KTH ROYAL INSTITUTE
OF TECHNOLOGY

Introduction to Robotics

DD2410

Lecture 1 - Introduction

Course layout

- Schedule
- Topics - People
- Examination
- Robotics
  - Introduction
  - History
  - State of the art
  - Research (RPL and elsewhere)

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Schedule - Lectures

Aug 29 - 1. Intro, Course fundamentals, Topics, What is a Robot, History Applications.

Aug 30 - 2 Manipulators, Kinematics
(Aug 31 - 3 ROS Introduction)
Sep 03 - 4. Differential kinematics, dynamics
Sep 04 - 5. Actuators, sensors I (force, torque, encoders, ...)
Sep 10 - 6. Grasping, Motion, Control

Sep 11 - 7. Behavior Trees and Task Switching
Sep 17 - 8. Planning (RRT, A*, ...)

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Oct 01 - 12. Navigation (how do I get from A to B?)

Schedule - Lab assigments

Aug 31 - 3 ROS Introduction (Sep 7)

Sep 6 - Kinematics (Sep 14, 17:00)

Sep 14 - Planning (Sep 21, 17:00)

Sep 20 - Mapping (Sep 28, 17:00)

Sep 28 - Pick.and-place Project (Oct 12)

Oct 8 - Help session

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Christian Smith
<ccs@kth.se>

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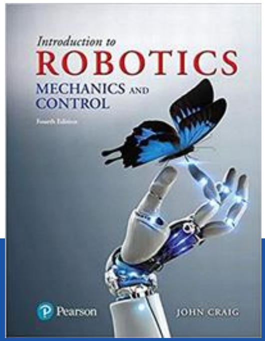
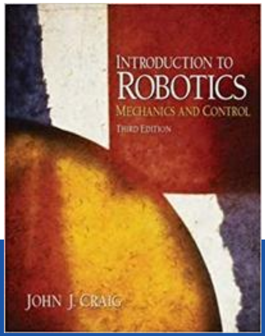
Manipulation

- Springer Handbook of Robotics
  2008, ~1500 pages

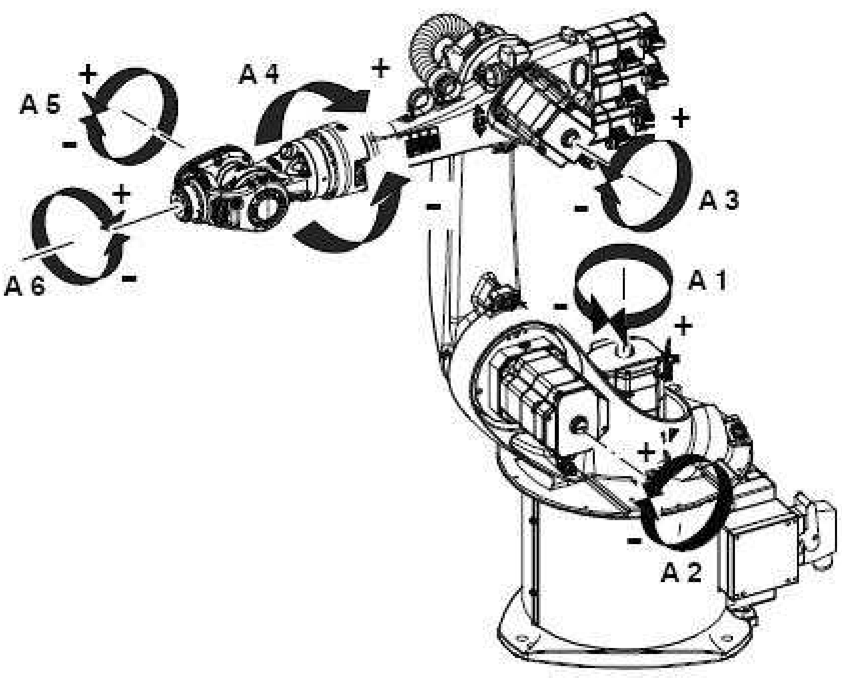
  Available via Springer link (KTH account)

- Introduction to Robotics - Mechanics and Control
  by J.J. Craig

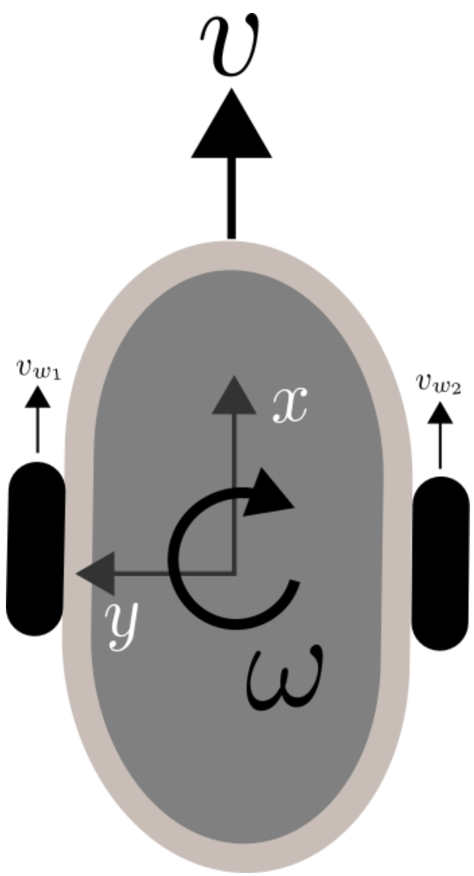




- The functions that maps the robot configuration $\mathbf{\Theta}$ to its pose $\mathbf{X}$
- Forward kinematics
  - $\mathbf{X} = K(\mathbf{\Theta})$
- Inverse kinematics
  - $\mathbf{\Theta} = K^{-1}(\mathbf{X})$
- Differential kinematics
  - $\dot{\mathbf{X}} = \mathbf{J}(\mathbf{\Theta})\dot{\mathbf{\Theta}}$



Differential kinematics - ROS lab



$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix}$$

$$v = \frac{v_{w_1} + v_{w_2}}{2}$$

$$\omega = \frac{v_{w_2} - v_{w_1}}{2b}$$

$$v_{w_i} = \frac{2\pi r f \Delta_{\text{enc}}}{\text{ticks per rev}}$$

Dynamics

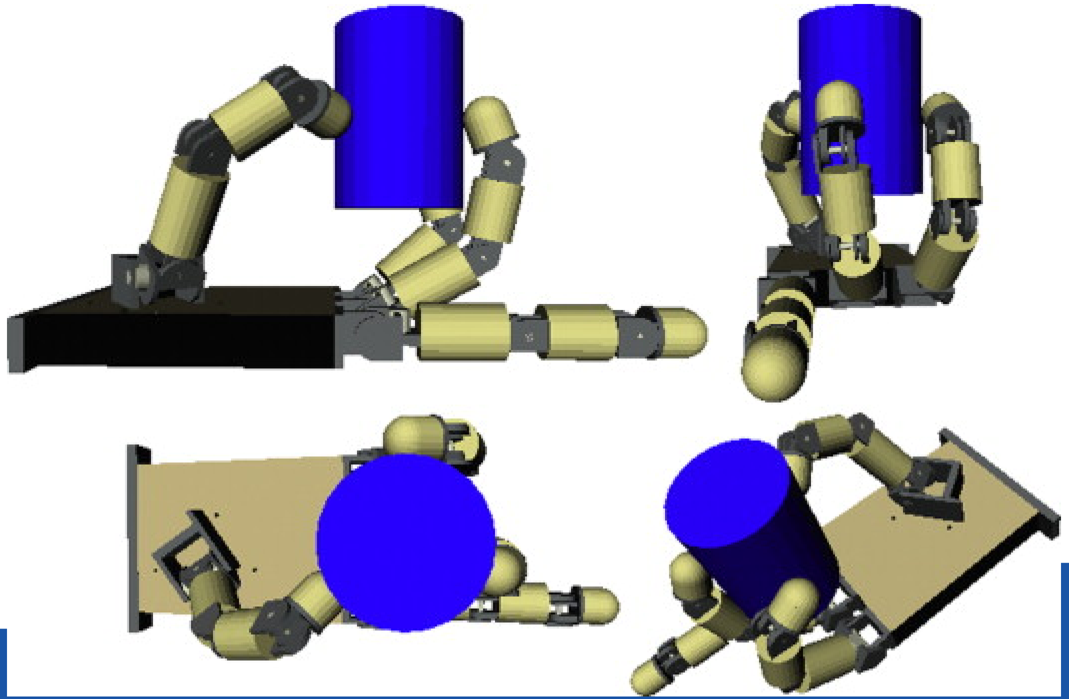
- The functions that maps the changes in robot configuration to applied forces and torques
- General form for articulated robot:

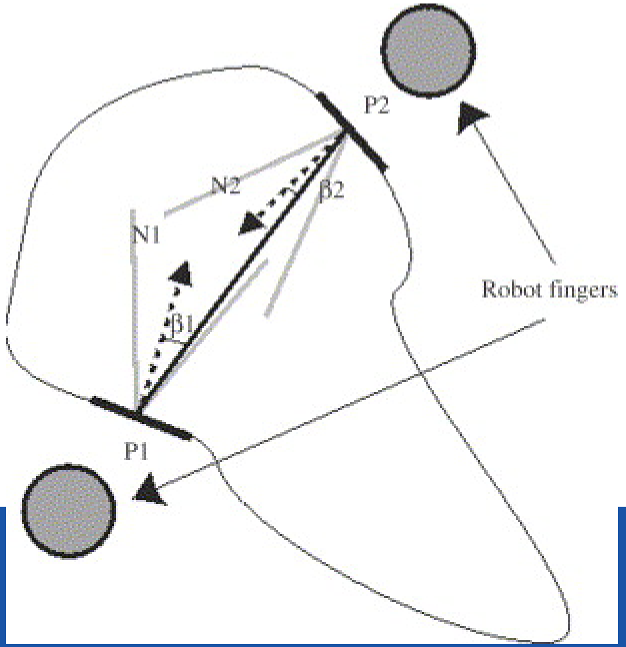
$$\boldsymbol{\tau} = \boldsymbol{H}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{C}(\boldsymbol{q}, \dot{\boldsymbol{q}})\dot{\boldsymbol{q}} + \boldsymbol{\tau}_g(\boldsymbol{q}) + \boldsymbol{J}(\boldsymbol{q})^{\mathrm{T}}\boldsymbol{f}_{ext}$$

Video: Boston Dynamics

Grasping

- The study of how to, given an object and an end effector, generate the necessary end effector configuration to impose limits in the motion (kinematic or dynamic) of the object with regard to the end effector.





Robot motion

- Motion planning
  - Generating a valid path to target configuration
- Control
  - Generating the motor commands necessary to follow a target path

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Petter Ögren
<petter@kth.se>

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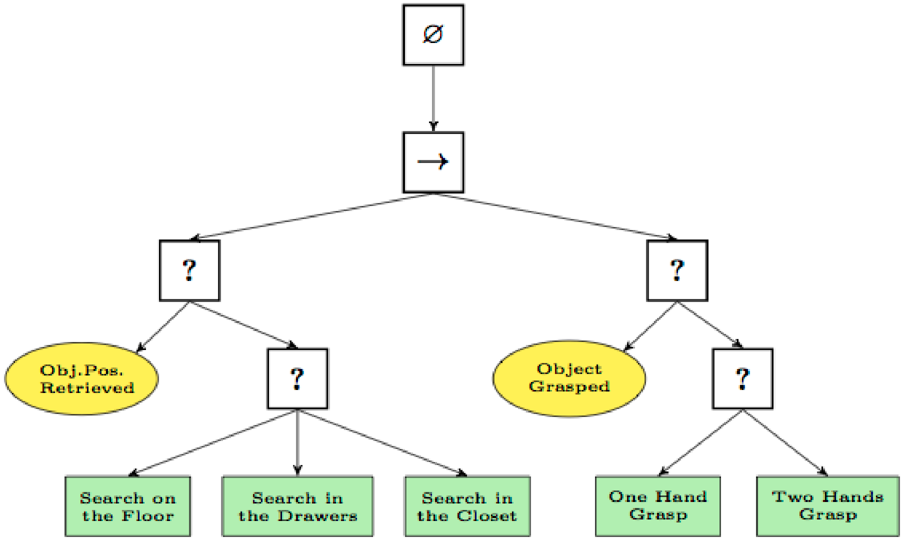
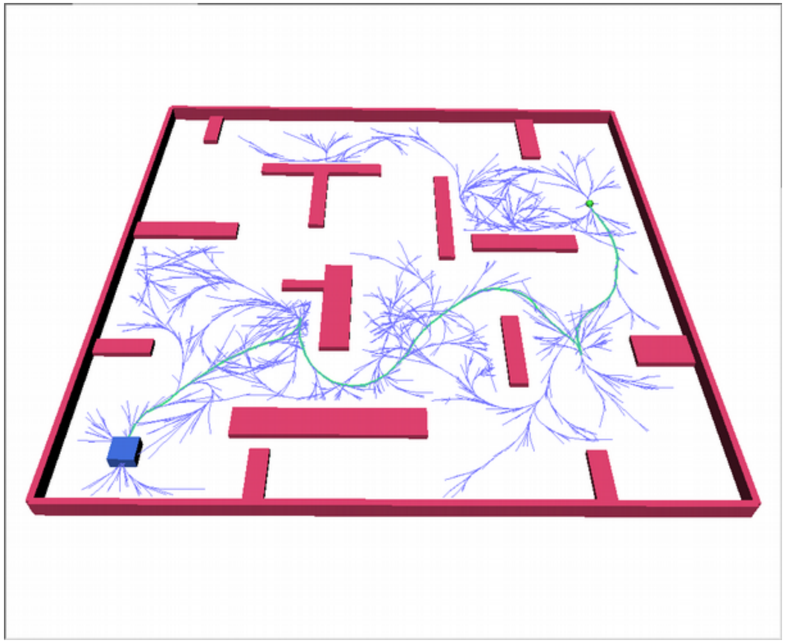
Planning



∅
→
?
?
Obj.Pos.
Retrieved
?
Object
Grasped
?
Search on
the Floor
Search in
the Drawers
Search in
the Closet
One Hand
Grasp
Two Hands
Grasp



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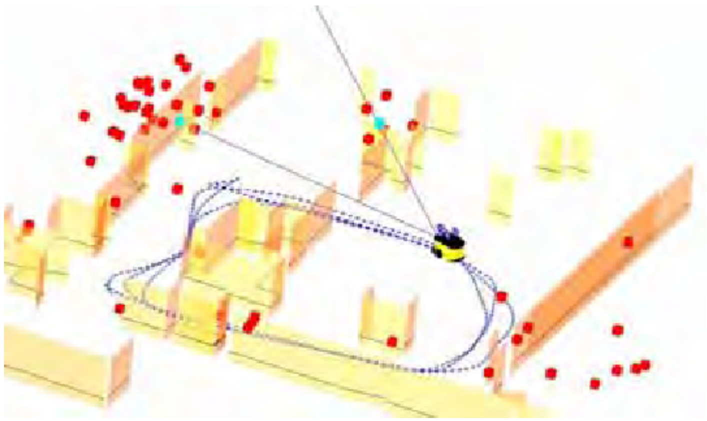
Patric Jensfelt
<patric@kth.se>

- Localization:
  - Finding the pose of a robot given sensor readings
- Mapping
  - Finding the environment model (and object poses) given sensor reading
- SLAM
  - Simultaneous localization and mapping
- Planning
  - Finding a traversable path to a target location

Navigation



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Examination

For result reporting purposes, the course is divided into 2 parts: TEN1 and LAB1.

TEN1 (2.5 ECT credits): This part consists of a written exam, that is graded P/F. Extra points gained from completing quizzes and handing in assignments on time can be added to the score on the exam, and a result of at least 80/100 will suffice to get a passing grade (P).

LAB1 (5 ECT credits): This part consists of 4 smaller assignments and a larger project. This part is graded A-F, and with the successful completion of TEN1, the grade on this part will be the grade given for the entire course.

Examination - Assignments (LAB1)

The first assignment (ROS basics) is graded with P/F, assignments 2-4 (manipulator kinematics, planning, and mapping) are graded with C/E/F, and the project is graded with A/C/E/F.

Assignment 1	Assignments 2-4	Project	LAB1 grade
P	C on all three	A	A
-"-	-"-	C	C
-"-	-"-	E	D
-"-	C on two, E on one	A	B
-"-	-"-	C	D
-"-	-"-	E	E
-"-	C on one, E on two	A	C
-"-	-"-	C	E
-"-	-"-	E	E
-"-	E on all three	A	D
-"-	-"-	C	E
-"-	-"-	E	E

Examination - Assignments (LAB1)

Assignment 1 - (ROS Basics) is graded as P/F. This assignment should be presented to the TA's during regular lab hours. Presentation by Fri 7th of September gives 3 bonus points towards the exam.

