different product visions of the application scenario **Robotic Workers** (see annex 3, figures 2.2.1 and 2.2.2), the **Rapid adaptable manufacturing cell** and the **Robot automation for small scale manufacturing** were considered the most relevant both for the social impact and economic impact. Nevertheless, higher level of consensus was gathered around the Economic impact of such technologies.

On the other hand the **Robot with integrated process control**, the **micro-manufacturing robot** the **mining robot** and the **space related product visions** were the considered the ones with less expected impact.

2.2.2 Robotic Co-workers

The product vision (see annex 3, figures 2.3.1 and 2.3.2) of the **Robotic Co-workers Application Scenario** that consensually gathered the option of the experts for the Economic Impact was the **Robot assistant in industrial environments.** On the other hand, for the Social Impact, the most relevant product visions were the **Rehabilitation robot**, the **Personal robot** and the **robot for physically challenged**. **Space robots** were again considered the less relevant both economically and socially.

2.2.3 Robots for exploration & inspection

The experts pointed out (see annex 3, figures 2.4.1 and 2.4.2) that Robots designed for the **Site protection (domestic and industrial)** will represent a product vision with the most relevant social and economic impact in this scenario.

2.2.4 Logistic robots

Experts consensually agreed (see annex 3, figures 2.5.1 and 2.5.2) that the **Autonomous transportation of people** and **goods** are product visions with economic impact in the future, but only partially agreed on the social impact.

2.2.5 Edutainment robots

In terms of **Edutainment Robots** scenario, (see annex 3, figures 2.6.1 and 2.6.2), the **Robot companion** was classified very high both in the economic and social impact. The **Robot toy** and the **Robot Trainer** were also considered good product visions in an economic point of view.

2.2.6 Robots for exploration and inspection

In terms of **Robot for surveillance and intervention** product visions, the experts (see annex 3, figures 2.7.1 and 2.7.2) didn't reached a significant consensus. Nevertheless **Robots for the inspection of places inaccessible to humans** were considered interesting product visions both economically and socially.

2.3 Conclusions/Executive Summary

2.3.1 Technologies

The analysis of the results of the delphi query made at the IROS workshop (see annex 3) show that the pool of experts clearly identify a **group of technologies** that will have a good impact in the future of robotics, and also a **set of product visions** that will have a good impact in the social and economic development of our society.

In terms of technologies, the **Sensing & Perception** is consensually considered the group of technologies with the highest potential impact in the future development of robotics. Nevertheless, taking a careful look into the sub-topics of **Sensing & Perception** only the **Object Recognition sub-topic** has a classification above 4, which may indicate that the current research sub-topics aren't inline with anticipated needs or at least with the expectations of this set of experts. This requires further investigation to properly identify the reasons of this classification.

Safety is the second technology in terms of impact in the future of robotics. Three of its sub-topics are consensually considered by the experts as the most relevant in terms of potential impact: **Safe robot controllers**, (**Safety) Sensors** and **Predictive failure detection**. This is a very important result, since also **Robotic co-Workers** is considered a very important application scenario.

The third most relevant technology group is the **Human-Robot Interaction** that got an average classification above 4, although with a standard deviation higher than **Sensing & perception** and **Safety**, which clearly show a lower level of consensus. From the **Human Machine Interface** sub-topics, the experts agreed that the **Programming-by-demonstration** is the technology with the highest impact. Again, very important result considering the **Robotic co-Worker scenario**.

Among the other technologies, several different sub-technologies got special remark by the experts. In their opinion the future development of robotics will benefit from advances in:

Actuation: **Compliant Manipulators**
Sensors: **Smart Sensors, 3D Vision Systems;**
Control: **Impedance Control**;
System Architecture: **Plug-n-Play**
System Engineering: **Robot programming**
(Real Time) Communication: **High speed networking**
Locomotion: **Wheels**
Power Management: **Batteries** and **Energy-efficient robots**

2.3.2 Application scenarios and product visions

From the **EURON Strategic Research Agenda** list of **Application Scenarios** the **Robotic Workers**, **Robotic Co-workers** and the **Logistic Robots** were the highly voted as the most promising ones.

The **Robotic Co-Worker** application scenario was considered the scenario with the highest expected impact. Nevertheless, looking in detail to the sub-topics (product visions), there is a strong differentiation of product visions by the type of impact (social or economical): **Rehabilitation robot**, **Personal Robot** and **Robot assistant for physically challenged** were product visions highly voted in terms of the social impact and the **Robot Assistant in industrial environments** got a consensual classification (above 4) in terms of the economic impact. This indicates a clear definition of what is needed considering what we all aim with the introduction of robots in our daily routine, and what will have a strong economic impact. This issue is very significant and requires further consideration in the future.

Considering the **Robotic Workers** product visions, the results from the delphi query show the **Rapidly adaptable manufacturing cell** and the **Robot automation for small scale manufacturing** will have a very positive economic and social impact in the future of our global society. However this fact is more consensual in terms of economic rather than social impact, which further enhances the previous remark of a clear and objective differentiation of the two types of impacts.

It's also interesting to notice that in the case of the **Logistic robots** product visions, the **Autonomous transportation of people** and **goods** were consensually considered the sub-topics with the highest economic potential impact, but only the **Autonomous transportation of People** repeats the result for the social impact.

Finally, it's important to notice that the social impact of the sub-topic **Robot Companion** and the economic impact of the sub-topic **Robot Toys** were considered very relevant, although the correspondent scenario (**Edutainment**) was classified as less relevant. This clearly indicates that some sub-topics of current robotic research clearly got awareness and have an identified potential both in the economic and social point of view.

3 Annex 1

Technologies delphi query questionnaire – round 1

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ECHORD Workshop at IROS 2011

Experts Delphi Query

In the context of the European ECHORD project there is an ongoing effort to characterize the robotics research activities.

At the IROS WORKSHOP on "European Efforts in Strengthening the Academia-Industry Collaboration" we are conducting a Delphi query to determine which technologies will have **more impact on the future development of robotics**, and which product visions and application scenarios **will have more social and economic impact** in the future of society.

Technologies - Fundamental domains that are the basis of the robotics development.

Application Scenarios and Product Visions - Different products that could appear in the robotics field grouped by sector-overarching application scenarios.

These classifications are an extended version of the classification made by EURON for the EURON Strategic Research Agenda.

For complete information about the results of this project and detailed definition of the technologies and product visions please check:

Thank you for your cooperation.

ECHORD team.

1.1 Technologies

	1-Lowest Impact	2	3	4	5-Highest Impact
Human-Machine Interface	○	○	○	○	○
Sensing & Perception	○	○	○	○	○
End Effectors	○	○	○	○	○
Safety	○	○	○	○	○
Navigation	○	○	○	○	○
Learning	○	○	○	○	○
Cooperating Robots & Ambient Intelligence	○	○	○	○	○
Planning	○	○	○	○	○
Actuation	○	○	○	○	○
Control	○	○	○	○	○
Sensors	○	○	○	○	○
System Architecture	○	○	○	○	○
(Real-Time) Communication	○	○	○	○	○
System Engineering Tools	○	○	○	○	○
Locomotion	○	○	○	○	○
Modelling	○	○	○	○	○
Power Managment	○	○	○	○	○
Materials	○	○	○	○	○

Sub-Topics

1.2 Human-Machine Interface sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
3D PMD Cameras					
Gesture Recognition					
Graphical Interfaces					
3D Virtual Reality					
Impedance Algorithms					
Object Transfer					
Spatial Augmented Reality					
Speech Interfaces					
Co-Transport					
Neural system interfaces					
Tele-Operation					
Interactive Demonstration					
Turn Taking Dialog					
Sound Processing					
Non invasive brain interfaces					
Body Language					
Force controlled HMI					
Programming-by-Demonstration					
Cognitive HMI					
Haptic devices					

1.3 Sensing & Perception Sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Object Recognition					
Human identification					
Visual servoing					
Speech recognition					
CAD based object recognition					
Emotion Recognition					
Smell recognition					
Visual servoing					
Face recognition					
Compound ultrasound recognition					
Data processing - Data mining					
Data processing - Bayesian					
Data processing - fuzzy					
Data processing-statistics					
Data processing-predictive					
Optical flow					

1.4 End Effectors sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Gripper development					
Grasping					
Dexterous hands					
Compliant grasping					
Robot hands					
Surgical robotics tools					
Force sensing					
Vision sensing					
Prostheses					

1.5 Safety sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Safe robot controllers					
Sensors					
Safe zones					
Standardization					
Force control for human protection					
Safety compliance of software (formal methods)					
Redundancy					
Majority voting					
Predictive failure detection					

1.6 Navigation sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Mapping					
Collision avoidance					
Assisted driving					
Piloting					
Laser guided vehicle					
Localisation					
Simultaneous Localisation and Mapping (SLAM)					
Certification					
Motion planning					
Cognition					
Social rules					

1.7 Learning sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Path learning					
Behavioural learning					
Evolutionary robots					
Object recognition					
Ontologies and Data representation					
Learning teamwork					
Adaptive control					
Life long learning					
Learning by observation					
Map learning					

1.8 Cooperating Robots & Ambient Intelligence sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Human-robot teams					
Swarm					
Collaboration					
Multiple Manipulators					
Bioinspired					
Middleware for physical multi-agent systems					
Cooperative manipulation					
Agents					
Cooperative perception and navigation					
Internet of things					
Microsystems technology (sensors/actuators)					
Distributed sensor networks					
RFID					
ZigBee					

1.9 Planning sub-topics

	1-Lowest Impact	2	3	4	5
Path Generation/Planning					
Map Building					
Cognitive					
Symbolic planning					
Task planning					
Grasp planning					
Manipulation planning					
Motion planning					

1.10 Actuation sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Compliant Manipulators					
Pneumatic muscles					
Electro-active polymer (EAP) muscles					
Passive Compliant Manipulators					
AC/DC motors					
Large scalle actuation					
High density drives					
Linear actuators					
Ball and sockets joints					
Gears					
Drives					
Piezoelectric actuation					
Shape memory alloy (SMA) muscles					
Micro actuators					
Exoskeletons					

1.11 Control sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Visual servoing					
Robot control					
Robot accuracy					
Underwater vehicle control					
Force control					
Robot accuracy					
Dynamic walking					
Robot arm control					
Hand control					
Aerial vehicle control					
Impedance control					

1.12 Sensors sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Force torque sensors					
Finger tips					
Haptic sensors					
Audio sensors					
Skin sensors					
Feet sensors					
Radar					
Smart sensors (sensing integration)					
Laser scanners					
Infrared					
Ultrasound					
PMD sensors					
Texture sensors					
Proprioceptive sensors					
Nano sensors					
3D vision systems					

1.13 System Architecture sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Service Oriented Architectures (SOA)					
Agent based systems					
Orchestration					
Plug-n-Play					
Grid technologies					
Ontologies					
Semantic web					
Safe languages					

1.14 (Real Time) Communication sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
High Speed Networking					
Ethernet based fieldbuses					
USB					
ZigBee					
Wireless					
Bluetooth					
Microwave					
Laser/fiber					
Knowledge/ontologies for protocols					

1.15 System Engeneering Tools sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Robot Programming					
Modelling of robot hardware					
Modelling of motion planning					
Modelling robotic systems with dynamic environment					
Product data managment (PDM)					

1.16 Locomotion sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Walking					
Wheels					
Tracks					
Propeller					
Waterjet					
Omnidirectional drives					
Miniaturisation					
Flapping wings					
Snake movments					
Climbing feet					
Legs/wheels coupled solutions					
Exoskeletons					

1.17 Modelling sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Robot kinematics/dynamics					
Standards and representation					
Modeling tools					
Sensor fusion					
High-level process/task description					
Online modelling					
Adaptive realtime modeling					
Environment modeling					
Interaction modeling					

1.18 Power Management sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Storage systems					
Wireless power transmission					
Power regeneration					
Batteries					
Microbiological power generation					
Energy-efficient robots					

1.19 Materials sub-topics

	1-Lowest Impact	2	3	4	5-Highest Impact
Shape memory alloys (SMA)					
Electroactive polymers					
Composites					
Carbon fiber					
Biomimetic materials					
Biodegrading					
Nanomaterials					
Metal foams					

4 Annex 1.1

Technologies delphi query questionnaire – round 2

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ECHORD Workshop at IROS 2011 - Experts Delphi Query

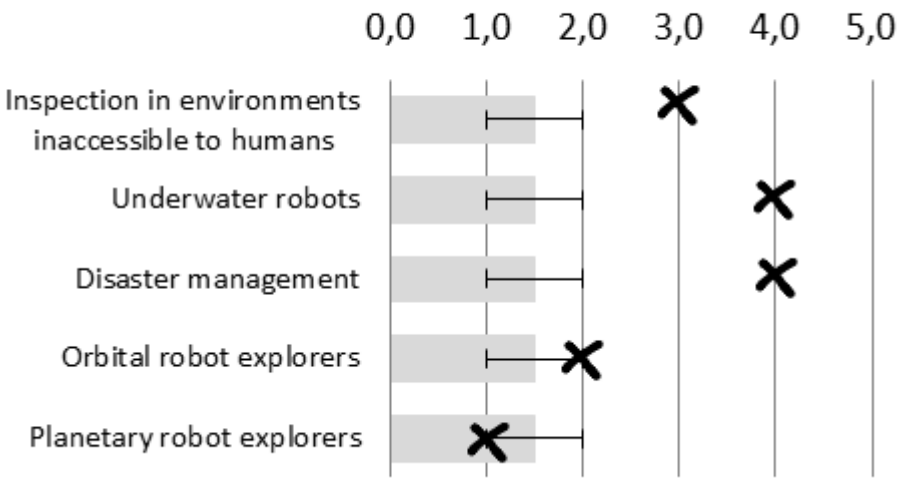
2nd round

In the context of the European ECHORD project there is an ongoing effort to characterize the robotics research activities.

