CMPUT 631: Autonomous Robot Navigation

Prof. Hong Zhang
407 Athabasca Hall
hzhang@ualberta.ca
http://www.cs.ualberta.ca/~zhang/c631

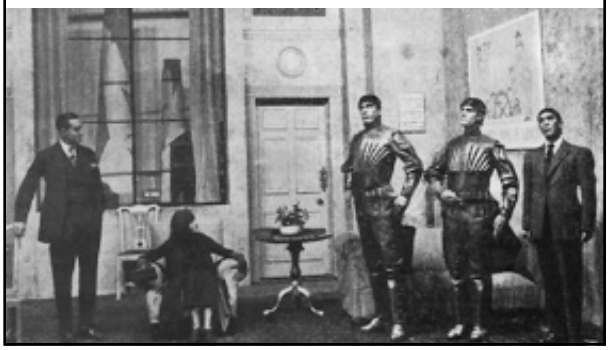
What you will learn in CMPUT 631 ..

- Robotics
  - Autonomous navigation
- How to do research
  - Process

What we will do today ..

- Robot
- Robotics
- Robotics research
- State-of-the-art robotics
- Course details
  - Contents
  - Road map
  - Content delivery
  - Evaluation

What is a robot?



Asimov's Laws of Robotics

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

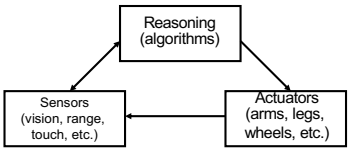
Source: https://en.wikipedia.org/wiki/Three_Laws_of_Robotics

What is a robot?

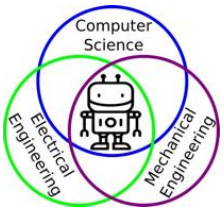
- Robot: Czech word for "labor", originating from the 1921 satire "Rossum's Universal Robot (R. U. R.)"
- Some definitions:
  - A device that replaces human labor (Boeing 747, Roomba)
  - A programmable multi-function manipulator designed to move parts through programmed motion (car assembly line)
  - An **intelligent** robot is one that can determine its own behavior and conduct through its functions of sense and cognition.

Robotics

- Robotics is the intelligent connection of perception to action (Brady, 1985)



Robotics Research



- ME, EE: Design, construction, operation, and application of robots, and
- CS, EE: Computer systems for their control, sensory feedback, and information processing

Robotics Research Keywords

- Applications
- Autonomy for Mobility and Manipulation
- Cognitive Robotics
- Field Robotics
- Human-Centered Robotics
- Humanoids and Animaloids
- Localization and Mapping
- Manipulation and Grasping
- Mechanisms, Design and control
- Medical and Rehabilitation
- Micro, Nano, and Biomimetic Systems
- Multiple and Distributed Systems
- Planning and Simulation
- Theoretical Foundations
- Vision and Sensor-Based Control
- Visual Perception and Learning

ME EE CS

ICRA18 in numbers

ICRA 2018

2586 papers submitted
→**1981** submitted to ICRA
→**605** submitted to RAL
→**48%** increase from 2017

submissions

Top 10 keywords

Deep Learning in Robotics and Automation*	613 USA
Motion and Path Planning*	230 China
Learning and Adaptive Systems*	159 Germany
Localization*	115 Japan
SLAM*	89 France
Multi-Robot Systems*	85 UK
Autonomous Vehicle Navigation*	83 Italy
Optimization and Optimal Control*	82 South Korea
Mapping*	75 Australia
Learning from Demonstration*	62 Canada

1052 papers presented
40% acceptance rate
31 workshops
6 forums
4 tutorials

presenting

7520 pages of proceedings **19GB** of data on the USB stick **80** student volunteers **8** palm trees **3050** registrations

Robotics Research: What's Hot?

Top Ten Robotics Research Areas ICRA 2017
Research included in Best Paper Finalists
icra2017.org

Rank*

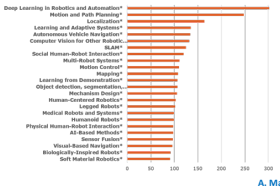
Rank*		
1	Motion and Path Planning	(108 papers)
2	Learning and Adaptive Systems	(101 papers)
3	Aerial Robotics	(82 papers)
4	Medical Robots and Systems	(62 papers)
5	Localization	(59 papers)
6	Optimization and Optimal Control	(56 papers)
7	SLAM	(53 papers)
8	Soft Material Robotics	(51 papers)
9	Biologically-Inspired Robots	(50 papers)
10	Mapping	(40 papers)
13	Autonomous Vehicle Navigation	(35 papers)
28	Physical Human-Robot Interaction	(27 papers)
44	Recognition	(20 papers)
54	Robot Safety	(18 papers)
77	Product Design, Development and Prototyping	(12 papers)
92	Swarms	(9 papers)
99	Computational Geometry	(8 papers)
	Formal Methods for Robotics	(8 papers)
121	Robotics in Construction	(3 papers)

*142 Topics at ICRA 2017

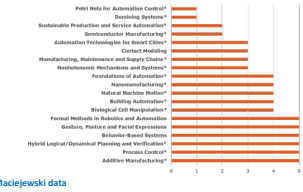
2018 IEEE/RSJ International Conference on Intelligent Robots and Systems
October 1-5th, 2018, Madrid, Spain
MADRID 2018 IROS

Key-words distribution (II)