Assignments 2-4 - (Kinematics, Planning, and Mapping) are graded as E/C. These assignments are submitted to the Kattis. There are different requirements for the grades E or C, see each assignment for details.

Fulfilling E by the deadlines is awarded with 3 bonus points.

Fulfilling C by the deadlines is awarded with 2 bonus more points.

The maximum possible bonus for completing all three assignments on time is (3*(3+2)) = 15 bonus points.

Project Assignment - (Mobile pick-and-place), is graded as E, C, or A.

This assignment should be presented to the TA's at a scheduled lab session, the latest at Friday, Oct 12.

Completing this assignment to an E level by the deadline (Oct 12) is rewarded with 3 bonus points, a C level by the deadline with 5 bonus points, and an A level with 7 bonus points.

Examination - Assignments (LAB1)

Grades for the assignments will be reported 3 times during the fall:

at their respective deadline
at the time of the exam in P1
at the time of the make-up exam in P2.

Assignments that have been given at least a passing grade by the respective deadline can be resubmitted for a higher grade up until the time of the make-up exam in P2.

Kattis

Kattis is the autograding system used by the EECS school. It is used for assignments 2, 3, and 4 in this course.

Use your personal KTH log-in. Kattis is equipped with a plagiarism checker, and if another student's solution is submitted with your account, this will count as attempted plagiarism.

Kattis is **not a debugging tool**. Ensure that all your code works in your own development environment, with all the supplied practice test cases, before submitting to Kattis.

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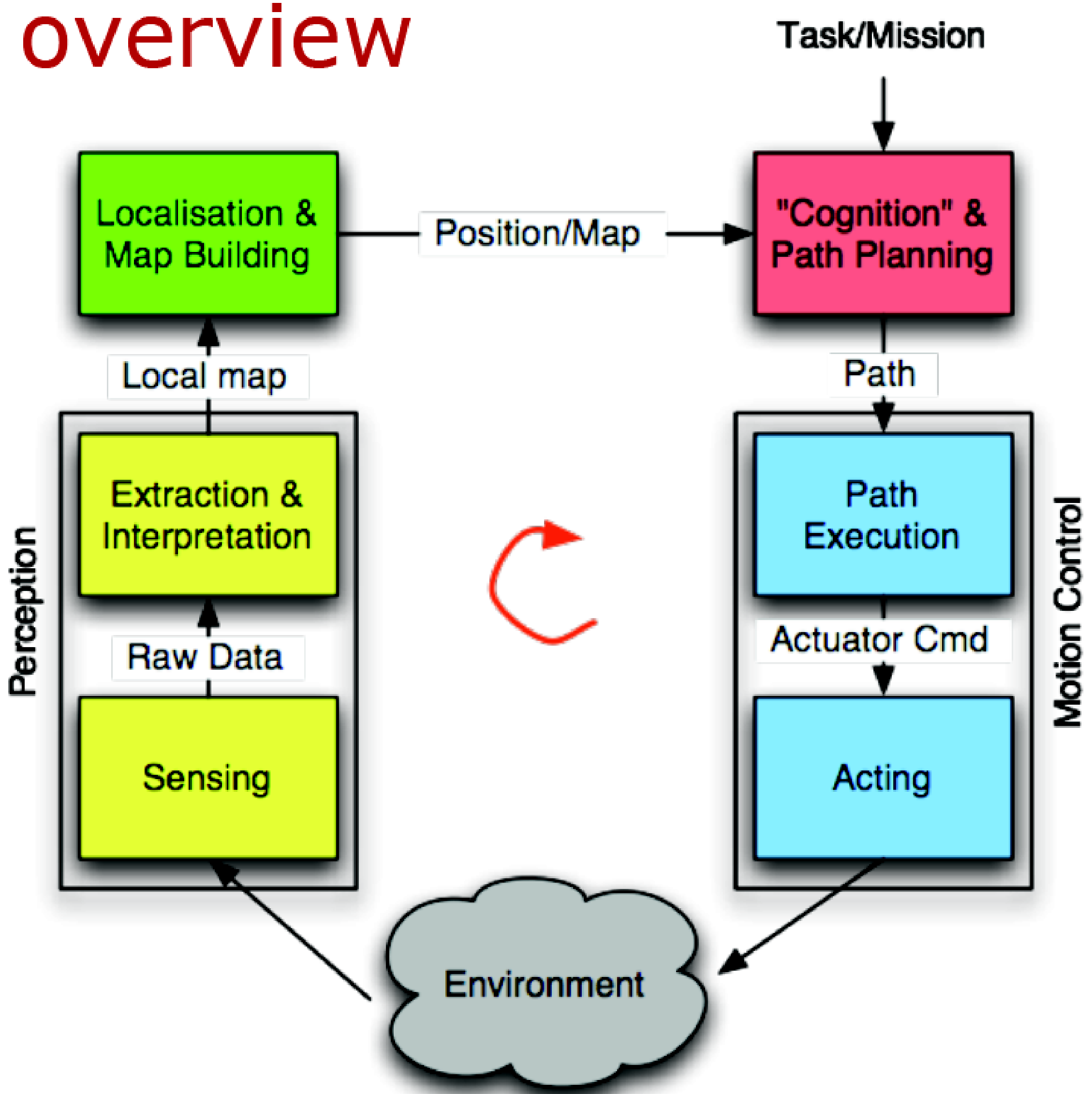
Robotics

- "Robot" originates from 1921 play "R.U.R", by Karel Čapek.
- Programmable machine with sensing and actuation capabilities.

System overview



Robotics

- Why do we have robots?
- Dirty, Dull, Dangerous

Robotics

- Why do we have robots?
- Better

Robotics

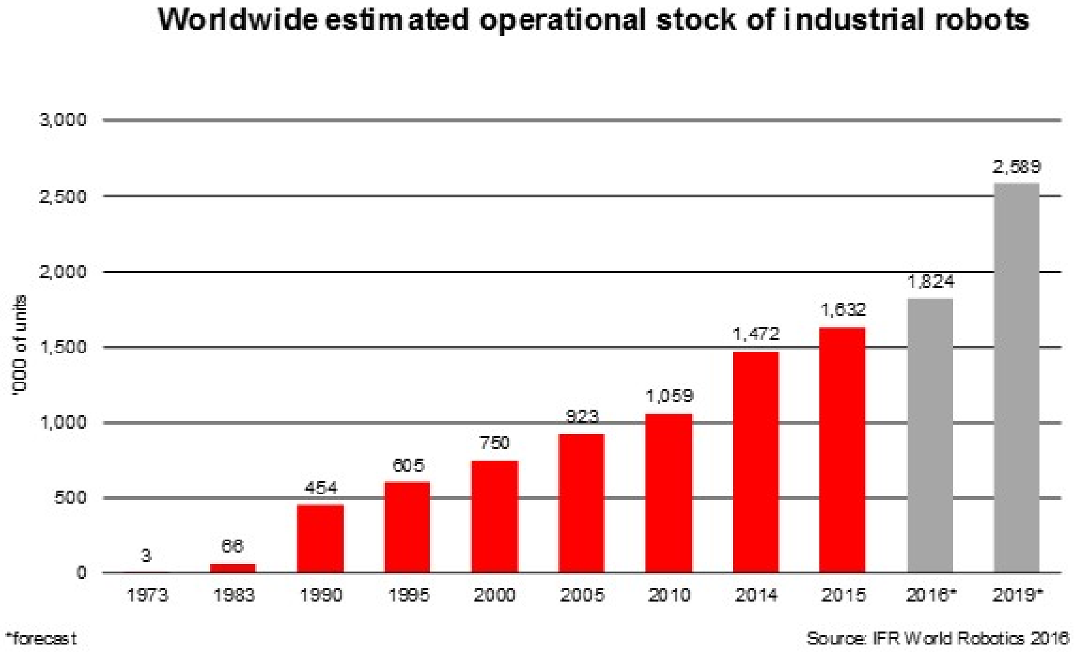
- Why do we have robots?
- Better

Image from http://www.davincisurgery.com/da-vinci-surgery/da-vinci-surgical-system/

Robotics

- "Robotics" originates from the 1941 short story "Liar!" by I. Asimov
- The study of all the subfields necessary to understand a robot.
  From IROS keywords list (selection):
  - Cognitive Human-Robot Interaction, Domestic Robots, Ethics and Philosophy, Learning and Adaptive Systems, Physical Human-Robot Interaction, Robot Audition, Social Human-Robot Interaction, Aerial Systems: Applications, Agricultural Automation, Environment Monitoring and Management, Failure Detection and Recovery, Field Robots, Mining Robotics, Reactive and Sensor-Based Planning, Robotics in Agriculture and Forestry, AI-Based Methods, Dual Arm Manipulation, Formal Methods for Robotics, Manipulation Planning, Perception for Grasping and Manipulation, Planning, Scheduling and Coordination, Task Planning, Automation at Micro-Nano Scales, Biological Cell Manipulation, Contact Modeling, Entertainment Robotics, Gripper and Other End-Effectors, Human-Centered Automation, Micro/Nano Robots, Brain Machine Interfaces, Dynamics, Human Factors and Human-in-the-Loop, Human Performance Augmentation, Natural Machine Motion, Physically Assistive Devices, Rehabilitation Robotics, Simulation and Animation, Aerial Systems: Perception and Autonomy, Computational Geometry, Computer Vision for Other Robotics Applications, Cooperating Robots, Localization, Marine Robotics, Motion and Path Planning, Space Robotics and Automation, Aerial Systems: Mechanics and Control, Computer Vision for Transportation, Logistics, Object detection, segmentation, categorization, Omnidirectional Vision, RGB-D Perception, Visual Learning, Visual Servoing, ...