At the IROS WORKSHOP on "European Efforts in Strengthening the Academia-Industry Collaboration" we are conducting a Delphi query to determine which technologies will have **more impact on the future development of robotics**, and which product visions and application scenarios **will have more social and economic impact** in the future of society.

This is the **2nd Round** of the delphi query and therefore we kindly ask you to answer taking into acount the results (mean and St. deviation) gathered from the first questionnaire.

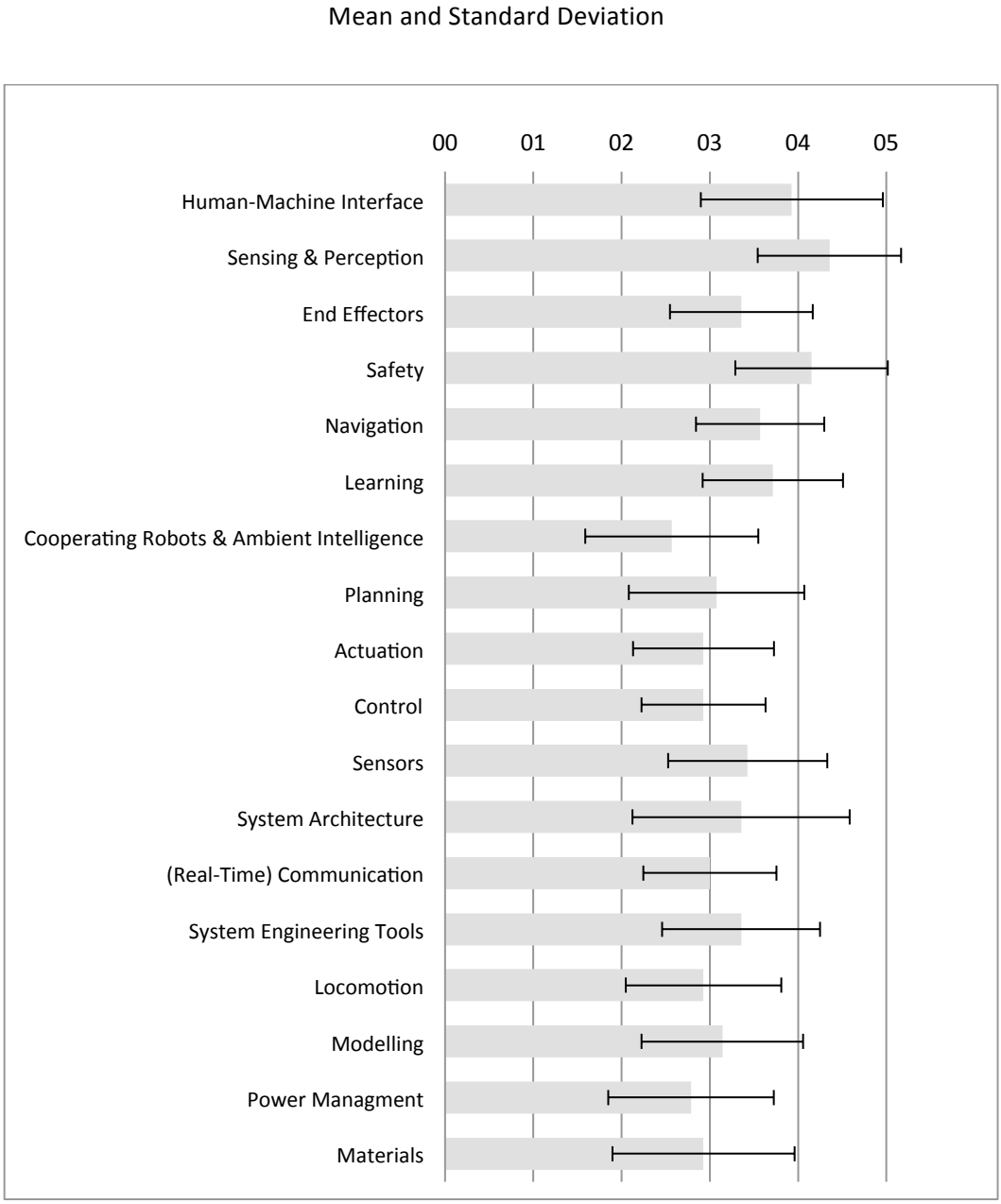
Example:



Thank you for your cooperation.

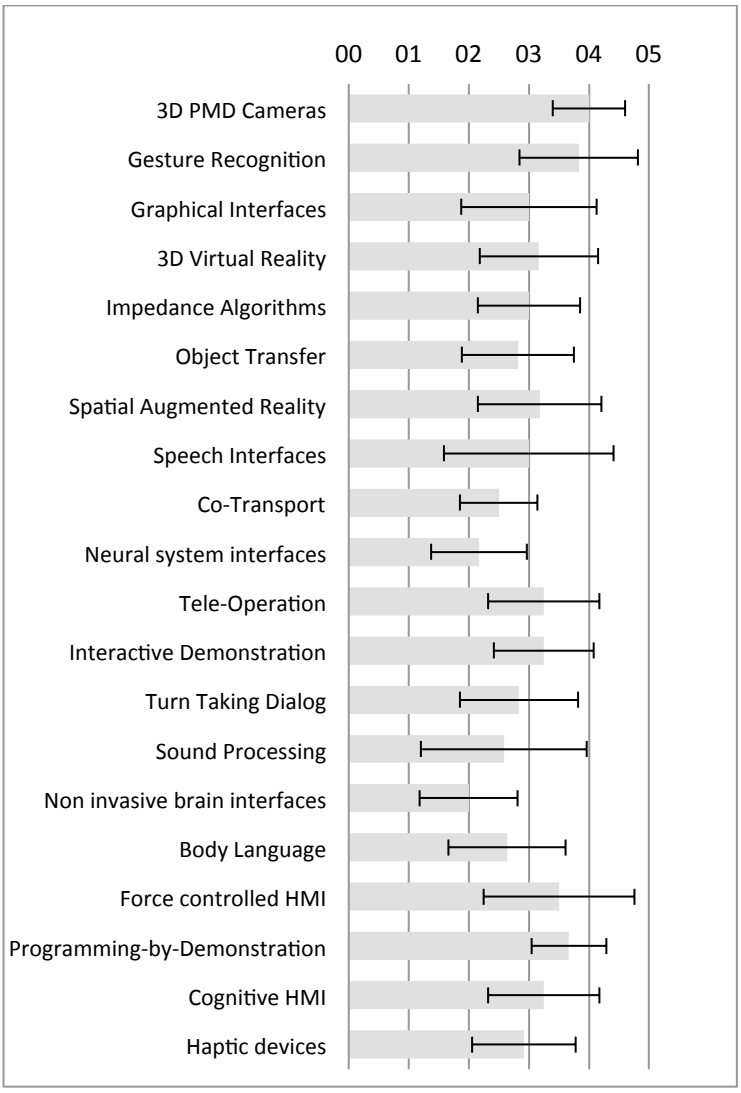
ECHORD team.

