Robotics

Erwin M. Bakker| LIACS Media Lab

7-2 2022

Universiteit Leiden

Bij ons leer je de wereld kennen

Organization and Overview

Period: February 7th – May 23rd 2022
Time: Monday 16.15 – 18.00
Place: Room 407 - 409
Lecturer: Erwin M. Bakker (erwin@liacs.nl)
Assistant: Hainan Yu (h.yu@liacs.leidenuniv.nl)

NB Register on Brightspace

Schedule:

7-2	Introduction and Overview
14-2	Locomotion and Inverse Kinematics
21-2	Robotics Sensors and Image Processing
28-2	SLAM + SLAM Workshop
7-3	Mobile Robot Challenge Introduction
14-3	Project Proposals I (presentation by students)
21-3	Project Proposals II (presentation by students)
28-3	Robotics Vision
4-4	Robotics Reinforcement Learning
11-4	Robotics Reinforcement Learning Workshop II
18-4	No Class (Eastern)
25-4	Project Progress I (presentations by students)
2-5	Project Progress II (presentations by students)
9-5	Mobile Robot Challenge
16-5	Project Demos I
23-5	Project Demos II

Website: http://liacs.leidenuniv.nl/~bakkerem2/robotics/

Grading (6 ECTS):
- Presentations and Robotics Project (60% of grade).
- Class discussions, attendance, workshops and assignments (40% of grade).
- It is necessary to be at every class and to complete every workshop and assignment.

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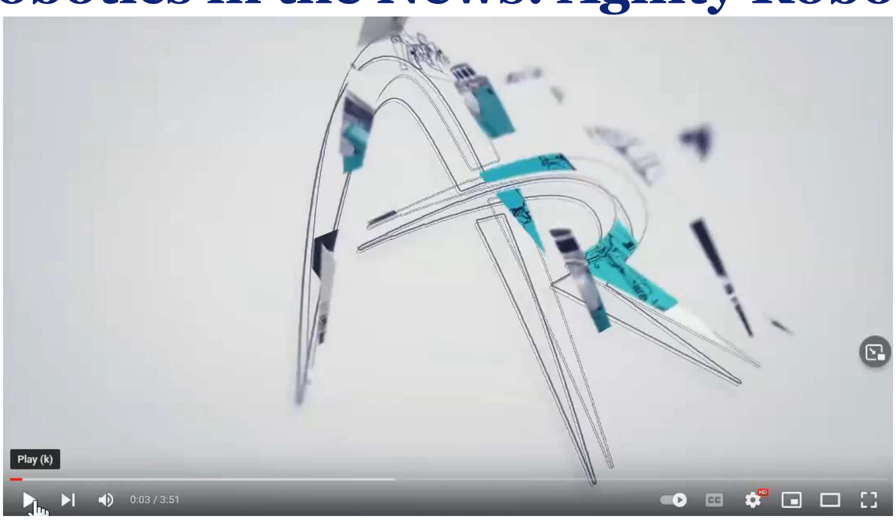
Robotics in the News: Agility Robotics

A Year of Agility Engineering.
Jan. 18 2022, https://www.youtube.com/watch?v=D8_VmWWRJgE

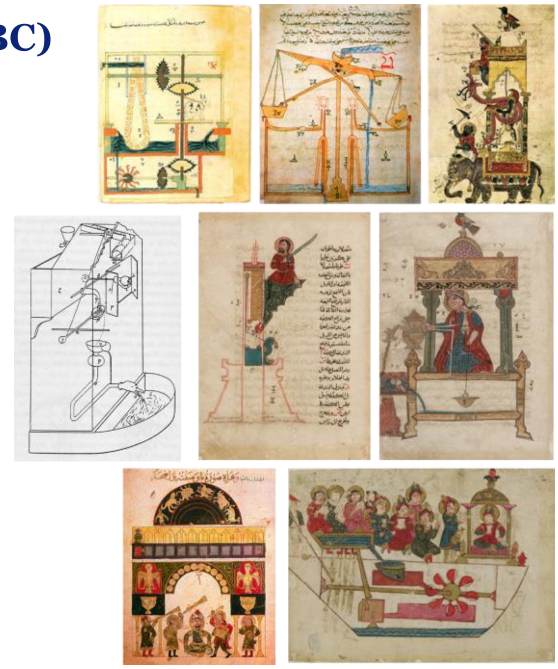
Robotics in the News: Agility Robotics



A Year of Agility Life | 2021
Dec. 2021, https://www.youtube.com/watch?v=s4IavcE4T2Q

Philo of Byzantium (~280 – 220 BC)
Al-Jazari (1136 – 1206)

- Mechanisms and methods for automation
- Water-raising machines
- Clocks
- Automata
  - Drink-serving waitress
  - Hand-washing automaton with flush mechanism
  - Peacock fountain with automated servants
  - Musical robot band