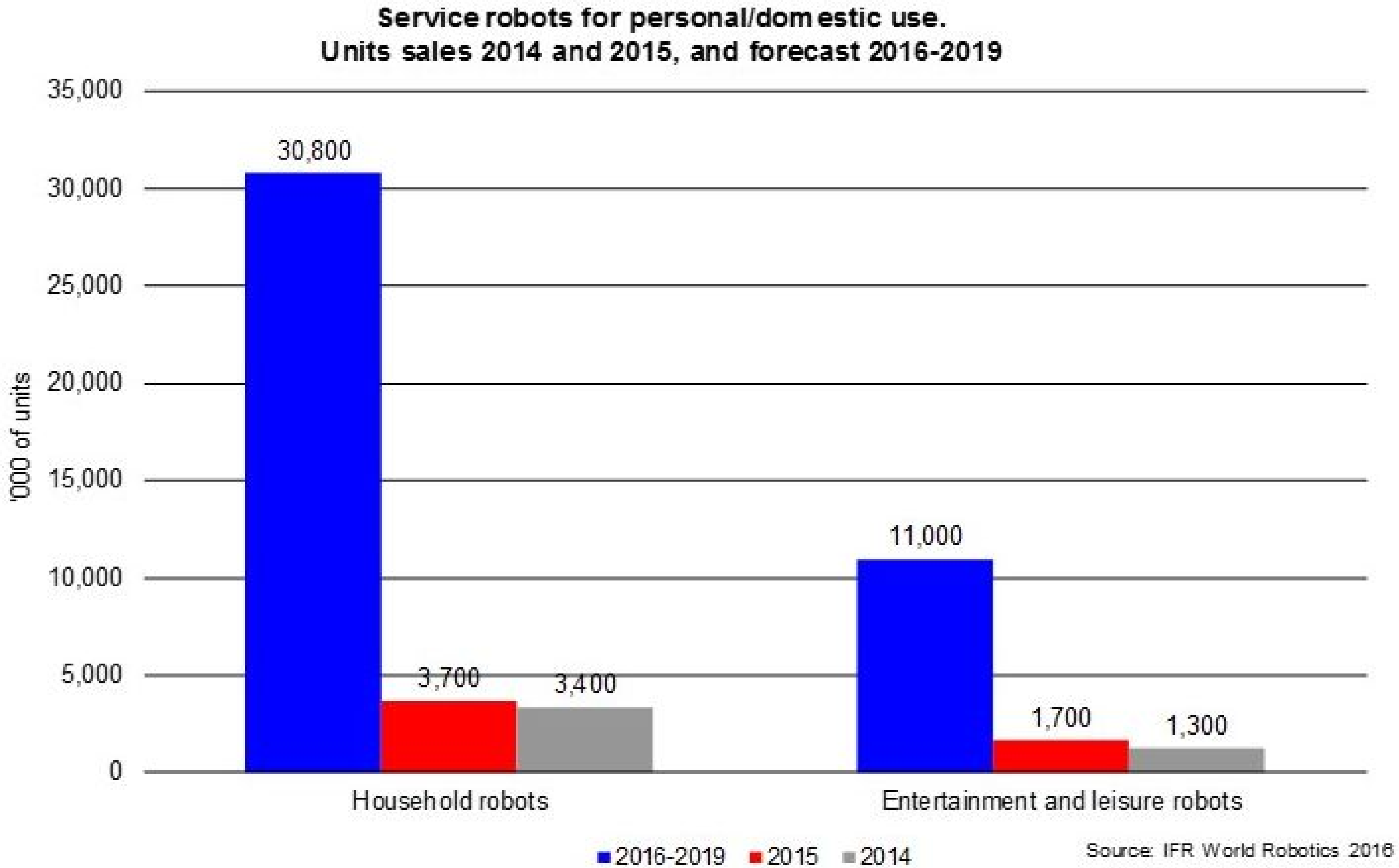
2019: 2.6 million robots in operation



IFR International Federation of Robotics

Hosted by VDMA

Robotics



Service robots for personal/domestic use.
Units sales 2014 and 2015, and forecast 2016-2019
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
'000 of units
30,800
3,700
3,400
11,000
1,700
1,300
Household robots
Entertainment and leisure robots
2016-2019
2015
2014
Source: IFR World Robotics 2016

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- Kakarakuri Ningyo

  Japan (1700s ~)

Image: Wikimedia Commons

History

- Mechanical Turk

  Hungary (1770s ~)