1.1 Technologies

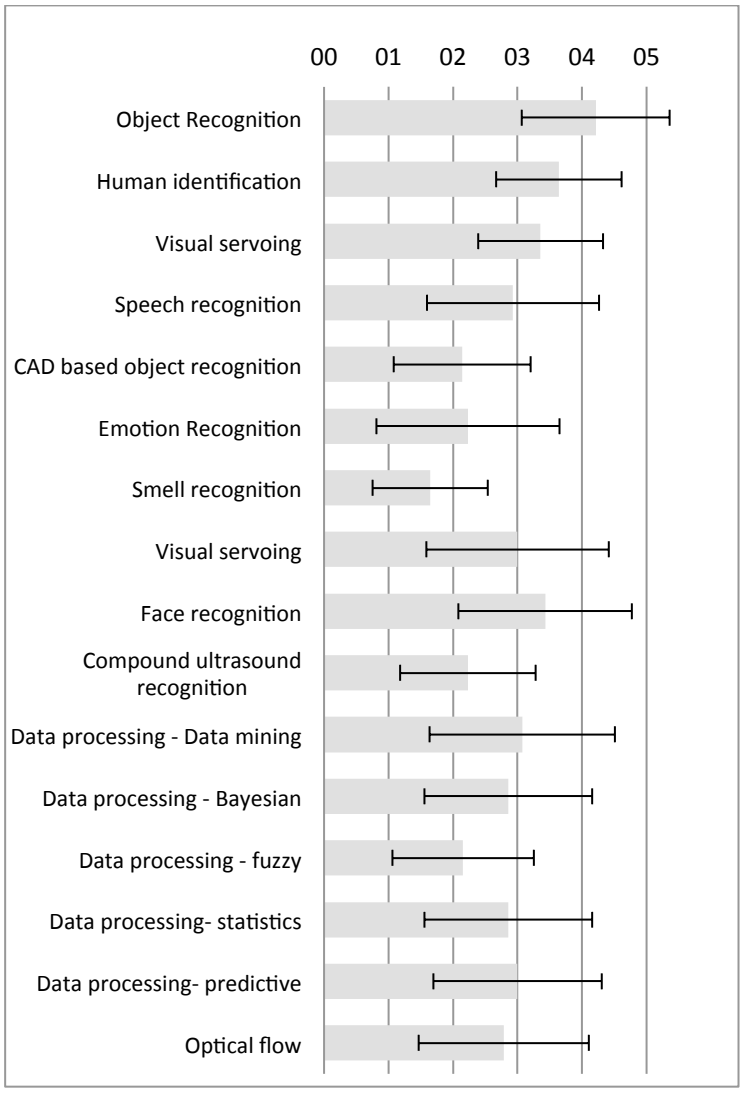


Sub-Topics

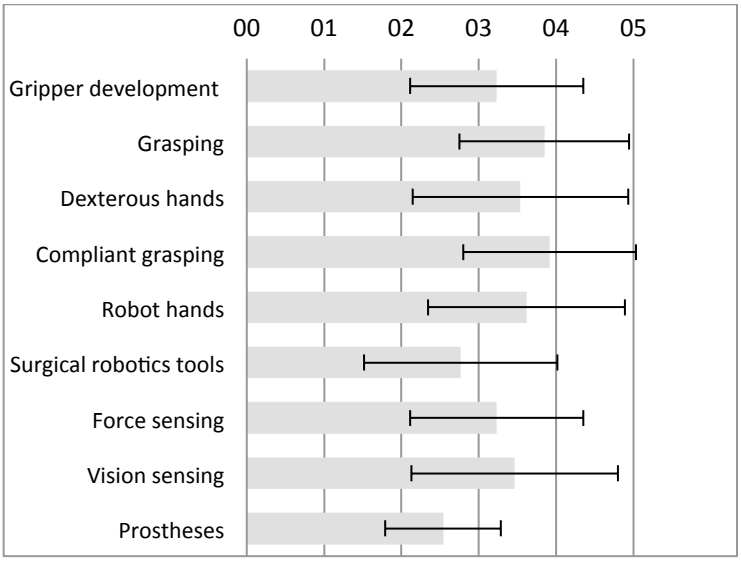
1.2 Human-Machine Interface sub-topics



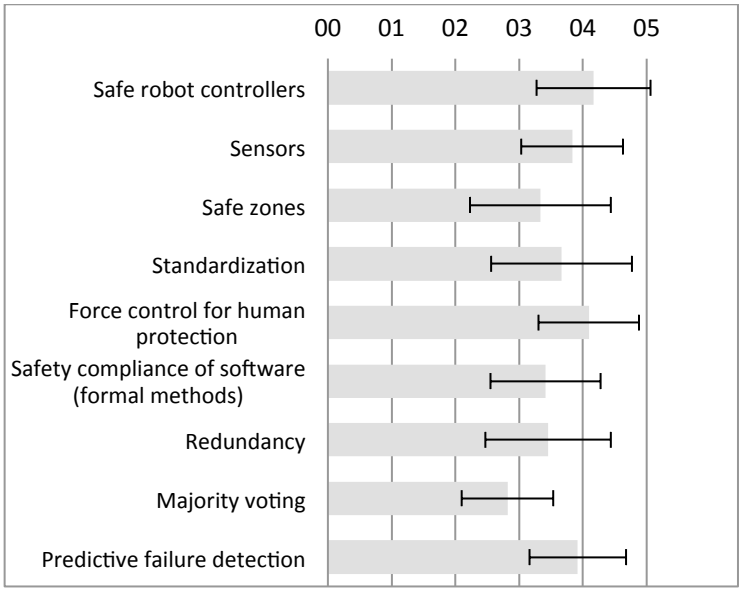
1.3 Sensing & Perception Sub-topics



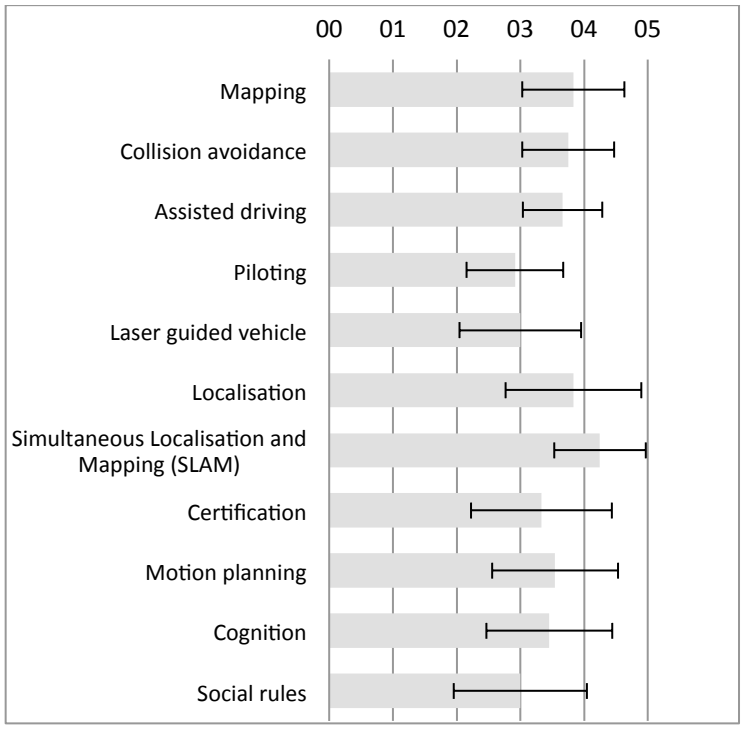
1.4 End Effectors sub-topics



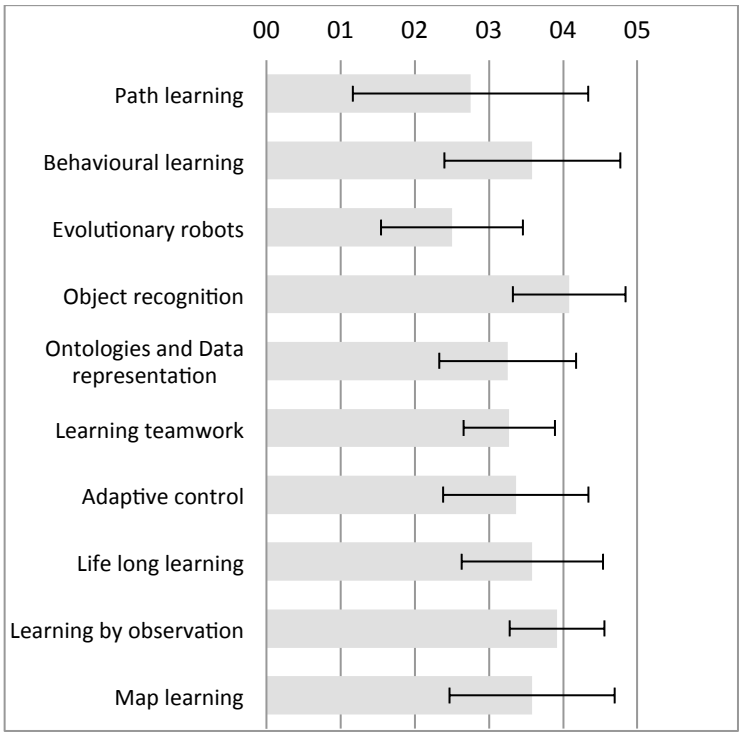
1.5 Safety sub-topics



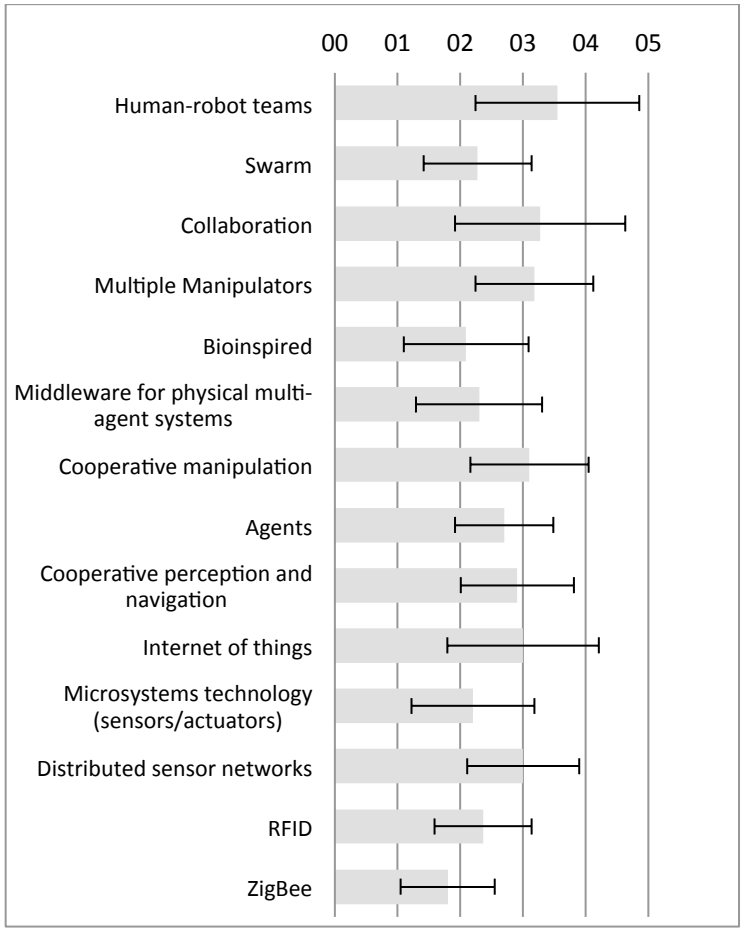
1.6 Navigation sub-topics



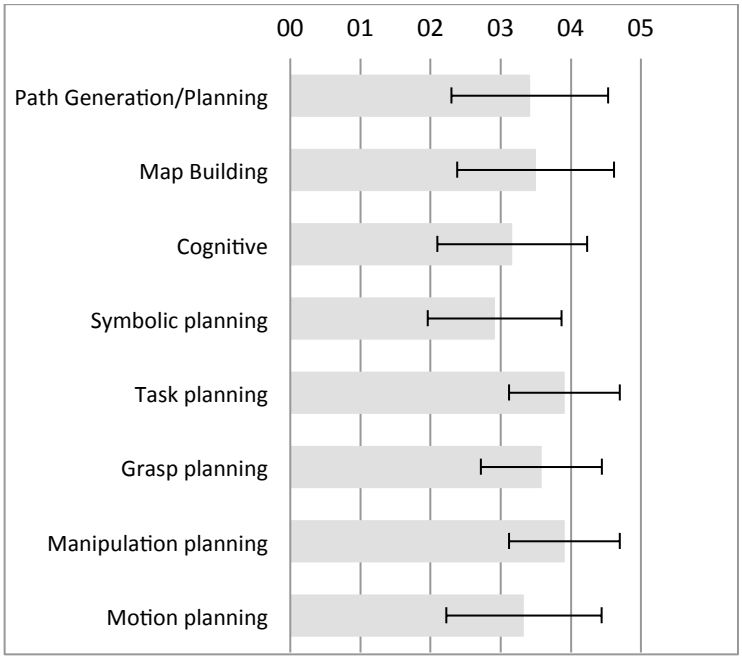
1.7 Learning sub-topics



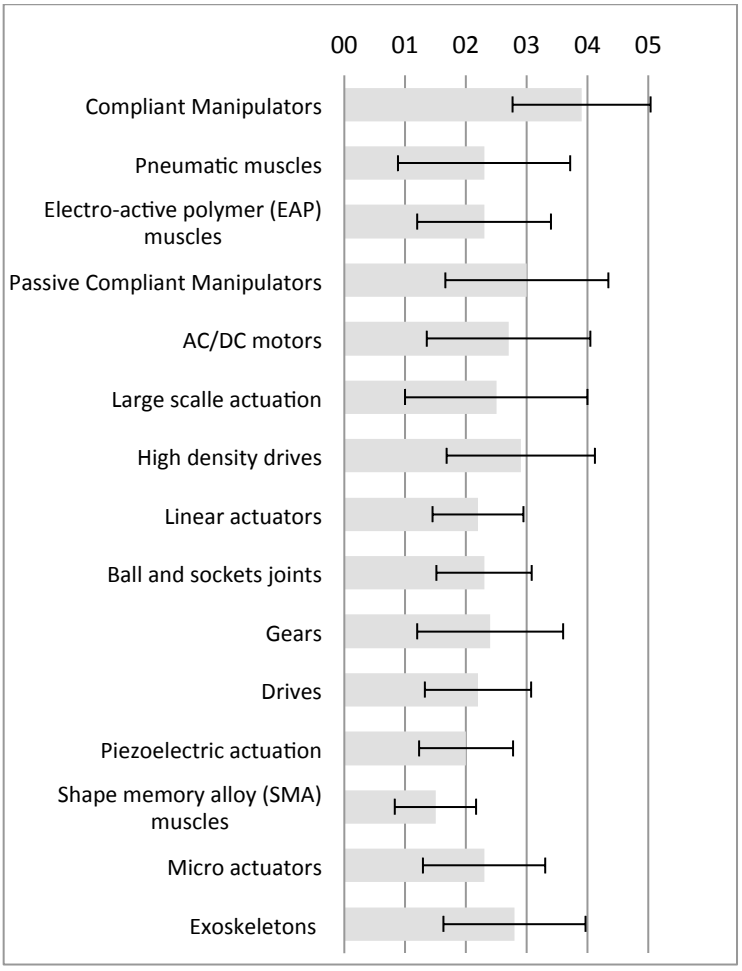
1.8 Cooperating Robots & Ambient Intelligence sub-topics



