FH AACHEN
UNIVERSITY OF APPLIED SCIENCES

Robots: Challenges, Chances and Risks for Solving 21st Century Problems

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Robot

(Definition from Encyclopædia Britannica)

Robot, any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner. By extension, robotics is the engineering discipline dealing with the design, construction, and operation of robots.

The concept of artificial humans predates recorded history (see automaton), but the modern term robot derives from the Czech word robota (“forced labour” or “serf”), used in Karel Čapek’s play R.U.R. (1920). The play’s robots were manufactured humans, heartlessly exploited by factory owners until they revolted and ultimately destroyed humanity. Whether they were biological, like the monster in Mary Shelley’s Frankenstein (1818), or mechanical was not specified, but the mechanical alternative inspired generations of inventors to build electrical humanoids.

European R&D Agenda for Robotics

Strategic Research Agenda For Robotics in Europe 2014–2020

“From today’s € 22bn worldwide revenues, robotics industries are set to achieve annual sales of between € 50bn and € 62bn by 2020.”

`http://www.eu-robotics.net/cms/upload/PPP/SRA2020_SPARC.pdf`

Robot types:

- Consumer Robots
- Civil Robots
- Commercial Robots
- Logistics and Transport Robots
- Military Robots

Forms of robots:

- Robot Arms
- Robot Platforms
- Exo-skeletal robots
- Metamorphic robots
- Nano and Micro Robots
- Humanoid

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Application Scenarios:

- Manufacturing
- Healthcare
- Agriculture
- Civil
- Commercial
- Logistics and Transport
- Consumer

Functions:

- Assembly
- Surface Process
- Interaction
- Exploration
- Transporting
- Inspection
- Grasping
- Manipulation

Mobile Robotics

Why robots?

Robots can perform tasks that are too dangerous, hazardous, annoying or expensive.

Robin Murphy put it this way: Robots are good for performing 3d (dull, dirty, dangerous) tasks

Some examples:

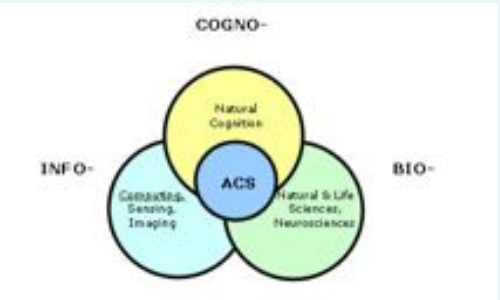
Eldery Care

Surveillance

Auton. Driving

Autonomous Intelligent Systems

Artificial Cognitive Systems



6th Framework Programme, EU,

http://cordis.europa.eu/ist/cognition/index.html

- Interpret information, acquire sensors
- act purposefully and autonomously towards achieving goals

Autonomous und intelligent (George Bekey, 2005)

- Autonomous robots act in real-world scenarios over extended periods of time without any form of external control
- Intelligent robots are machines that sense, think and act.

As a side note: what the heck is *Cognitive Robotics*?

Definition

Robots/agents perceive their environment through their sensors and interact with it by performing actions

The field of Cognitive Robotics studies problems of knowledge representation and planning of robots that act in dynamic and partially-known environments.

AI and robotics research fields:

- Knowledge representation
- Planning
- AI methods
- Human-machine interaction
- Agent architectures

A Word about Myself

- 1994–2001: Studies of Computer Science at RWTH Aachen, Germany
- 2001–2007: PhD student at RWTH Aachen
- 2006: First visit to SA, INSITE 2006 in Sandton
- 2007: Research Visit at CSIR, help launching the RoboCup project in SA
- 2009–2011: Post-doc at UCT with an AvH fellowship
- 2011–today: Professor for Robotics at FH Aachen

Outline

- Introduction
- Area I: Assistive Robots
- Area II: Autonomous Driving
- Area III: Urban Search and Rescue Robots
- Area IV: Robots for Future Automation
- Summary: Challenges, Chances and Risks

Getting Started:
Feature “AwesomeRobotics 2014”