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Leonardo da Vinci (1452 – 1519)

- Robotic Carts
- Studies on locomotion
- Robotic Soldier
- Robotic Lion

Pictures from:
http://www.leonardo3.net
http://brunelleschi.imss.fi.it

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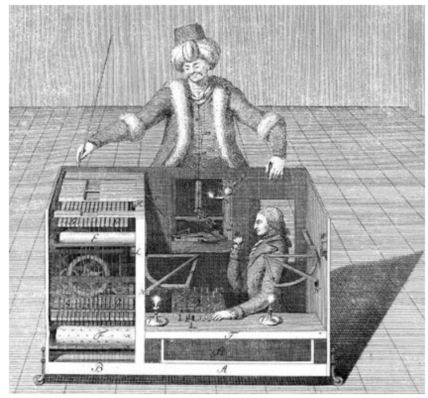
The Turk
Constructed and unveiled in 1770
by Wolfgang von Kempelen (1734–1804)



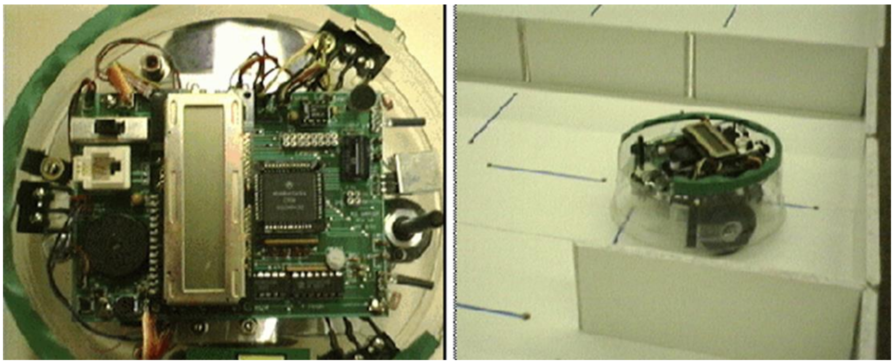
Pictures from:
http://en.wikipedia.org/wiki/The_Turk

EARLY ROBOTS

LOCOMOTION & INVERSE KINEMATICS

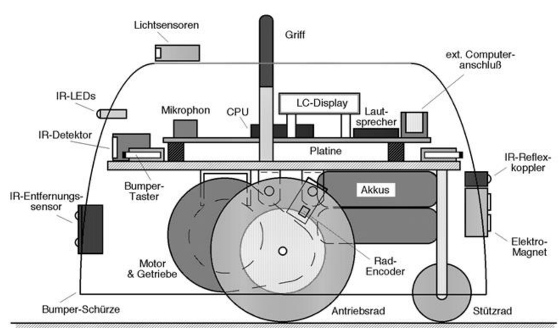
South Pointing Chariot
by Ma Jun (c. 200–265)

Autonomous Robots for Artificial Life (MIT, T. Braunl, Stuttgart University) ‘Rug Warrior’



Autonomous Robots for Artificial Life

- Sensors
- Bumper
- Photoresistors (2)
- Infrared Obstacle Detectors w. 2 infrared LED’s
- Microphone
- Two Shaft-Encoders



Tekening van: http://ag-vp-www.informatik.uni-kl.de

Autonomous Robots for Artificial Life

Software (PC, Macintosh, UNIX)

Interactive C Compiler and Libraries

- **motor(0,speed), motor(1,speed)**
- **music: tone(), analog(micro)**
- **get_left_clicks(), get_right_clicks()**
- **analog(photo_left), analog(photo_right)**
- **left_ir, right_ir**
- **left_, right_, back_bumper**

- Note: Microsoft Robotics Studio 4: development environment for different robotic platforms (Lego Mindstorm, Fischertechnik, Lynxmotion, Parallax Boe-Bot, Pioneer P3 DX, iRobot Roomba), Kinect (2014†);
- ROS (Robot Operating System) 50+ robots, etc.