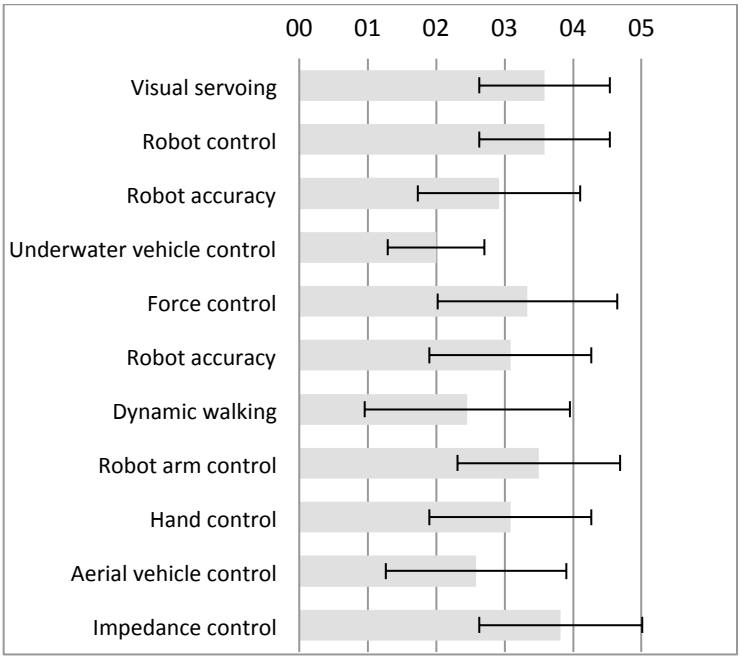
1.9 Planning sub-topics



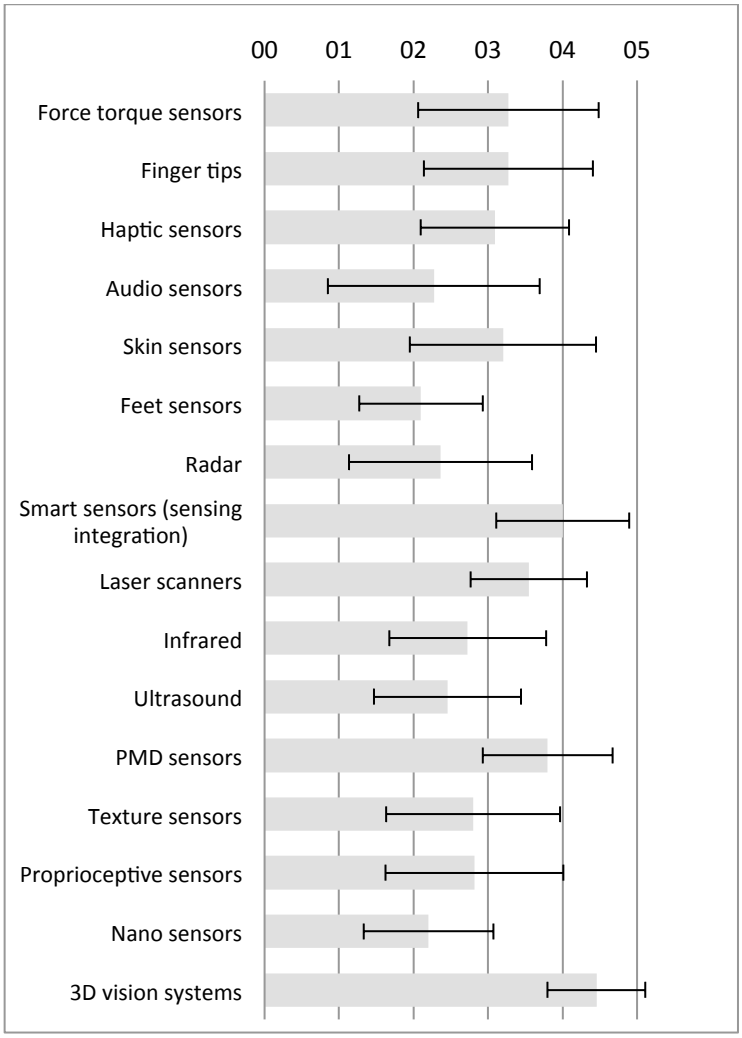
1.10 Actuation sub-topics



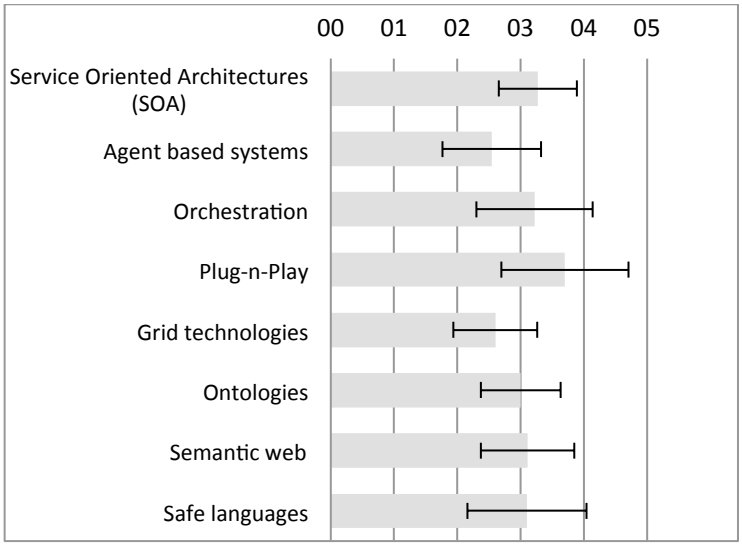
1.11 Control sub-topics



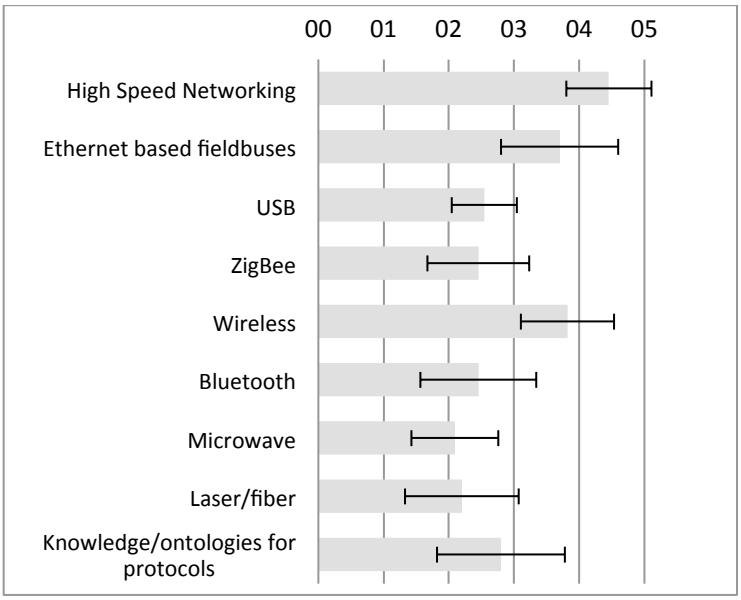
1.12 Sensors sub-topics



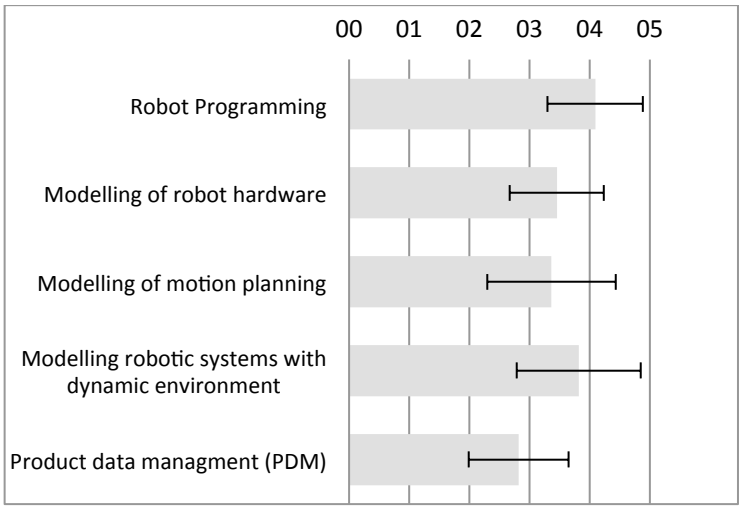
1.13 System Architecture sub-topics



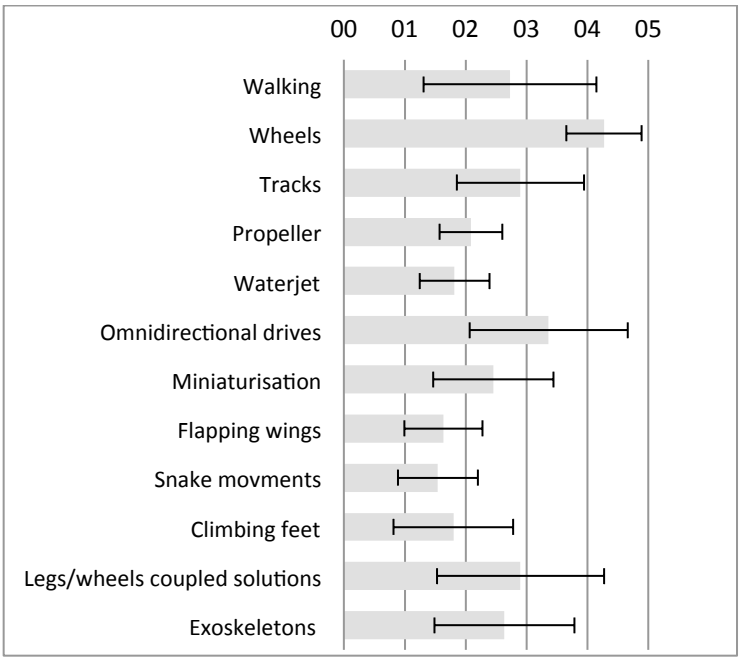
1.14 (Real Time) Communication sub-topics



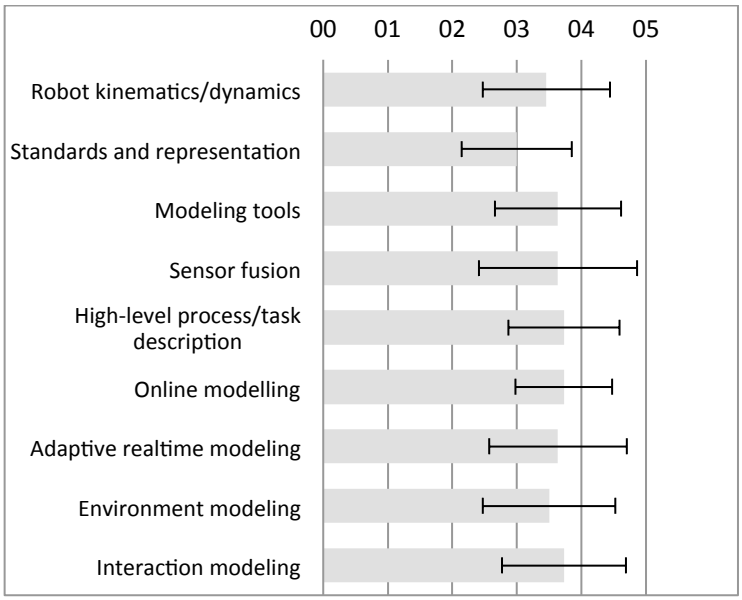
1.15 System Engeneering Tools sub-topics



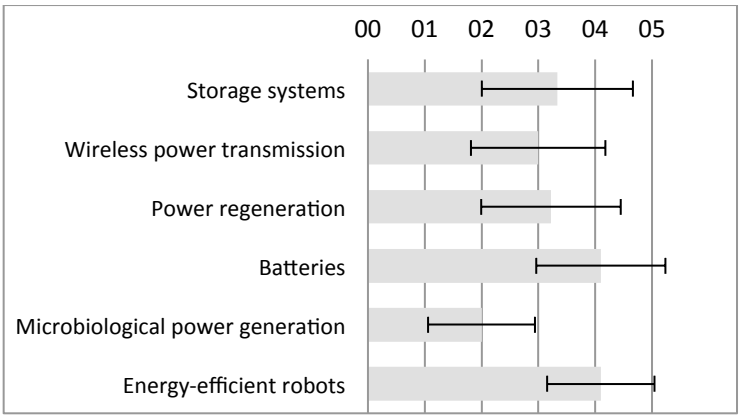
1.16 Locomotion sub-topics



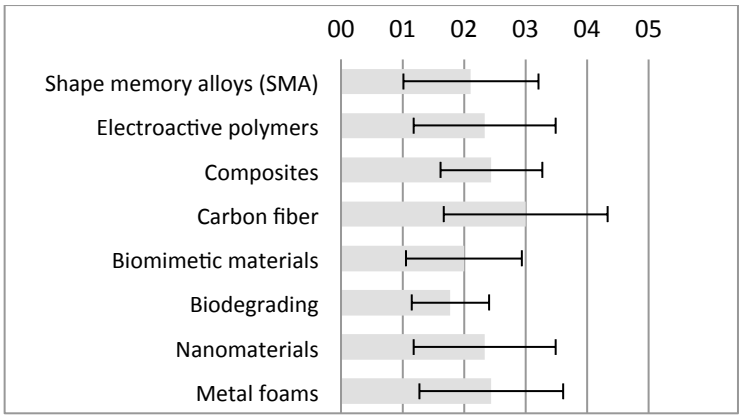
1.17 Modelling sub-topics



1.18 Power Management sub-topics



1.19 Materials sub-topics



5 Annex 2

Application Scenarios delphi query questionnaire – round 1

European Clearing House
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ECHORD Workshop at IROS 2011

Experts Delphi Query

In the context of the European ECHORD project there is an ongoing effort to characterize the robotics research activities.

At the IROS WORKSHOP on "European Efforts in Strengthening the Academia-Industry Collaboration" we are conducting a Delphi query to determine which technologies will have **more impact on the future development of robotics**, and which product visions and application scenarios **will have more social and economic impact** in the future of society.

Technologies - Fundamental domains that are the basis of the robotics development.

Application Scenarios and Product Visions - Different products that could appear in the robotics field grouped by sector-overarching application scenarios.

These classifications are an extended version of the classification made by EURON for the EURON Strategic Research Agenda.

For complete information about the results of this project and detailed definition of the technologies and product visions please check:

Thank you for your cooperation.

ECHORD team.

2.1 Application Scenarios

	1-Lowest Impact	2	3	4	5-Highest Impact
Robotic workers	○	○	○	○	○
Robotic co-workers	○	○	○	○	○
Robots for exploration & inspection	○	○	○	○	○
Logistics robots	○	○	○	○	○
Edutainment Robots	○	○	○	○	○
Robot for surveillance & intervention	○	○	○	○	○

Product Visions

Social Impact

2.2.1 Robotics workers product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Large structure manufacturing (incl. civil eng.)					
Robot with integrated process control					
Rapidly adaptable manufacturing cell					
Coordinated mobile manipulators					
Human-like assembly robot					
Robot automation for small scale manufacturing					
Postproduction automation (recycling, re-manufacturing)					
Micro-manufacturing robot					
Maintenance Robot					
Forestry and agriculture robot					
Mining robot					
Professional cleaning robot					
Orbital robot agent					
Planetary Rrobot agent					

2.3.1 Robotics co-workers product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Robot assistant in industrial environments					
Robot assistant for professionals					
Surgical robot					
Rehabilitation robot					
Personal robot					
Robot assistant for physically challenged					
Robot assistant in security contexts					
Orbital robot assistant					
Planetary robot assistant					

Economic Impact

2.2.2 Robotics workers product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Large structure manufacturing (incl. civil eng.)					
Robot with integrated process control					
Rapidly adaptable manufacturing cell					
Coordinated mobile manipulators					
Human-like assembly robot					
Robot automation for small scale manufacturing					
Postproduction automation (recycling, re-manufacturing)					
Micro-manufacturing robot					
Maintenance Robot					
Forestry and agriculture robot					
Mining robot					
Professional cleaning robot					
Orbital robot agent					
Planetary Rrobot agent					

2.3.1 Robotics co-workers product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Robot assistant in industrial environments					
Robot assistant for professionals					
Surgical robot					
Rehabilitation robot					
Personal robot					
Robot assistant for physically challenged					
Robot assistant in security contexts					
Orbital robot assistant					
Planetary robot assistant					

Social Impact

2.4.1 Robots for exploration & inspection product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Border surveillance					
Site protection (domestic and professional)					
Security checks of goods and people					

2.5.1 Logistics robots product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Autonomous transport of goods					
Autonomous transport of people					
Industrial mobile manipulators					
Service mobile manipulators					

2.6.1 Edutainment Robots product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Motion simulator					
Robot guide					
Robot teacher					
Robot trainer					
Robot companion					
Robot toy					
Robot Advertiser					

2.7.1 Robot for surveillance & intervention product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Inspection in environments inaccessible to humans					
Underwater robots					
Disaster management					
Orbital robot explorers					
Planetary robot explorers					

Economic Impact

2.4.2 Robots for exploration & inspection product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Border surveillance					
Site protection (domestic and professional)					
Security checks of goods and people					

2.5.2 Logistics robots product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Autonomous transport of goods					
Autonomous transport of people					
Industrial mobile manipulators					
Service mobile manipulators					

2.6.2 Edutainment Robots product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Motion simulator					
Robot guide					
Robot teacher					
Robot trainer					
Robot companion					
Robot toy					
Robot Advertiser					

2.7.2 Robot for surveillance & intervention product visions

	1-Lowest Impact	2	3	4	5-Highest Impact
Inspection in environments inaccessible to humans					
Underwater robots					
Disaster management					
Orbital robot explorers					
Planetary robot explorers					

6 Annex 2.1

Application Scenarios delphi query questionnaire – round 2

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ECHORD Workshop at IROS 2011 - Experts Delphi Query

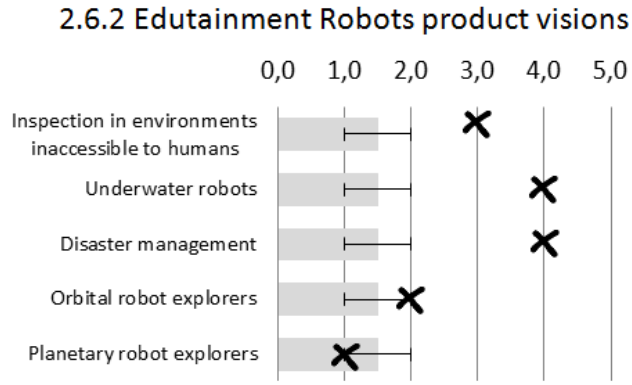
2nd round

In the context of the European ECHORD project there is an ongoing effort to characterize the robotics research activities.