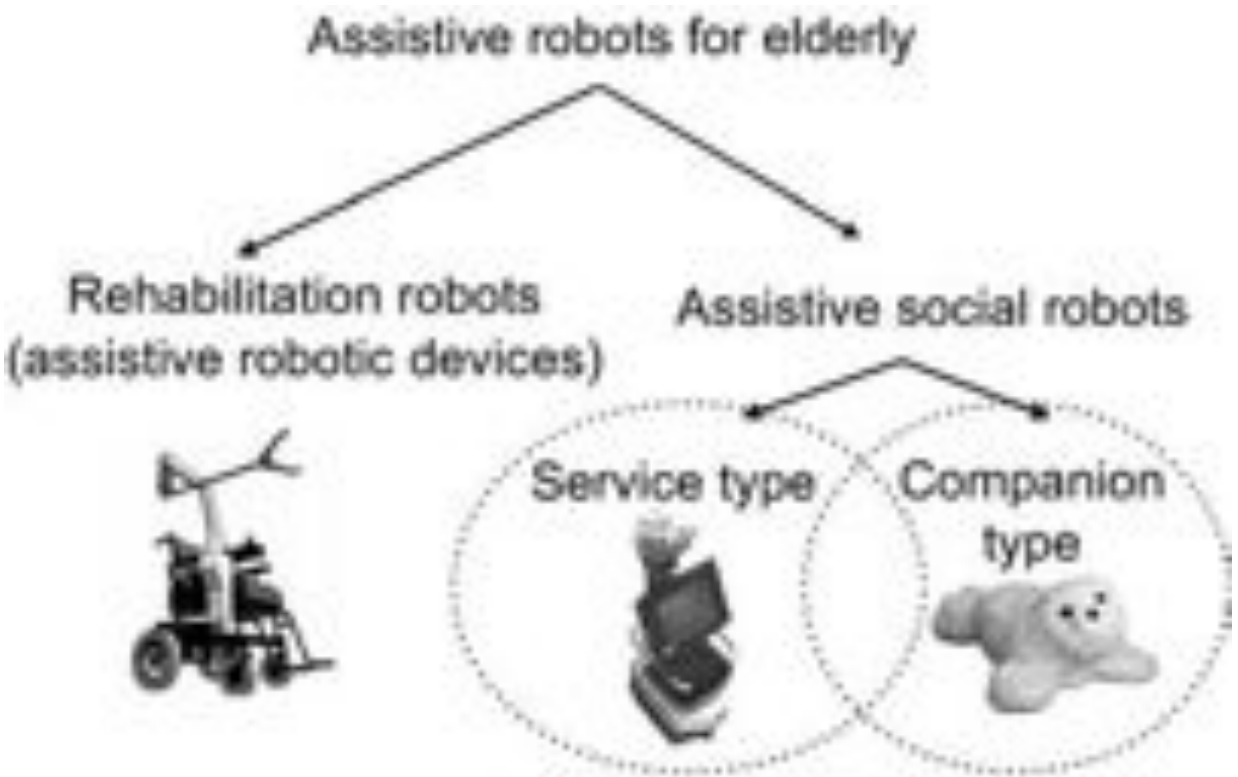
by Enno Düllberg

Assistive Robots

Application Areas for Assistive Robots

- (Elderly) care vs. social participation
- Monitoring vital functions
- Smart homes
- Robot helpers with memo or motivation functions (remind to take medicine etc.)
- Support for handling tasks
- Intelligent prothetics/orthetics
- Intelligent user devices
- . . .

Robots in Elderly Care



from: (Broekens et al., 2009)

Rehabilitation Robot Projects

Fig. 53.4 Wheelchair manipulator robot MANUS developed at the Rehabilitation R&D Center, Hoensbroek, and marketed by Exact Dynamics (The Netherlands)