Most Frequent Keywords

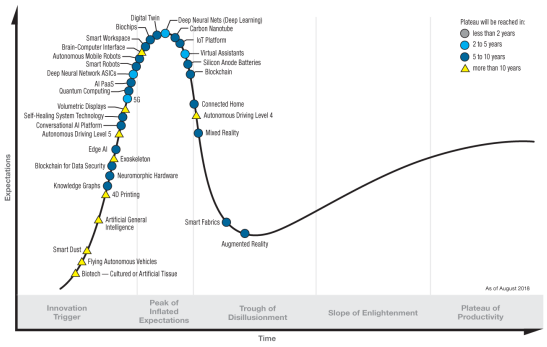


Least Frequent Keywords



A. Maciejewski data

Hype Cycle for Emerging Technologies, 2018



gartner.com/SmarterWithGartner

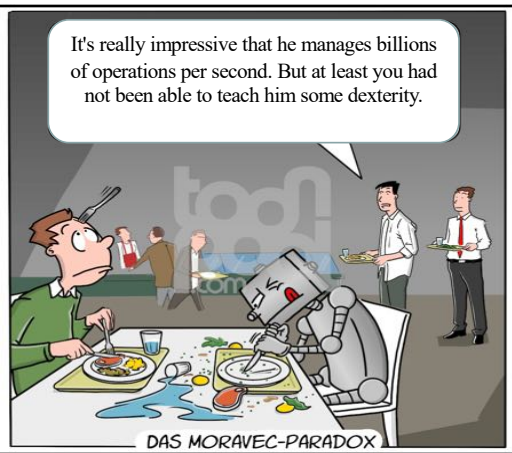
Robotics: State-of-the-Art

- Mercedes A-class assembly
- Amazon's fulfillment centre
- Prime Air
- Delft: winner of 2016 Amazon picking challenge
- Boston Dynamics
- Handle Robot by Boston Dynamics (2019)
- Robocup SPL 2019

Navigation: State-of-the-Art

- Roomba vacuum cleaning robot
- Nvidia self-driving car
- Mercedes truck
- James Bond Air Drones
- Visual SLAM: ORB-SLAM

Challenges and Opportunities



What is easy for humans is difficult for robots and vice versa!

Credit: https://ranjanicnarayan.com/2018/01/28/the-ai-paradox/

Moravec's paradox

Easy for AI/Robots
- Math or computation
- Internet search
- Games (Chess, Go)
- …

Easy for Humans
- Use chopsticks
- Walking
- Tie shoe lace
- …

"*The older a skill is, the more time natural selection has had to improve the design. Abstract thought developed only very recently, and consequently, we should not expect its (human) implementation to be particularly efficient.*" - Wikipedia

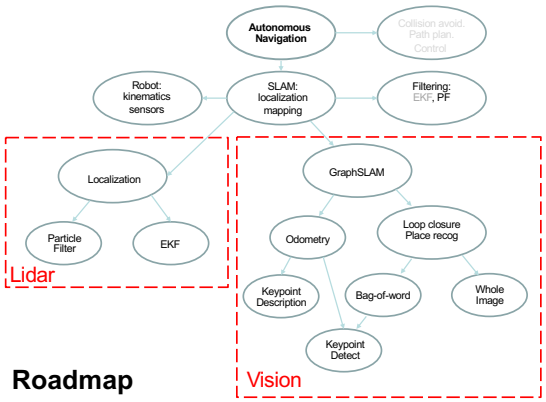
Are Low-Skilled Jobs More Vulnerable to Automation?

From a robot's point of view, which of these jobs require more skills: a waiter or a highly trained radiologist who interprets CT scans? A waiter, hands down. It requires hundreds of skills, from spotting rancid meat to cleaning up baby vomit. But because we take all those things for granted, we don't think they are all that hard. To a robot, the radiologist job, by comparison, is a cakewalk. It is just data in, probabilities out.

https://gigaom.com/2018/05/17/are-low-skilled-jobs-more-vulnerable-to-automation/

Course Details: Contents

1. Introduction to robotics
2. Robot Operating System (ROS)
3. Mobile robot kinematics
4. Sensors: lidars and cameras
5. Filter-based solutions to robot localization and mapping
6. Optimization-based solutions to SLAM
7. Visual odometry and visual SLAM
8. Place recognition and loop closure detection
9. Additional topics (time permitting): e.g. learning for robotics



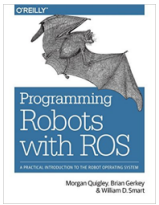
Roadmap

Course Details: Delivery

Textbook (recommended)

Programming Robots with ROS: A Practical Introduction to the Robot Operating System

(available at https://**safari**.oreilly.com/)



ROS

Kinetic on Ubuntu 16.04

http://wiki.ros.org/kinetic

References

Research papers

Evaluation

- Four Assignments: 40%
  - Spatial transforms and statistics
  - GraphSLAM with non-linear optimization
  - Visual odometry
  - Running RTAB-Map and ORB-SLAM
- Midterm: 20%
- Project: 40%
  - Group of two
  - One of the defined problems or proposed by the students with instructor's permission
  - Use of existing datasets or real sensors
  - Credit for creativity

Announcements

- Linux and ROS: you need a computer running Ubuntu (e.g. 16.04) and ROS (e.g., kinetic)
- ROS "TA's": Sean Scheideman and Siqi Yan
- Read pp. 1-12 (1309-1320) and pp. 17-18 (1326-1327) of [Cadena 2016]
- Follow the course and find reference materials on www.cs.ualberta.ca/~zhang/c631

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Coming up ..

- Robot kinematics
- Sensors
  - Odometry
  - IMU
  - Lidar
  - Camera
  - RGB-D
- Introduction to ROS
- Stata Dataset: http://projects.csail.mit.edu/stata/