At the IROS WORKSHOP on "European Efforts in Strengthening the Academia-Industry Collaboration" we are conducting a Delphi query to determine which technologies will have **more impact on the future development of robotics**, and which product visions and application scenarios **will have more social and economic impact** in the future of society.

This is the **2nd Round** of the delphi query and therefore we kindly ask you to answer taking into acount the results (mean and St. deviation) gathered from the first questionnaire.

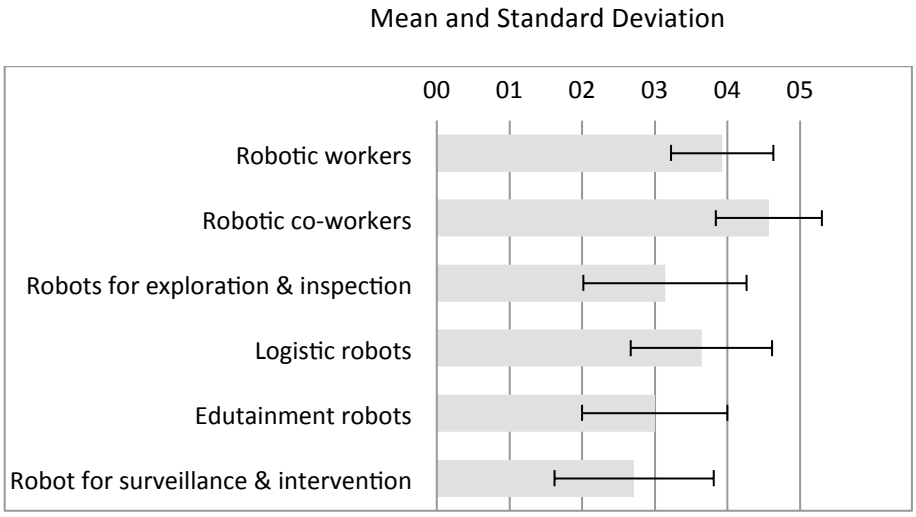
Example:



Thank you for your cooperation.

ECHORD team.

2.1 Application Scenarios

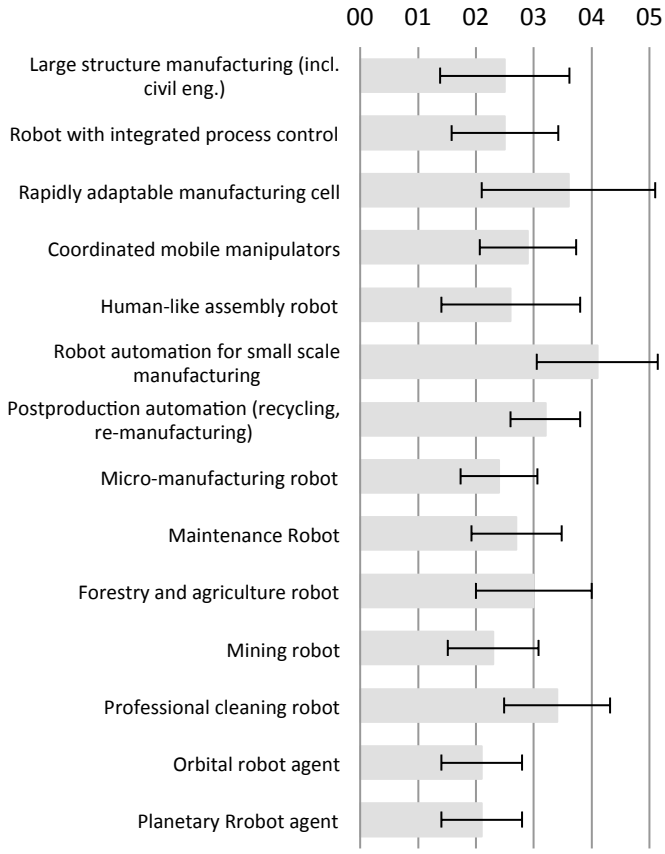


Product Visions

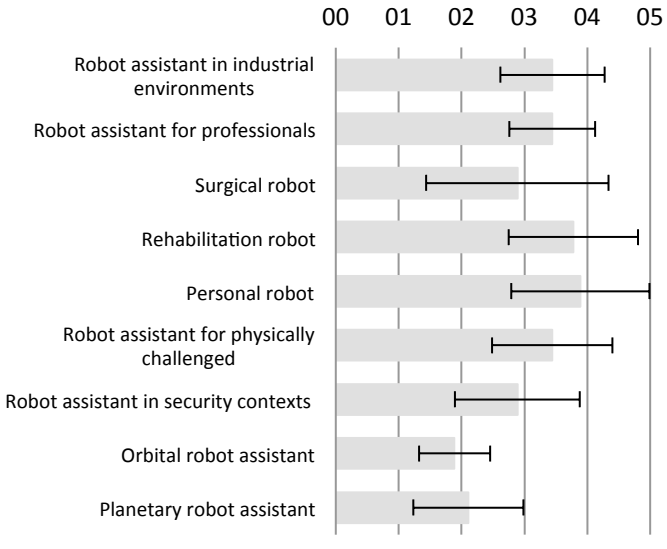
Social Impact

2.2.1 Robotics workers product visions

Mean and Standard Deviation



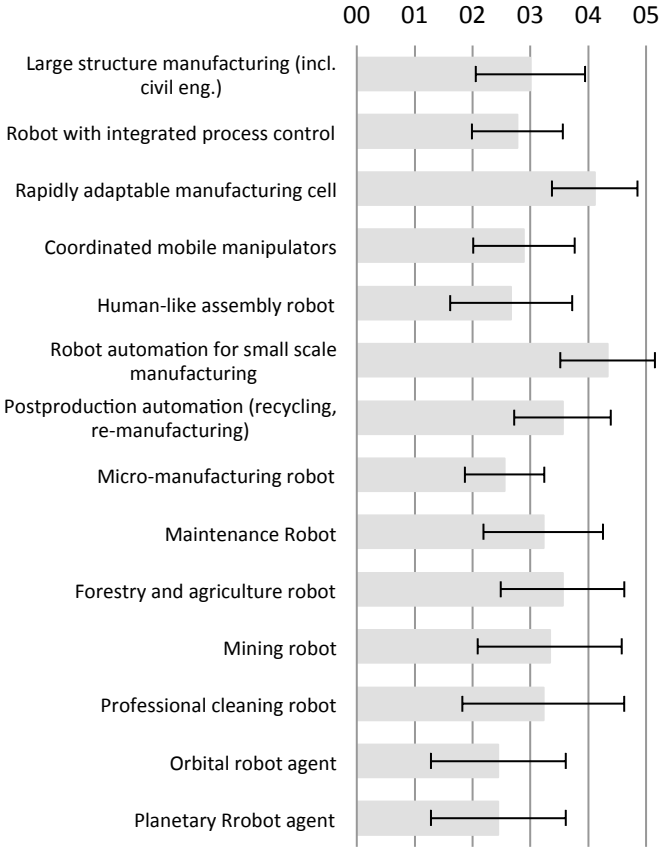
2.3.1 Robotics co-workers product visions



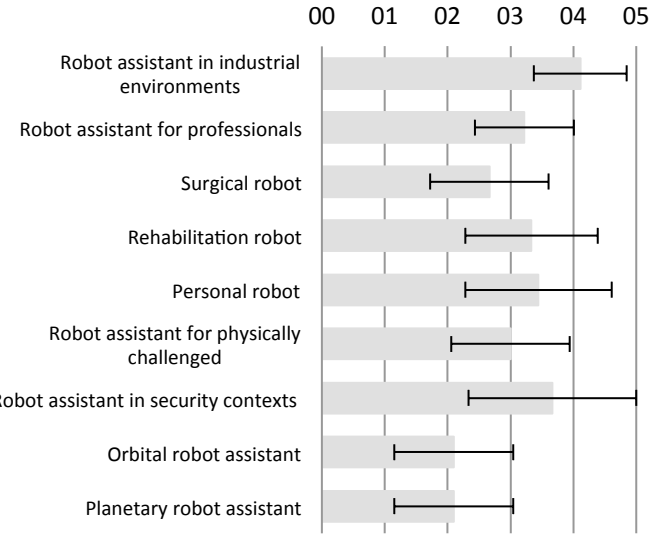
Economic Impact

2.2.2 Robotics workers product visions

Mean and Standard Deviation



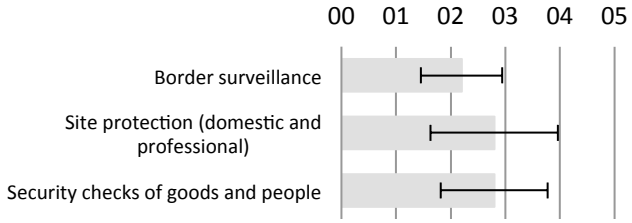
2.3.1 Robotics co-workers product visions



Social Impact

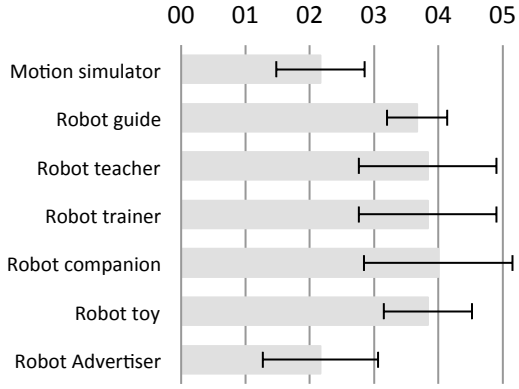
2.4.1 Robots for exploration & inspection product visions

Mean and Standard Deviation

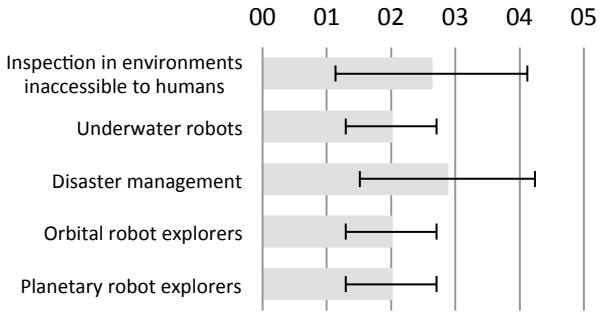


2.5.1 Logistics robots product visions

2.6.1 Edutainment Robots product visions



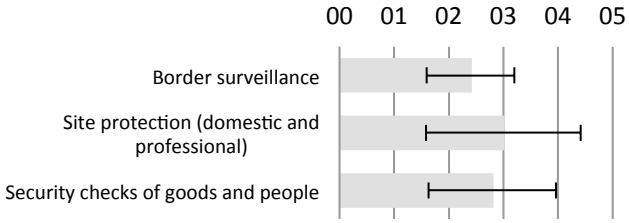
2.7.1 Robot for surveillance & intervention product visions



Economic Impact

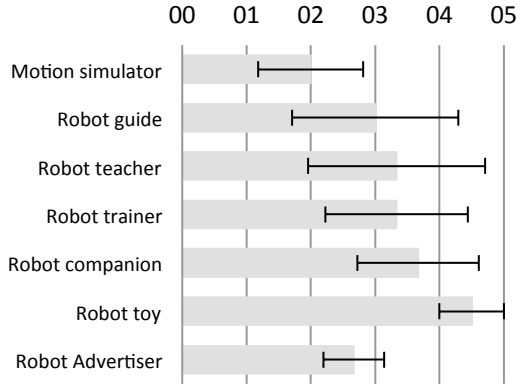
2.4.2 Robots for exploration & inspection product visions