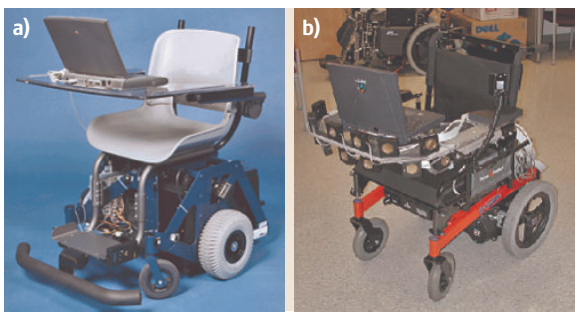
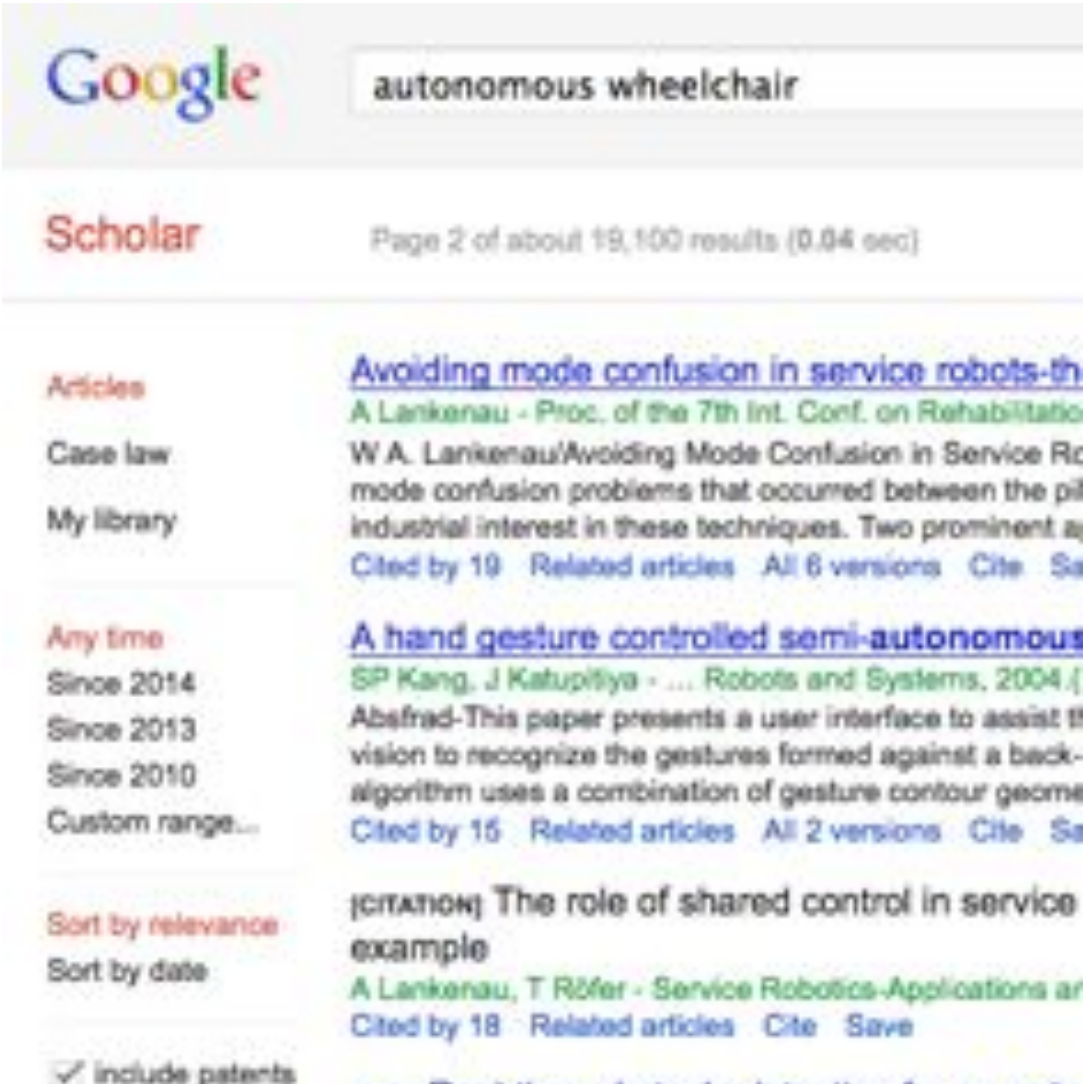


Fig. 53.5a,b Wheelchair navigation aids: **(a)** Wheelesley and **(b)** Hepahaestus

from : (Siciliano & Khatib, 2008)



Assistive Robot Examples

Figure 2. Assistive social robots; (a) Aibo, (b) Pearl, (c) Robocare with screen, (d) Robocare without screen, (e) Care-o-bot I, (f) Care-o-bot II, (g) Care-o-bot III, (h) Homie, (i) iCat, (j) Paro and (k) Huggable

from (Broekens et al. 2009)

Smart (Nursing) Homes

from: (Böhm et al., 2003)

- Equip home environments with sensors and actuators
- Introduce monitoring and assistive functionalities
- Monitor vital functions by sensor implants

Participation in Social Life at Home

from: http://www.wired.com/2014/01/safety-self-driving-car/

- S. Thrun @ World Economics Forum 2014 on his vision of self-driving cars
- Increasing the mobility of elderlies leads to social participation
- Introduce novel mobility concepts

Autonomous Driving

The Google Driverless Car Project

- Google Driverless Car Project recruited researchers from the DARPA Grand Challenge
- As of 2014, Google managed 700,000 autonomous miles
- Nevada, Florida, California, and Michigan allow autonomous cars on their roads

Other Car Makers won’t leave it all to Google . . .