  Wolfgang von Kempelen

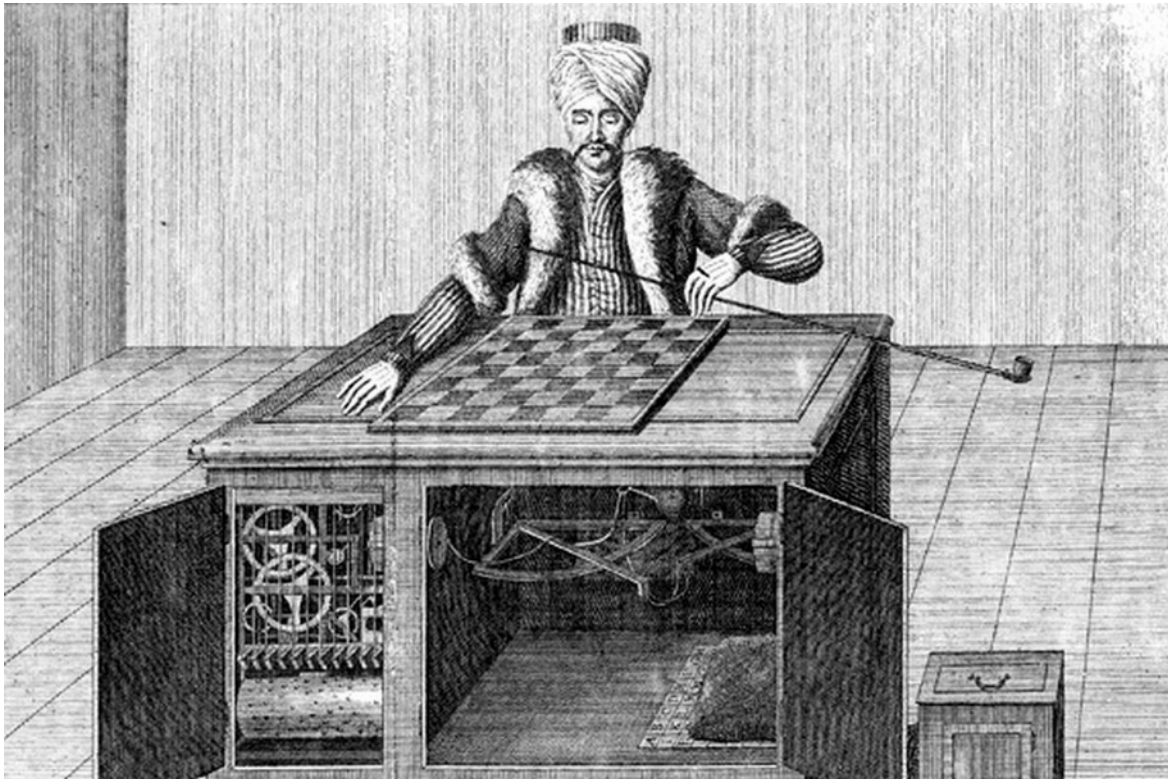


Image: Wikimedia Commons

History

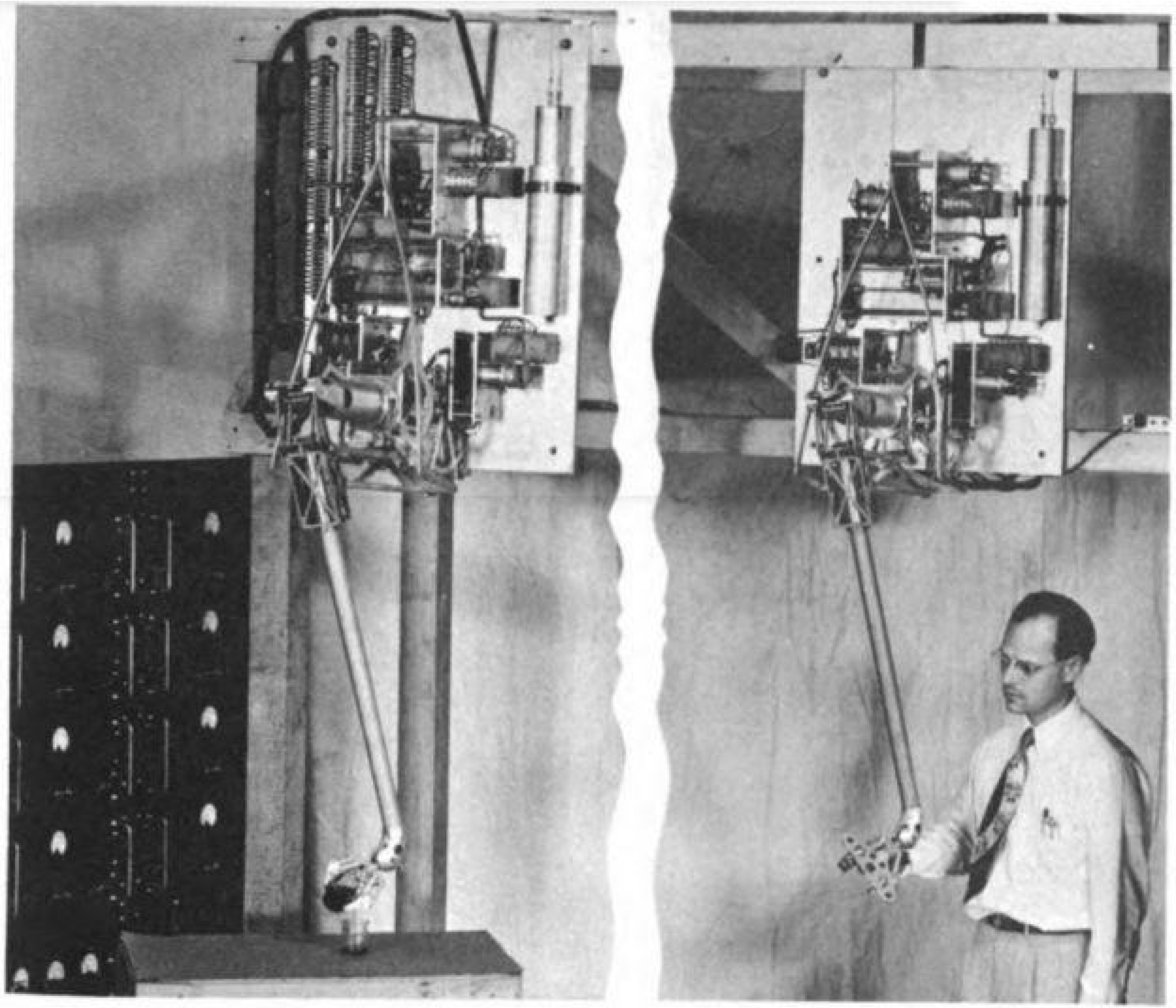
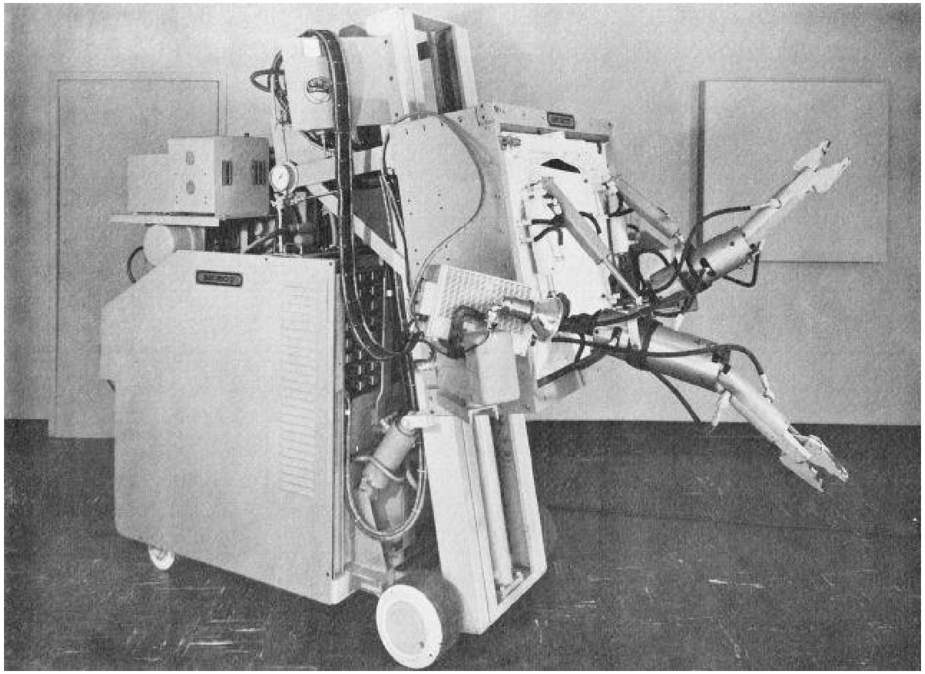
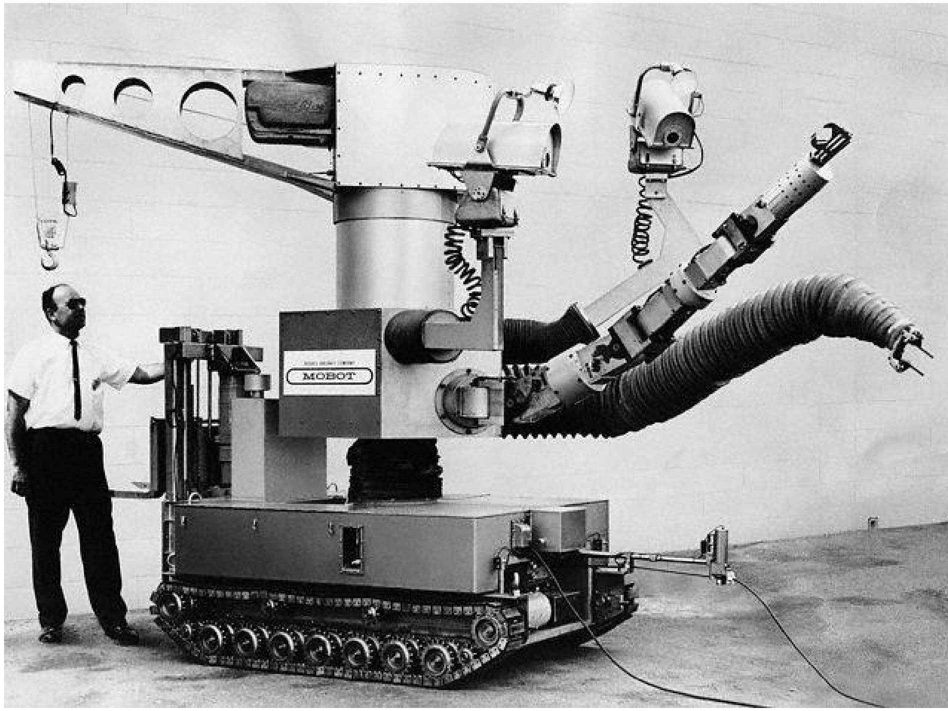


FIGURE 6.—The ANL Model E1 electric master slave. Used only for experimental purposes, this bilateral manipulator was developed in 1954. (Courtesy of Argonne National Laboratory.)