Mean and Standard Deviation

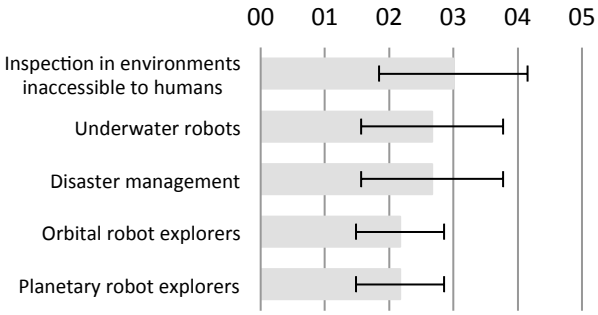


2.5.2 Logistics robots product visions

2.6.2 Edutainment Robots product visions



2.7.2 Robot for surveillance & intervention product visions



7 Annex 3

Results of delphi query

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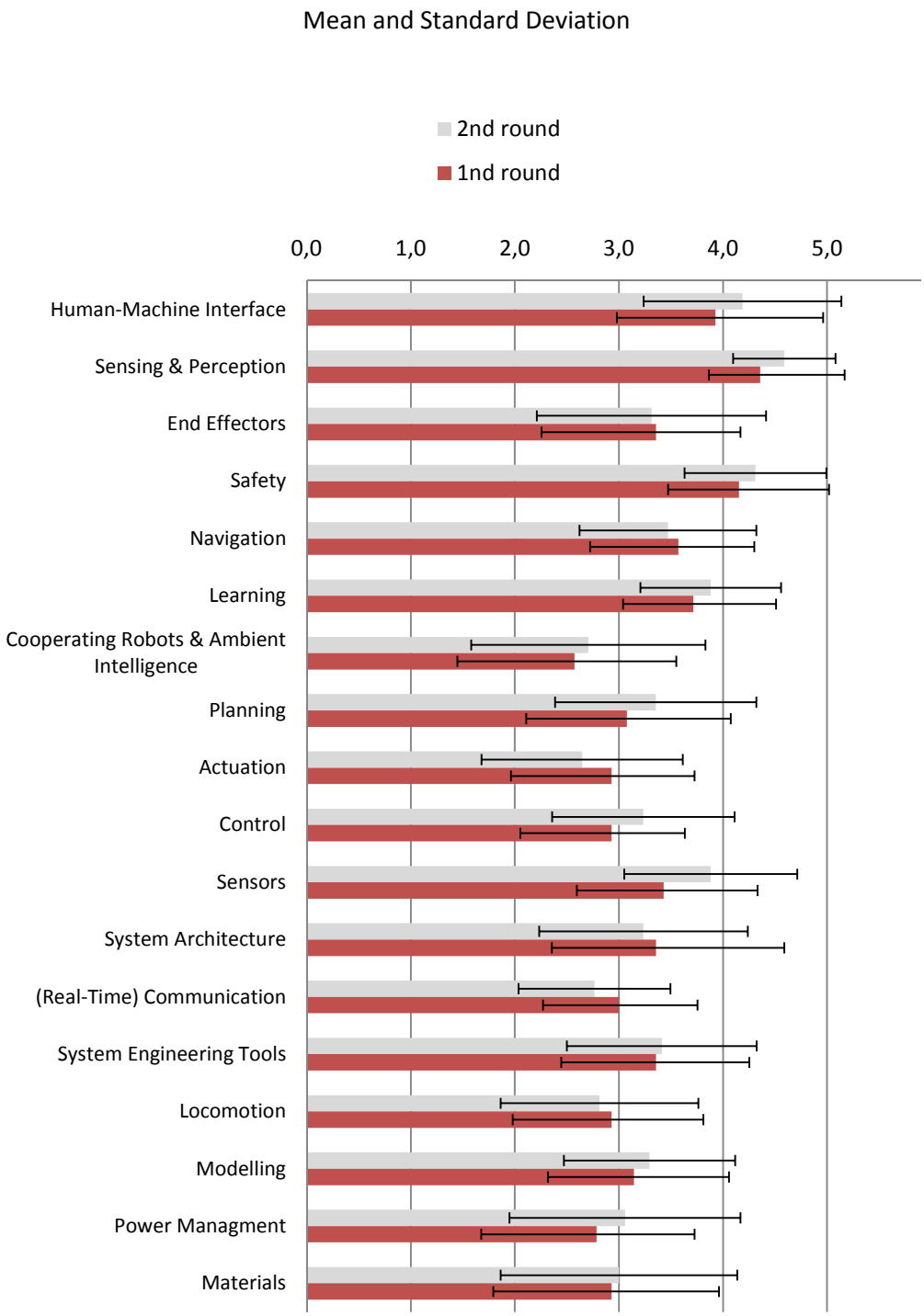
ECHORD Workshop at IROS 2011 - Experts Delphi Query