- Autonomous concept car by Mercedes-Benz
- Audi drives autonomously on race tracks
- Germany decides on test track for self-driving cars
- Honda, Nissan, And Toyota team up on self-driving car

While this seems visionary, Mercedes (and others) launch autonomous trucks

The DARPA Challenges

- 2004 + 2005, Grand Challenge: Drive 170 miles autonomously through the Mohave Desert
- 2007 Urban Challenge: Autonomous Driving in an urban enviroment
- 2013–today, Robotics Challenge: Deploy a humanoid robot for disaster response

Video: `https://www.youtube.com/watch?v=w222KFAiMQc`

Urban Search and Rescue Robots

Tasks of USAR Robots

from: Handbook of Robotics, Springer, 2008

- USAR deals with robot systems that support first responders in disaster scenarios
- Identify victims and survivors under rugged and dangerous conditions
- Gather intelligence on the extend of the disaster site and hazardous spots
- Deployment of UGVs, UAVs and ROVs

Real Deployment Example of USAR Robots at 2012 Earthquake in Italy

- NIFTI (Natural Human-Robot Cooperation in Dynamic Environments) is a large-scale EU project (6.7 Mill. EUR) about USAR robots
- Project goals: “NIFTi focuses on tasks in Urban Search & Rescue. Human-robot teams work together to explore a disaster area, to assess the situation, locate victims.”
- After the Emiglia-Romagna earthquake in 2012, the NIFTI was called in to report on safety of structures

Inside Fukushima Power Plant

from: http://www.popularmechanics.com/

from: http://spectrum.ieee.org

- Very harsh and hostile environment
- Several USAR robots inspected the Fukushima power plant
- TEPCO lost an inspection robot last month

USAR in Education: RoboCup Rescue

- Goal: “*Develop and demonstrate advanced robotic capabilities for emergency responders using annual competitions to evaluate, and teaching camps to disseminate, best-in-class robotic solutions*”
- NIST provides standardized environment
- Main tasks: locomotion, mapping, object detection

Robots for Future Automation

The RoboCup Logistics League and the Carologistics RoboCup Team

- The RoboCup Logistics League aims at fostering logistics scenarios in smart factory environments
- Teams of robots keep track of producing correct orders in time and resources
- Automated referee box keeps track of the scores
- Further infos at `http://carologistics.org`

Cyber-Physical Systems and the 4th Industrial Revolution

- Cyber-Physical systems will be predominant in future work settings: “Internet of Things”
- Communication ability will “things” allows to exchange information
- Massive amounts of data needs to be processed (big data).

Example 1 – Aftersales markets: A generator turbine will call inspection staff before it breaks down.

Example 2 – Manufacturing: In future smart factories products will know how they are to be machined, leading to a more flexible production.

Example 3 – Environmental monitoring/Infrastructure management: Monitoring water or air quality and finding leaks in the sewer early leads to better living conditions.

Caveat:

It might sound like the Brave New World. Think of the risks!

KIVA robots

- Hundreds or thousands of *robotic drive units* cruise through a warehouse
- Mobile Inventory shelves (pods) are carried by the bots to the pick worker
- Kiva: good-to-person solution
- Kivarobotics will be called amazonrobotics soon.