History



Hughes Mobot, 1959



1963

History

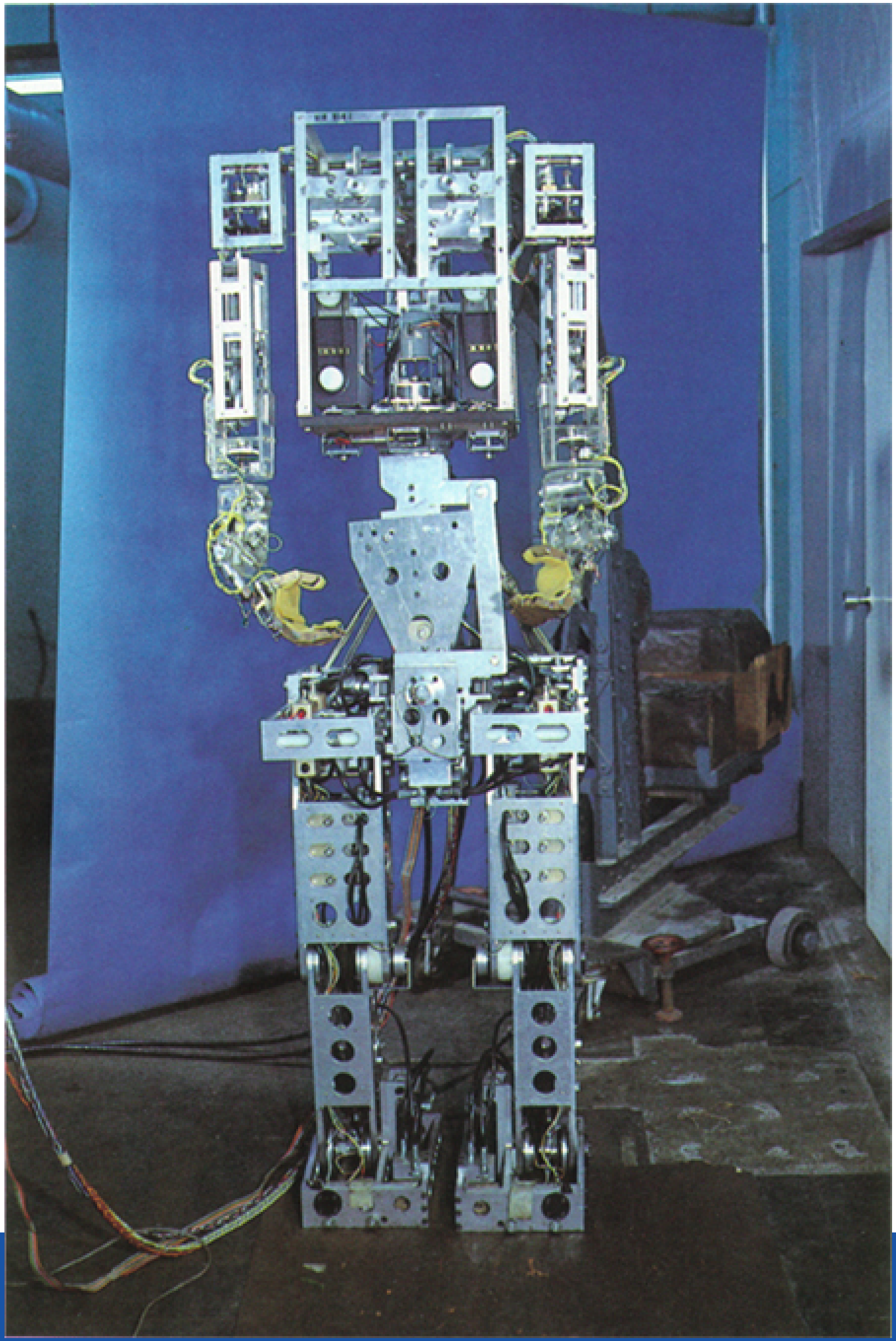
- Unimate Puma, based on Stanford Arm (1969), the first arm with a closed form for inverse kinematics

History

- 1973, ABB Robotics (ASEA) introduced IRB 6, among the world's first commercially available all electric micro-processor controlled robot.

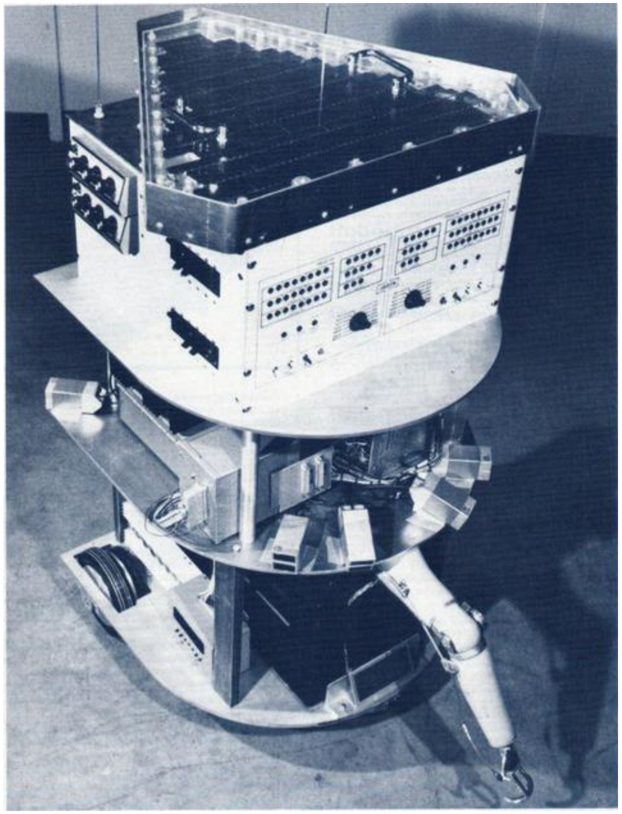
History

- Wabot
  Waseda 1973



History

- Berkeley 'Jason'
- Mobile autonomous robot (1974)



History

- Nintendo 'Chiritorii' (1979)

History

- Omnidirectional robot (1980)