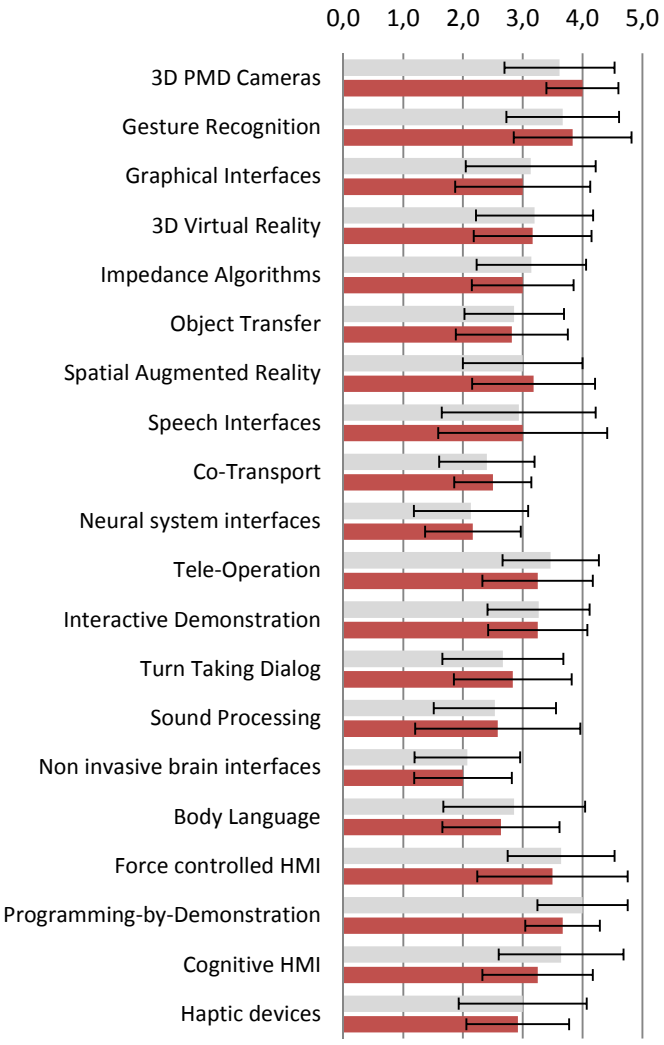
Results from 1nd and 2nd round

1.1 Technologies

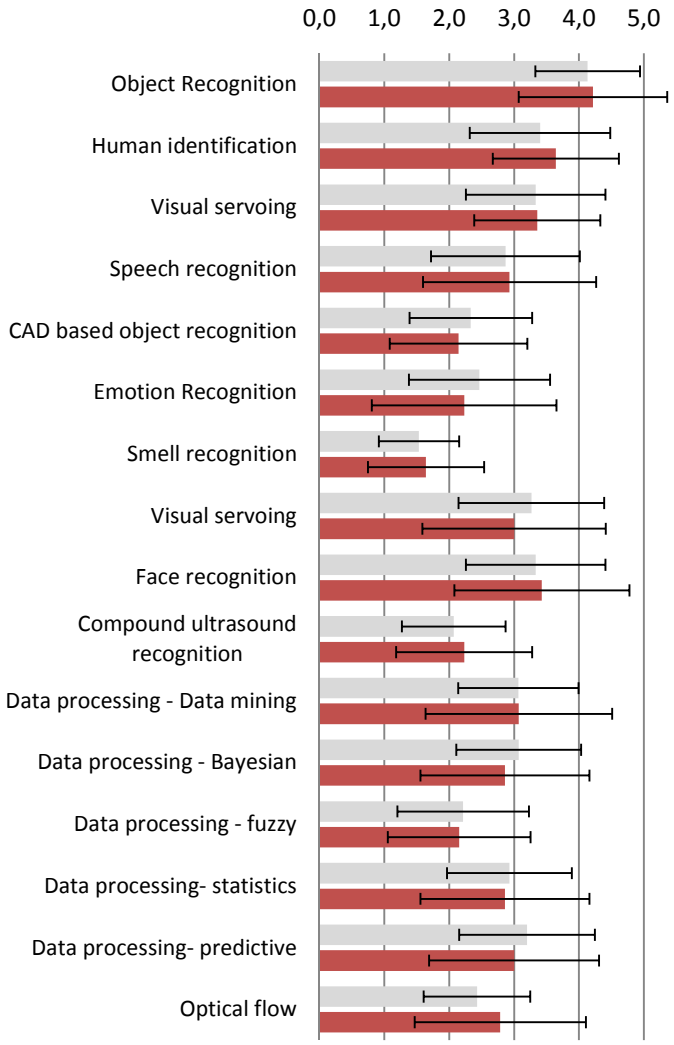


Sub-Topics

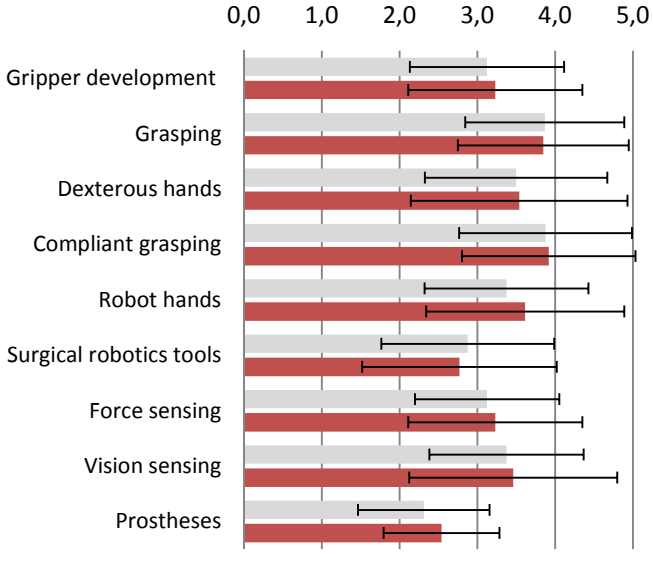
1.2 Human-Machine Interface sub-topics



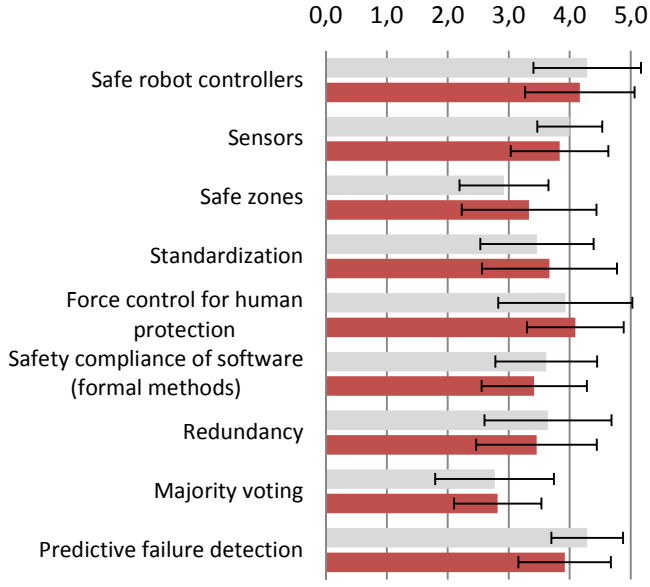
1.3 Sensing & Perception Sub-topics



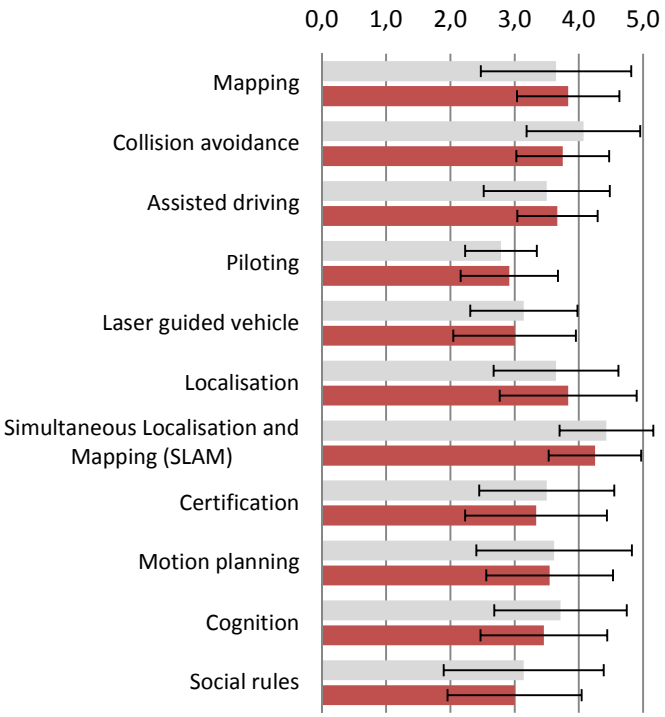
1.4 End Effectors sub-topics



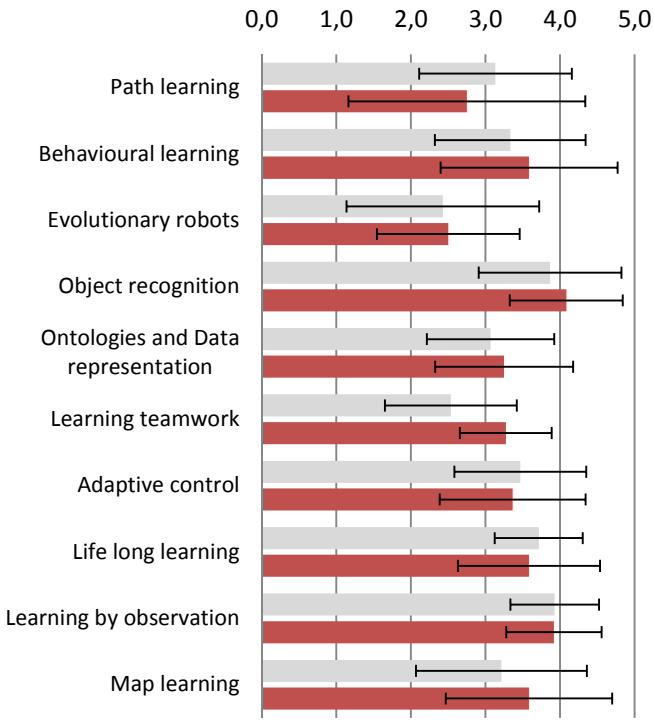
1.5 Safety sub-topics



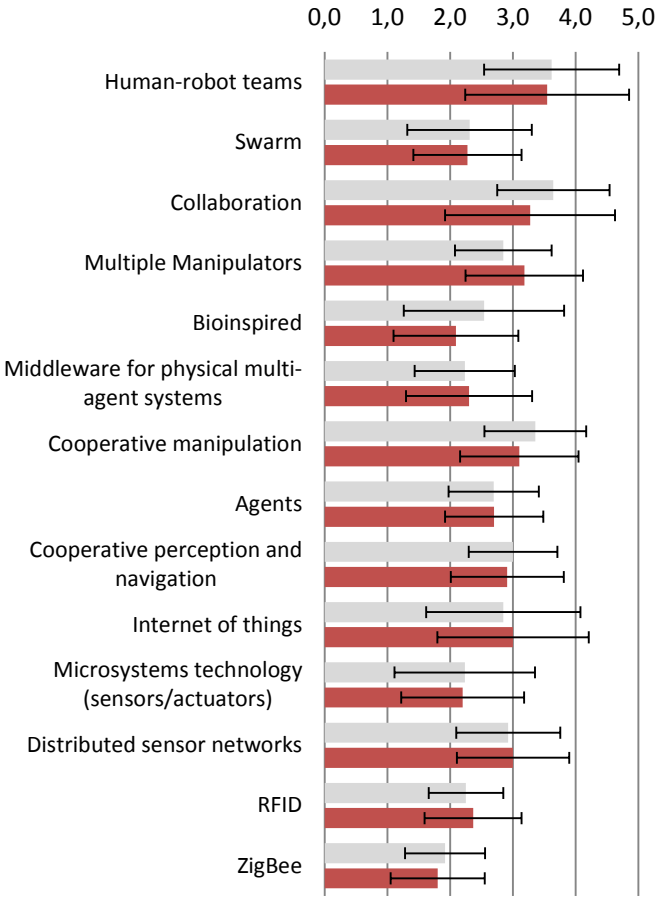
1.6 Navigation sub-topics



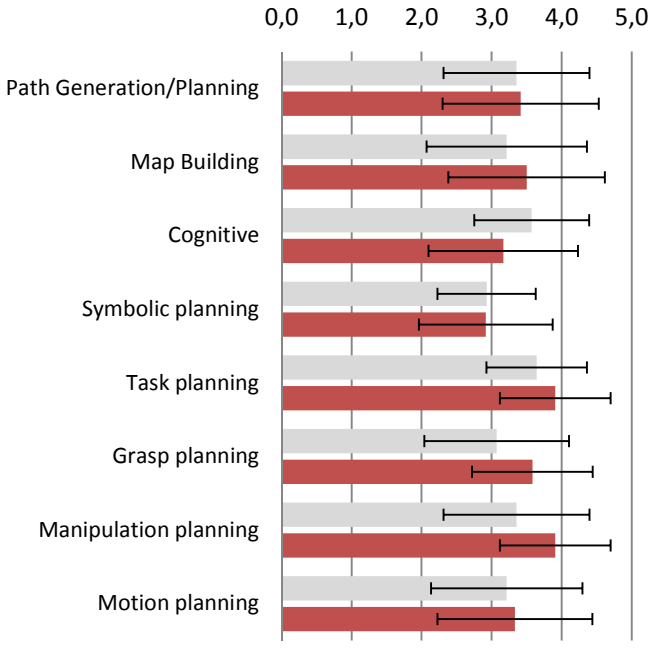
1.7 Learning sub-topics



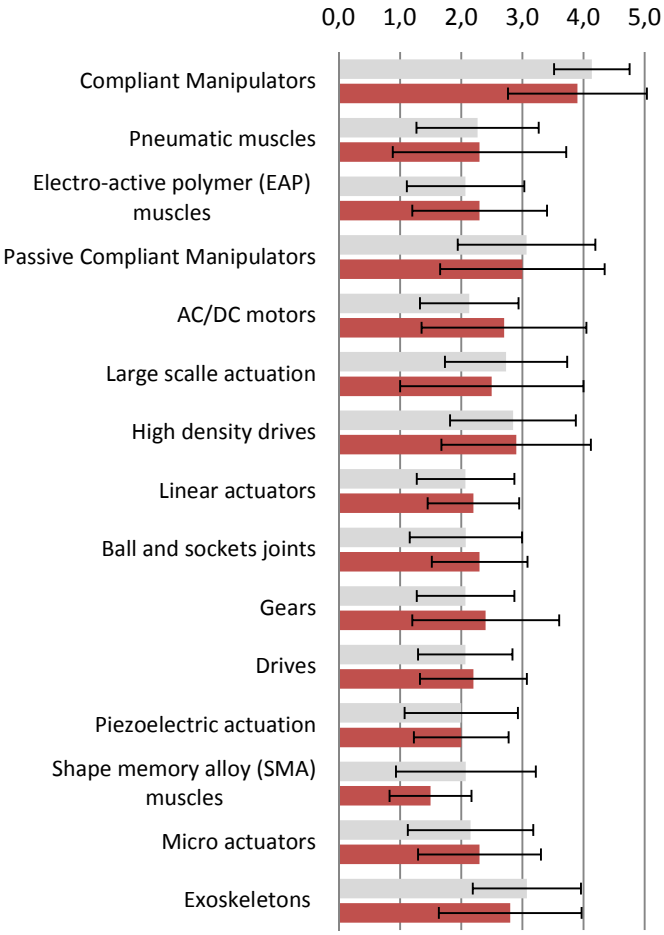
1.8 Cooperating Robots & Ambient Intelligence sub-topics



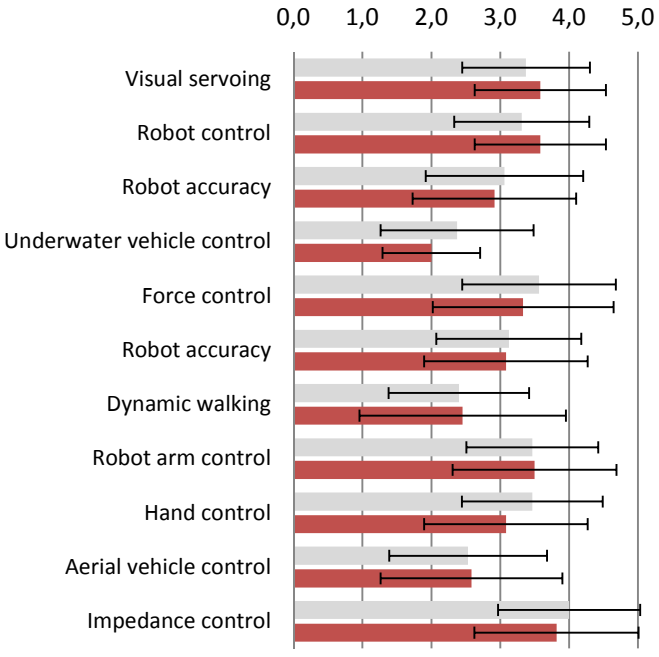
1.9 Planning sub-topics



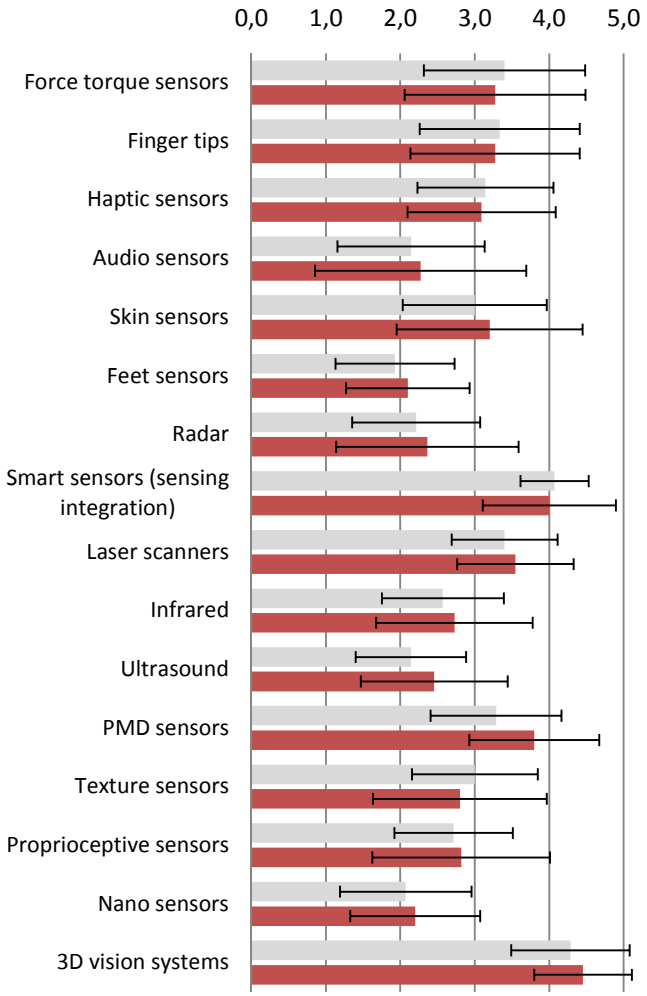
1.10 Actuation sub-topics



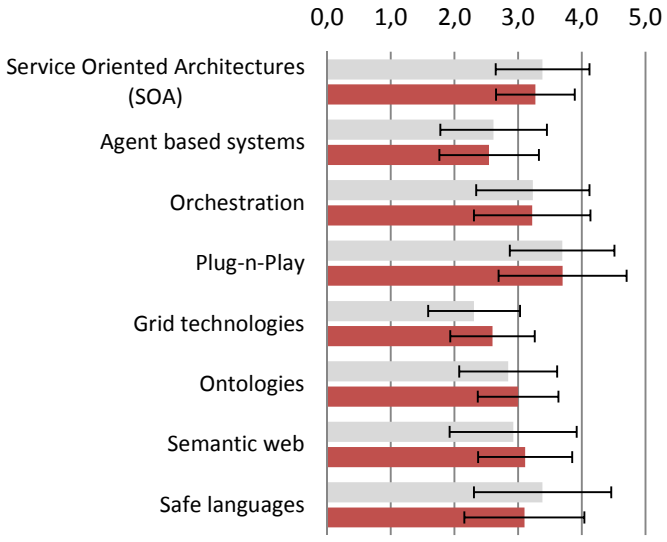
1.11 Control sub-topics



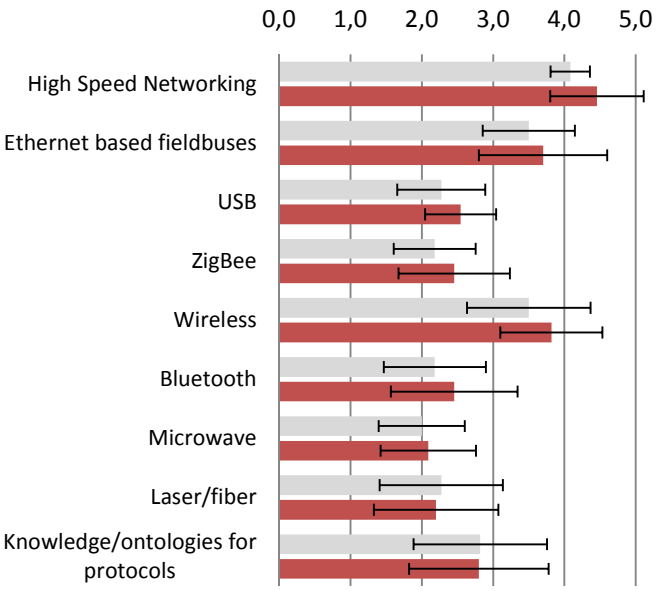
1.12 Sensors sub-topics



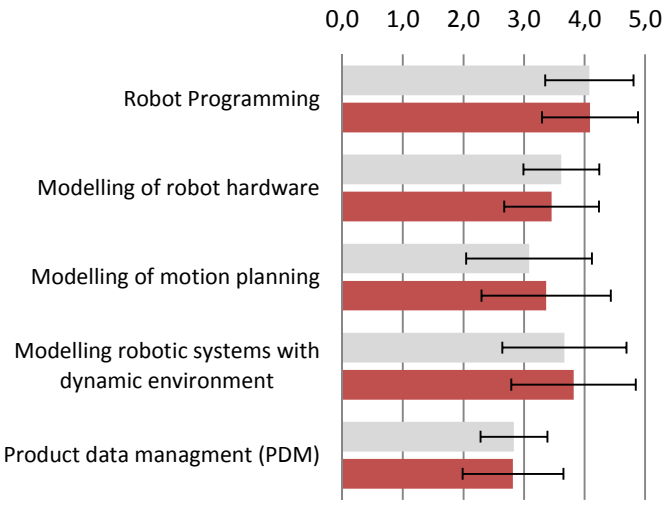
1.13 System Architecture sub-topics



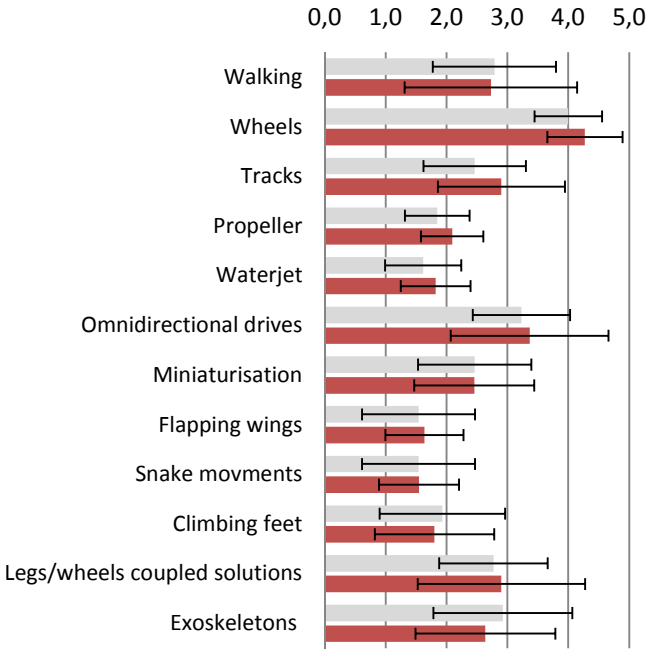
1.14 (Real Time) Communication sub-topics