Fetch and Freight by Fetch Robotics

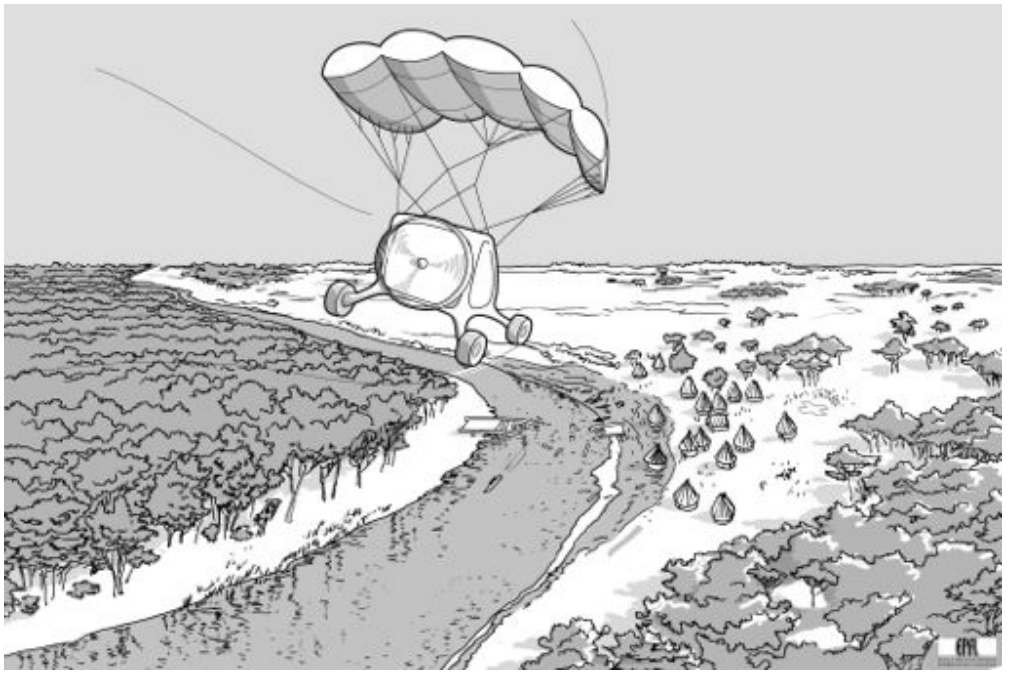
http://spectrum.ieee.org

- Same application as Kiva but different approach
- Robots do the pick and place in the warehouse
- While the Kiva system is a large-scale solution, this one has to prove useful

Delivery UAVs

The service will use an autonomous quadcopter to deliver small parcels to the German island of Juist, a sandbar island 12km into the North Sea from the German coast, inhabited by 2,000 people. Deliveries will include medication and other goods that may be “urgently needed”. http://www.theguardian.com/technology/2014/sep/25/german-dhl-launches-first-commercial-drone-delivery-service

The Flying Donkey Project



- Objective: “*Flying donkeys are cargo drones with rugged air frames capable of lifting suitcase loads over long distances. The first commercial flying donkeys, due in Africa by 2020, will carry at least 20 kilos over 50 kilometres in less than one hour.*”
- `http://www.flyingdonkey.org/`

Summary: Challengens, Chances and Risks

Technological Challenges

according to the European Strategic Research Agenda

- Configurability
- Adaptability
- Interaction Ability
- Perception Ability
- Dependability
- Motion Ability
- Manipulation Ability
- Decisional Autonomy
- Cognitive Ability

Technological Challenges (cont'd)

according to the European Strategic Research Agenda

(Manufacturing) ▸ Accurate indoor positioning systems for mobile manipulators particularly in dynamic environments ▸ Sensor based safety systems to enhance human robot interaction ▸ Higher levels of realism in system modelling to speed application development ▸ Reactive planning and control able to operate a robot safely in real industrial environments. (Healthcare) ▸ Improved teleoperation and physical interaction ▸ Miniaturised mechanical systems and sensing ▸ Multiple degree of freedom tactile feedback ▸ Inherently safe systems ▸ Monitoring of patient condition and improved data interpretation during procedures (Agriculture) ▸ Predictive and distributed planning ▸ Crop and livestock assessment and recognition of condition ▸ Produce handling and processing ▸ Synchronisation and coordination between farm vehicles and with processing equipment ▸ In-field localisation and communication

Technological Challenges (cont'd)

according to the European Strategic Research Agenda

(Civil) ▸ Mission and task planning, particularly between multiple modalities ▸ Sensing, perception and interpretation of the environment ▸ Cooperative and distributed planning for multiple robots ▸ Cognitive technologies for assessment and high level interpretation. ▸ Human robot interaction (Commercial) ▸ Safety integrated design processes ▸ Physical human robot interaction ▸ Long term autonomy ▸ Light weight robust mechanical structures (Logistics and Transport) ▸ Interaction technology ▸ Compliant mechanical systems ▸ 3D environment interpretation ▸ Task planning and optimisation (Consumer) ▸ Improved sensing of the surrounding environment ▸ Improved interpretation of the environment ▸ Low cost sensing ▸ Physical human robot interfaces ▸ Improved energy efficient systems.