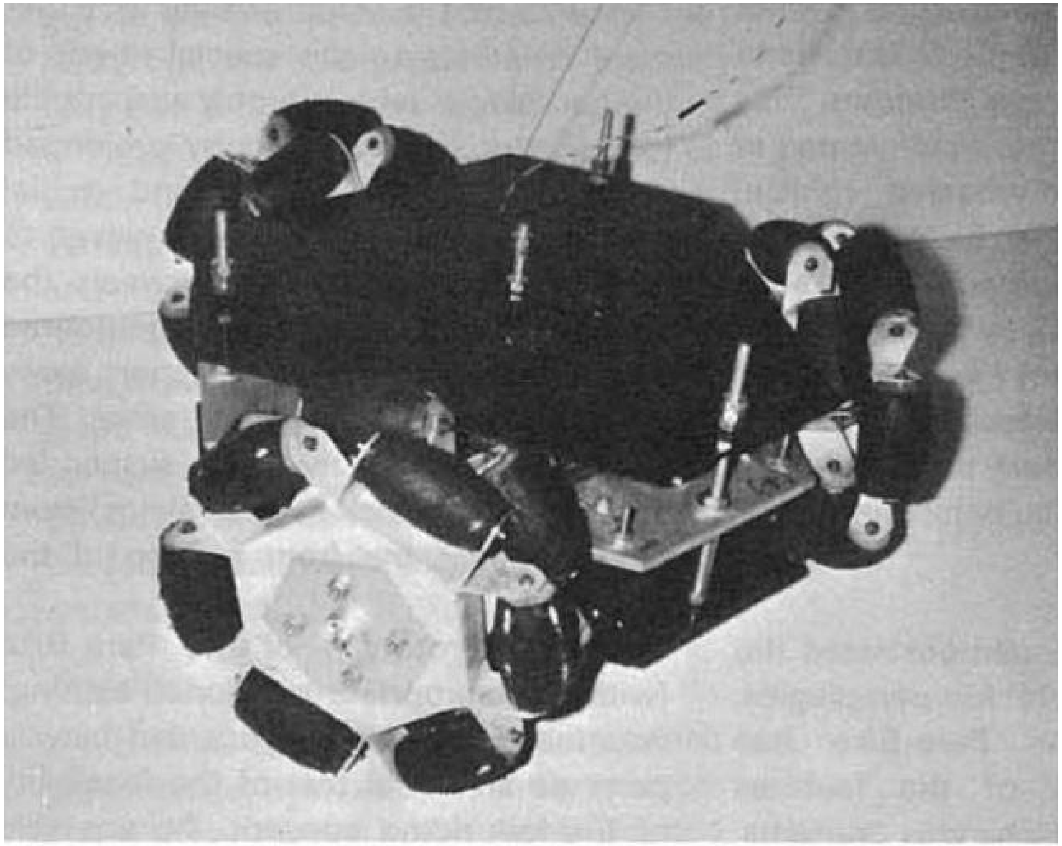


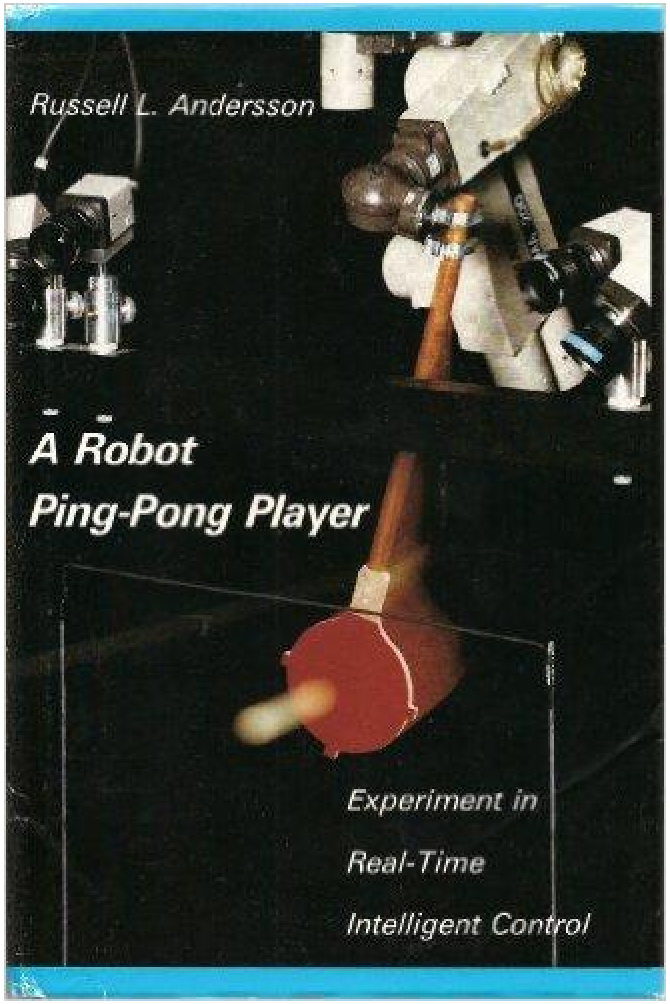
FIGURE 7.
Scale model of omnidirectional mobility base.

History

- Ernst Dickmanns (VaMoRs) 1986, Vision-based autonomous driving.

History

- Robot table tennis
  Russell Andersson (MIT)
  1988



History

- Electrolux 'Trilobite' 1997

History

- Draganflyer (1999)

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State of the art - industrial manipulation

State of the art - industrial manipulation

State of the art - drone manipulation

State of the art - autonomous driving

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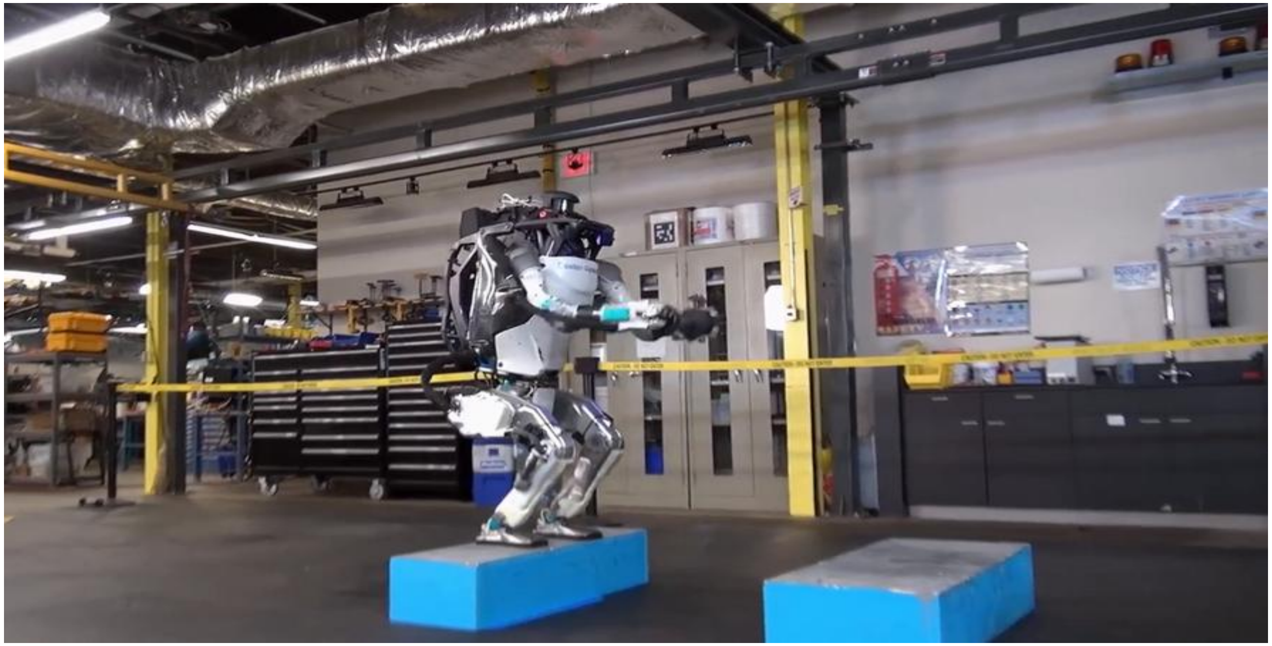
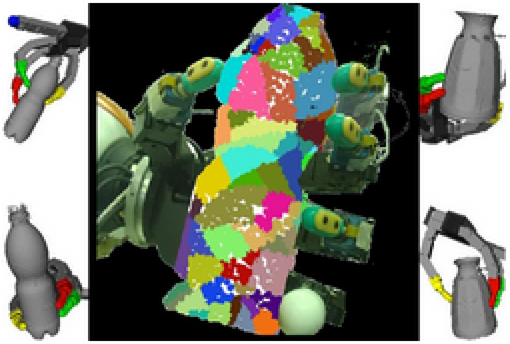
- Generalization
  - How does a robot interact with unknown objects, environments, or tasks?