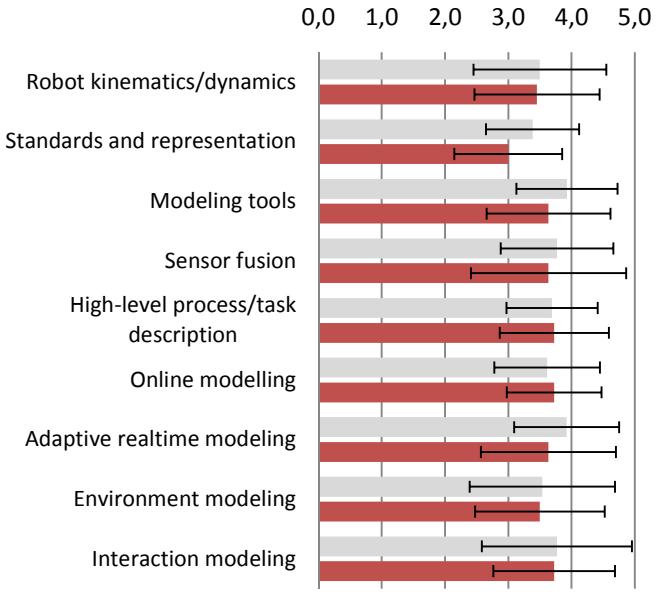
1.15 System Engeneering Tools sub-topics



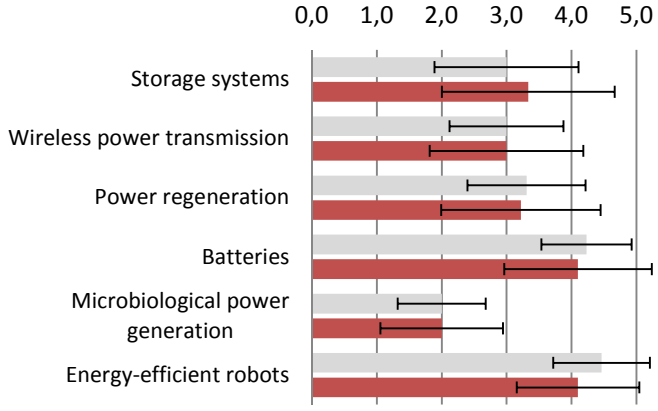
1.16 Locomotion sub-topics



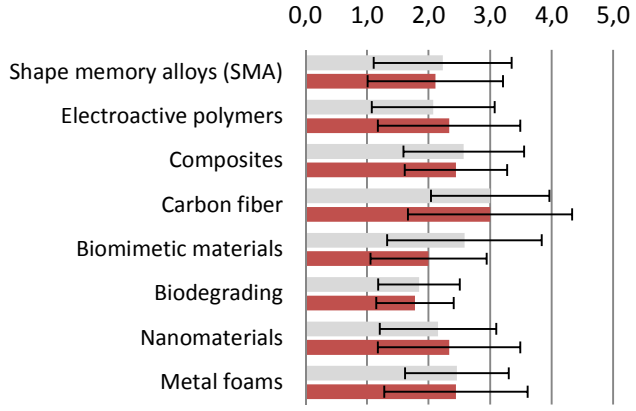
1.17 Modelling sub-topics



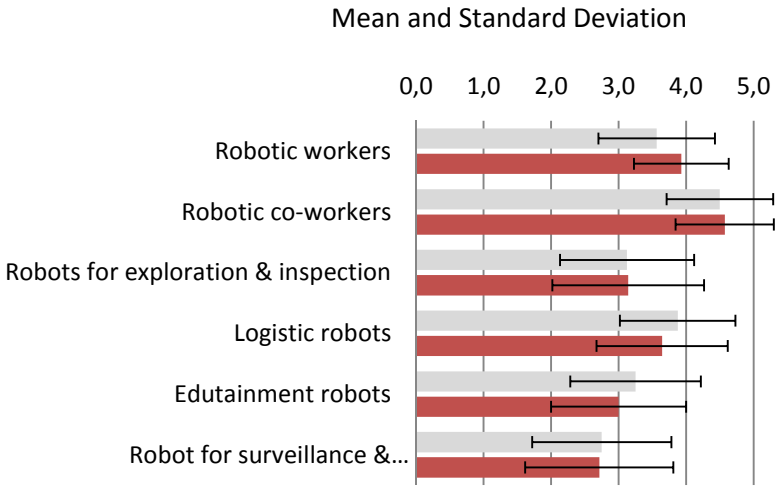
1.18 Power Management sub-topics



1.19 Materials sub-topics



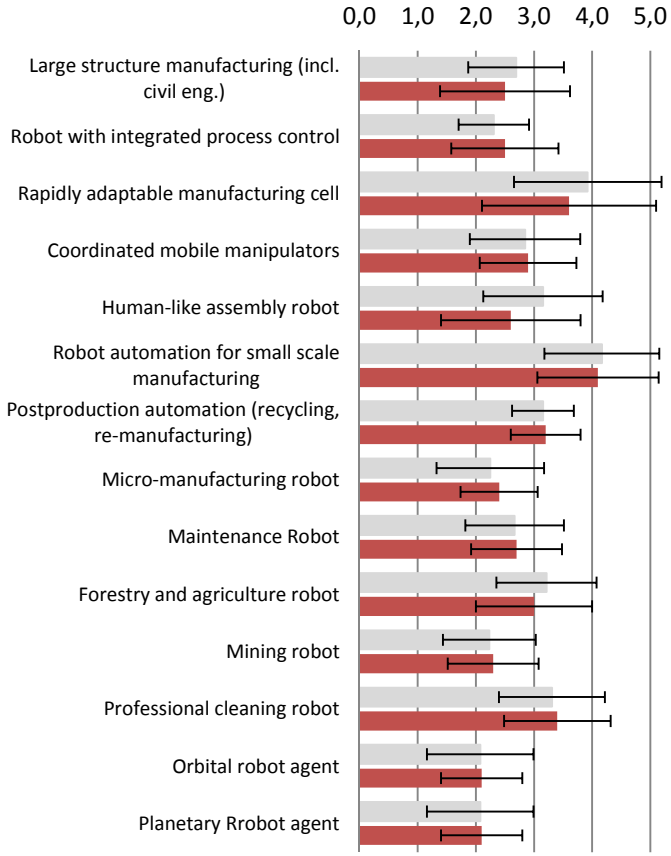
2.1 Application Scenarios



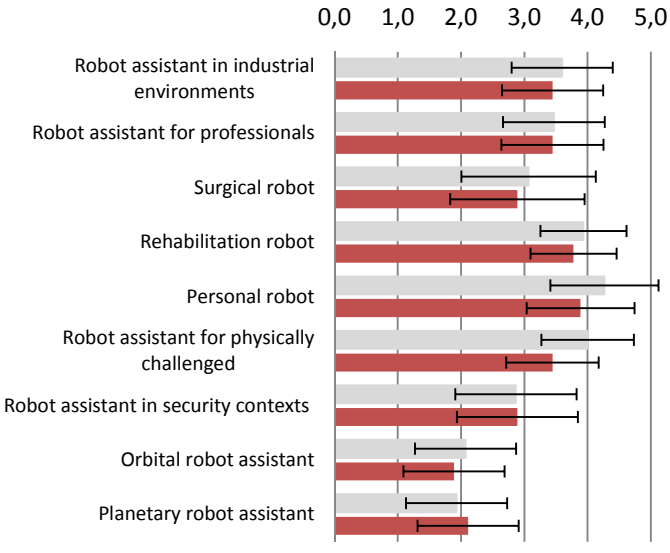
Social Impact

2.2.1 Robotics workers product visions

Mean and Standard Deviation



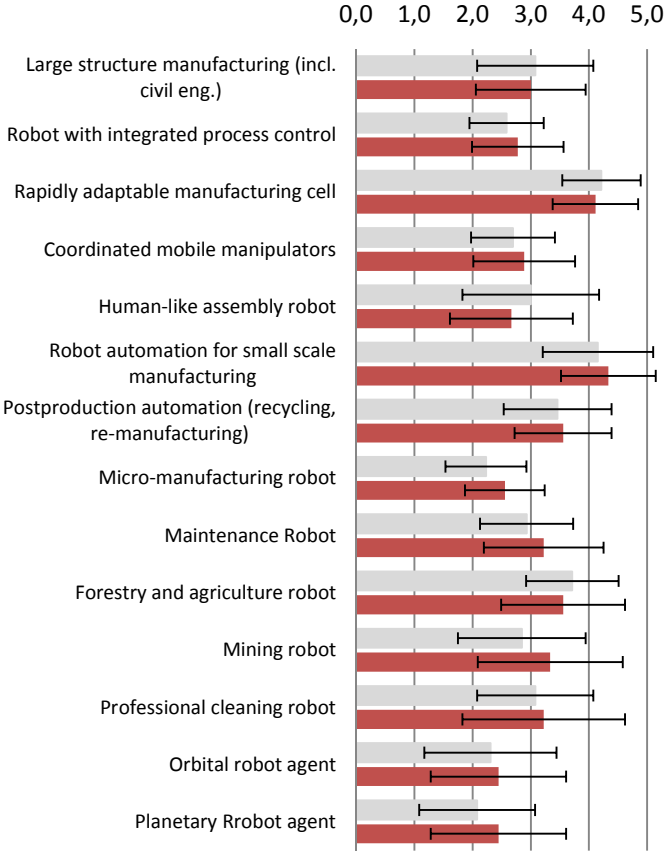
2.3.1 Robotics co-workers product visions



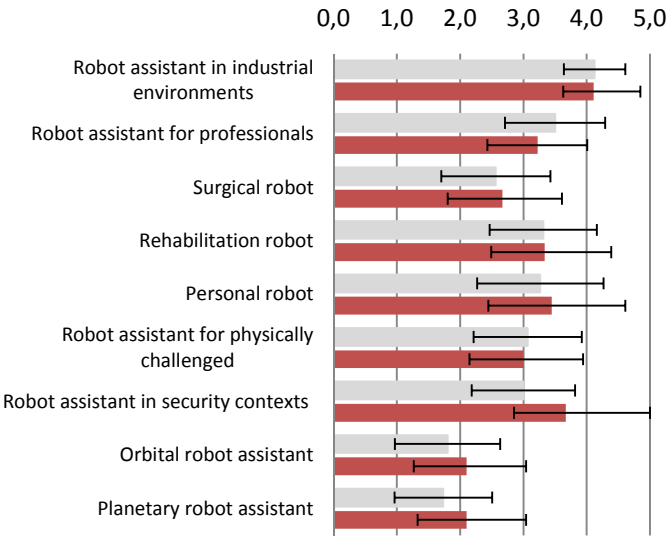
Economic Impact

2.2.2 Robotics workers product visions

Mean and Standard Deviation



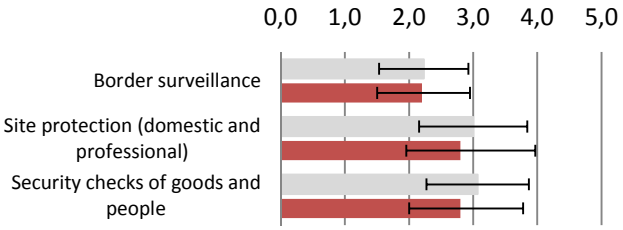
2.3.2 Robotics co-workers product visions



Social Impact

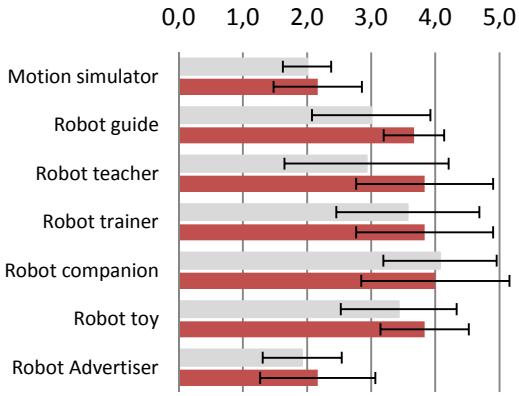
2.4.1 Robots for exploration & inspection product visions

Mean and Standard Deviation

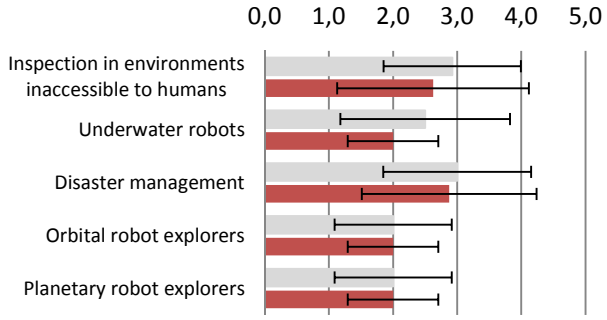


2.5.1 Logistics robots product visions

2.6.1 Edutainment Robots product visions



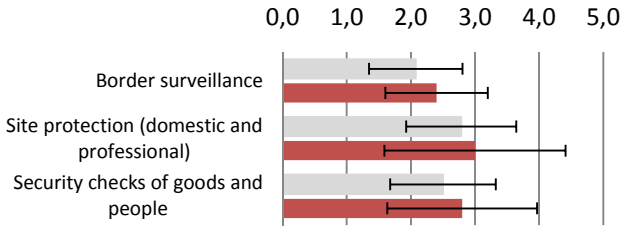
2.7.1 Robot for surveillance & intervention product visions



Economic Impact

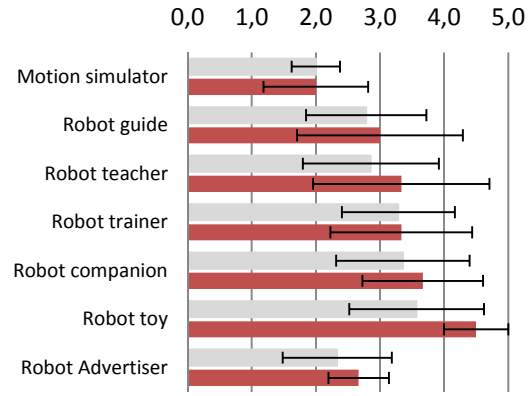
2.4.2 Robots for exploration & inspection product visions

Mean and Standard Deviation



2.5.2 Logistics robots product visions

2.6.2 Edutainment Robots product visions



2.7.2 Robot for surveillance & intervention product visions