Ethical Challenges

Some Quotes from: Why the future doesn't need us (B. Joy, 2000)

- "The 21st-century technologies - genetics, nanotechnology, and robotics (GNR) - are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them."
- "In the 21st century, this requires vigilance and personal responsibility by those who would work on [...] GNR technologies to avoid implementing weapons of mass destruction and knowledge-enabled mass destruction."
- "I don't know where these people hide their fear. [...] I am aware of how much has been written about, talked about, and lectured about so authoritatively. But does this mean it has reached people? Does this mean we can discount the dangers before us?Knowing is not a rationale for not acting. Can we doubt that knowledge has become a weapon we wield against ourselves?"

Ethical Challenges

Some Quotes from: Promise and peril (Kurzweil, 2001)

- “On the other hand, how many people in the year 2000 would really want to go back to the short, disease-filled, poverty-stricken, disaster-prone lives that 99 percent of the human race struggled through a couple of centuries ago? We may romanticize the past, but until fairly recently, most of humanity lived extremely fragile lives, in which a single common misfortune could spell disaster.”
- “Abandonment of broad areas of technology will only push these technologies underground where development would continue unimpeded by ethics or regulation. In such a situation, less stable, less responsible practitioners–for example, terrorists–would have a monopoly on deadly expertise.”
- “Technology will remain a double-edged sword, and the story of the 21st century has not yet been written. So, while we must acknowledge and deal with the dangers, we must also recognize that technology represents vast power to be used for all humankind’s purposes. We have no choice but to work hard to apply these quickening technologies to advance our human values, despite what often appears to be a lack of consensus on what those values should be.”

Societal Challenges

Some of the most challenging problems for the 21st century is an health, demographic change, to guarantee food security, sustainable agriculture, efficient energy, climate actions or resource efficiency, to name just a few.

Good, but what about the impact of these new technologies for, say, the job market?

AI, Robotics, and the Future of Jobs (Smith & Anderson, 2014)

1. Throughout history, technology has been a job creator—not a job destroyer
2. Advances in technology create new jobs and industries even as they displace some of the older ones
3. There are certain jobs that only humans have the capacity to do
4. The technology will not advance enough in the next decade to substantially impact the job market
5. Our social, legal, and regulatory structures will minimize the impact on employment

from: `http://www.pewinternet.org/2014/08/06/future-of-jobs/`

Legal Challenges

Some Quotes from: Legal Issues with Robots (Kirckpatrick, 2013)

- For example, with vehicle operation, we know [people] cause 93% of all accidents. [...] What is an acceptable level of reliability for autonomous cars? Because if the answer is 99.99%, let's stop now, let's quit investing money, because perfection is not a realistic expectation.
- This has created a scenario in which manufacturers of robots are focused on perfecting their systems for 100% reliability, which would, in effect, make liability a non-issue.
- [...] the only way open source robotics will see support from manufacturers is if they develop some sort of framework to codify acceptable robot behavior, and create a method for indemnifying upstream suppliers of hardware and software from potential liabilities.

- Who will be held liable for damages?
- Who will be responsible for/owns all the data acquired?
- Can we (humans) live with (cold) rational decisions?

Robotics Activites in SA (not comprehensive)

Some Activities at tertiary institutions

- RobMech Conference
- CSIR: MIAS, MSM or the Meraka Institute
- UCT: The Robotics and Agents Research Lab
- NMMU: Mechatronics in an automotive context
- UKZN: Mechatronics and Robotics Research Group (manufactuing, search and rescue, bio-engineering)
- RoboCup activities between 2008–2012: US, UCT, UKZN, UP

Sparking interest below university level:

- Robotscience at University of Johannesburg's Technolab
- FIRST Lego League Activities
- Sci-Bono (Johannesburg)
- Many small projects throughout the country to interest bright youngsters for technology and science

Relevance for the (South) African Context

- Well-educated technically skilled young people are needed in every economy!
- Find solutions for problems that may not exist somewhere else
- Technological gap between nations becomes smaller
- New production methods (AM, smart factories)
- Lower production costs

List of (random) application areas for robotics in (S)A:

- USAR, EOD
- Prothetics
- Agricultural robotics
- Intelligent water/power supply
- New mobility concepts
- Mining/Mine safety
- Anti-poaching units

In Planning: Robotics Centre SA

Conclusions

- Robotics (and AI) are some of the main drivers for technological progress
- It has been never that easy to devle into robotics, for instance, with open source software middlewares such as ROS
- But, there is a number of risks to be aware of as well

Conclusion 1:
Help more people to a better life with right technology use

Conclusion 2:
Keep in touch with the technology and its implications

Conclusion 3:
Robotics is a great field and you should get involved!

Acknowledgements: T. Booysen, E. Düllberg, S. Schiffer, R. Stopforth

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