Research questions in robotics



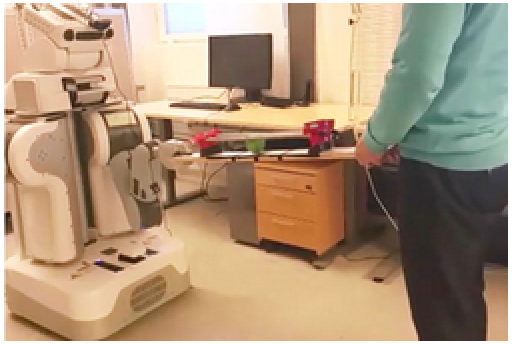
Research questions in robotics

Robotics at RPL

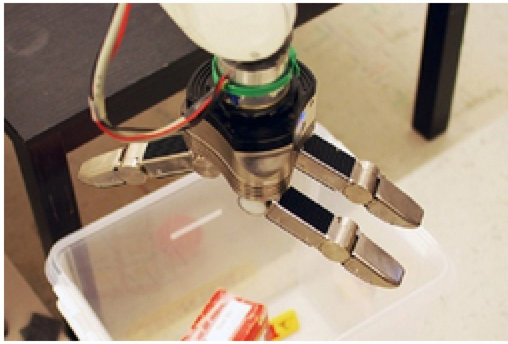


- Active perception

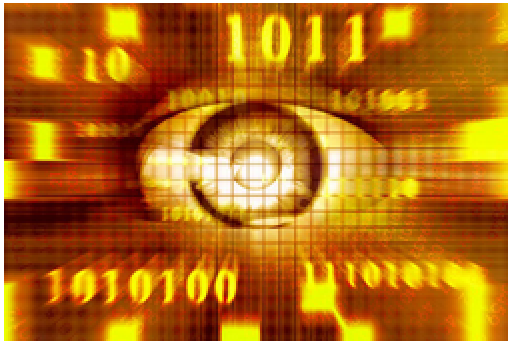
- Mobile robotics



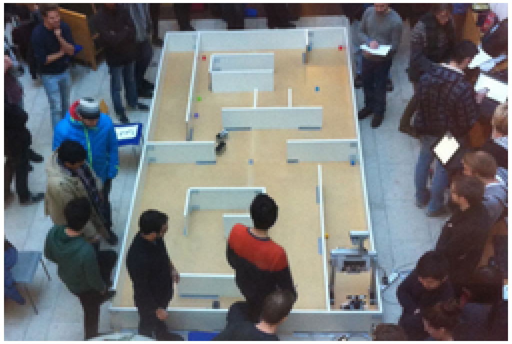
- Social robotics



- Grasping and Manipulation



- Computer Vision and Machine Learning

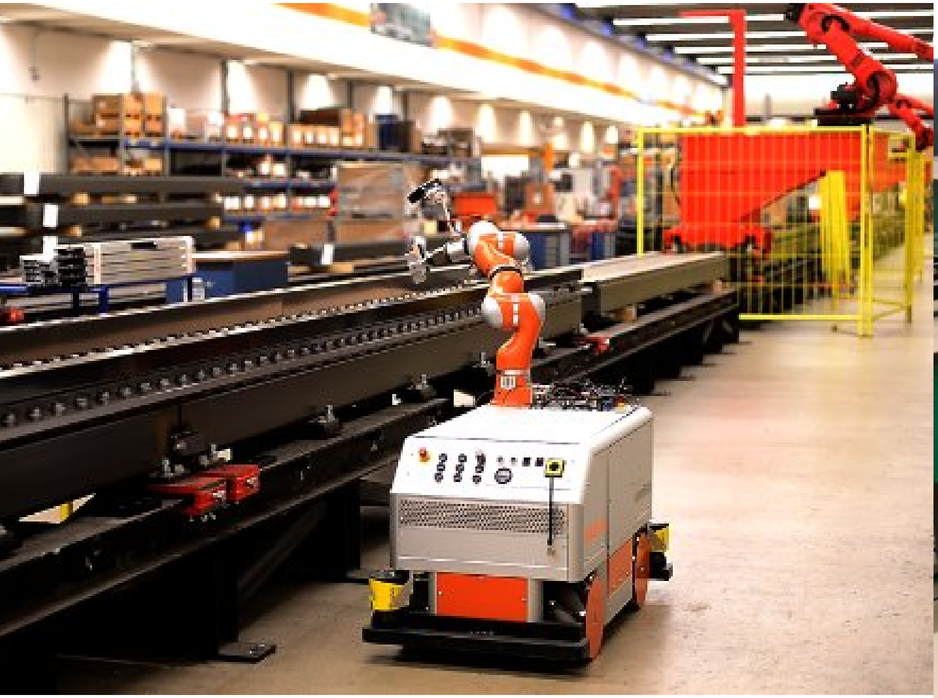


- Planning and decision making

Robotics at RPL

TRADR

Robotics at RPL



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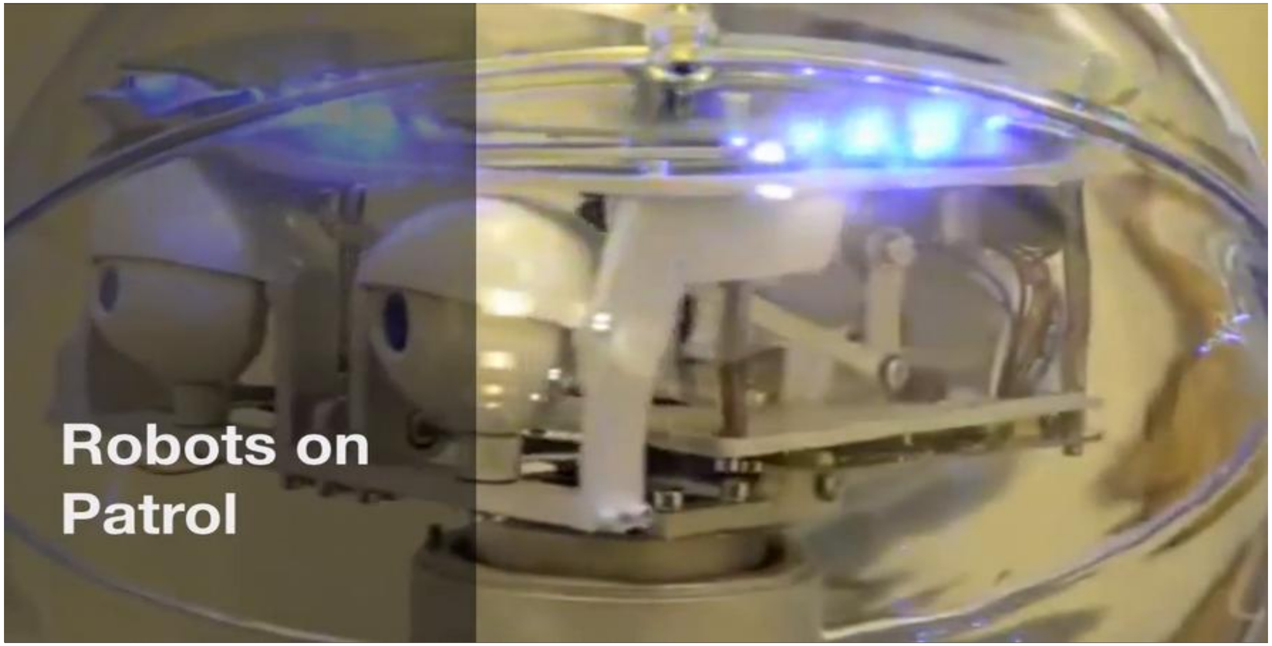

Robotics at RPL

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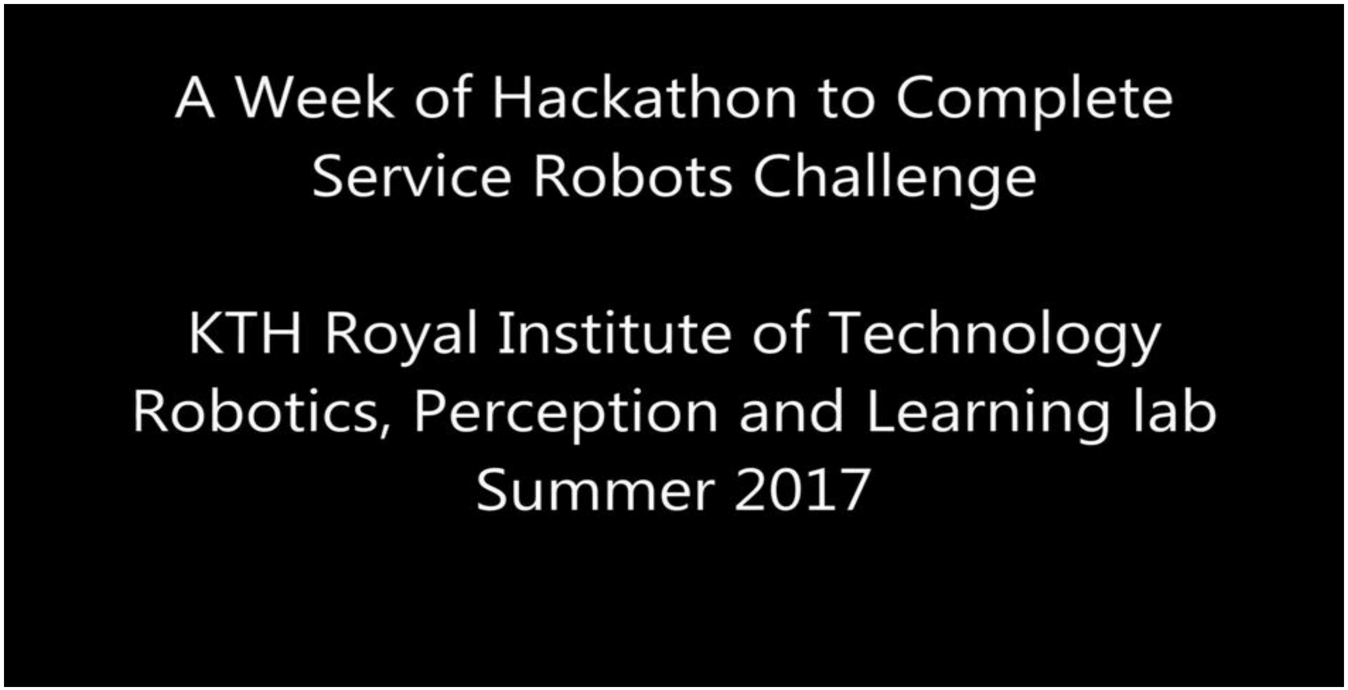

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