Autonomous Robots for Artificial Life

Straight ahead

Straight Ahead

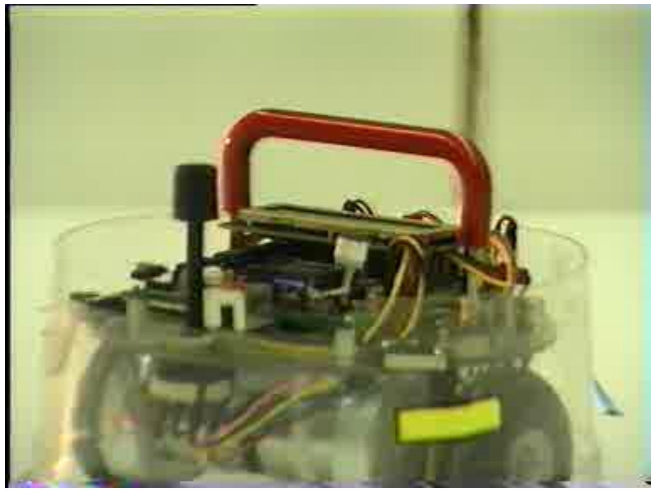
```
void main()
{       int pid_clicks, pid_fahre;
        test_number =! test_number;
        if (test_number)
        {       sleep(1.0); alert_tune();
                pid_clicks=start_process(clicks());
                pid_fahre=start_process(fahre_geradeaus());
                geschwindigkeit = anfangsgeschwindigkeit;
                while (rclicks < 500) {}
                ... code to stop ...
                kill_process(pid_fahre);
                kill_process(pid_clicks);
                printf("max. Abw.: %d",dmax);
 } else  printf("----HALT----\n");   }
```


Straight Ahead

```
void clicks()          // Continuously read out odometer
{ init_velocity();
  while(TRUE)
  {
      if (rechts>0.0)
          rclicks+=get_right_clicks();
      else
          rclicks-=get_right_clicks();
      if (links>0.0)
          lclicks+=get_left_clicks();
      else
          lclicks-=get_left_clicks();
          printf("l: %d  r: %d\n",lclicks,rclicks);
  }
}
```

```
void fahre_geradeaus()
{ int d;
  while(TRUE)
  { d=rclicks-lclicks;        // Difference
    if (abs(d)>abs(dmax))
          dmax=d;
    links = geschwindigkeit + DELTA*(float) d;
    rechts =geschwindigkeit - DELTA*(float) d;
    drive( 0, links);
    drive( 1, rechts);
    sleep(0.1);
  }
}
```

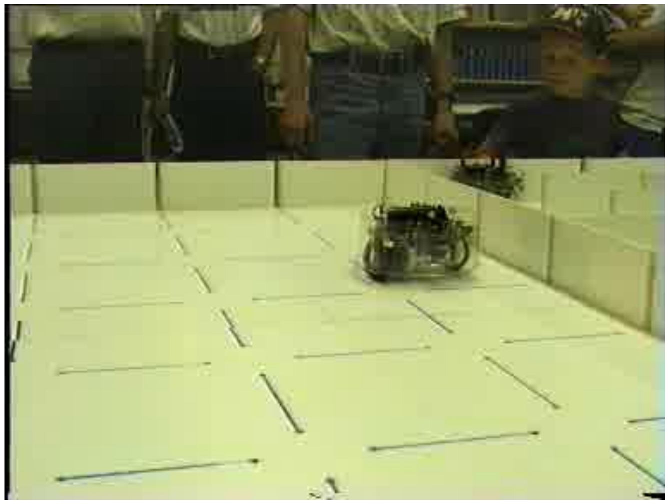
Finding the Light



Finding the Light

```
if ( analog(photo_right) < analog(photo_left) )
 { motor(0, speed);      /* rechtsdrehen */
    motor(1, -speed);
} else
{ motor(0, -speed);      /* linksdrehen */
   motor(1, speed);
}
clicks = 0;
while( (  (clicks += (get_left_clicks() + get_right_clicks()) / 2)) < 37
              && !all_bumper )  /* eine Umdregung machen solange kein Bumper
betaetigt */
{ printf("FIND MAX  %d   %d\n", clicks, light);
   light = get_light();                  /* Lichtwert holen */
   if ( light > max_light )              /* maximum merken */
  { max_light = light; }
    sleep(0.2);
  }
```

Finding the Light 2



Mechanical Tortoise (1951)

British Pathé, 1951.
YouTube: https://www.youtube.com/watch?v=wQE82derooc&t=14s

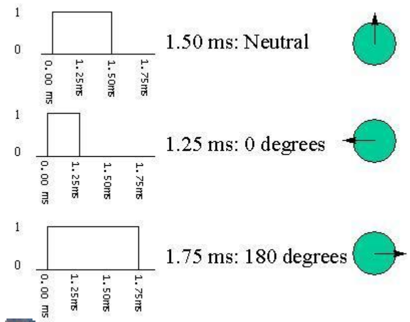
Finding the Light 2

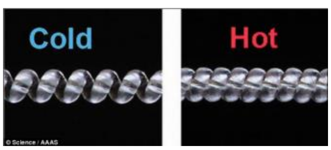
- Drive along the wall until the light source is found.
- Drive with a left curve until the IR-sensors detect an obstacle, then make a correction to the right until no sensor input is read.
- If an obstacle is found that cannot be resolved this way, then drive 1.5 seconds backwards and start over again.

Vacuum Cleaner & Lawn Mower

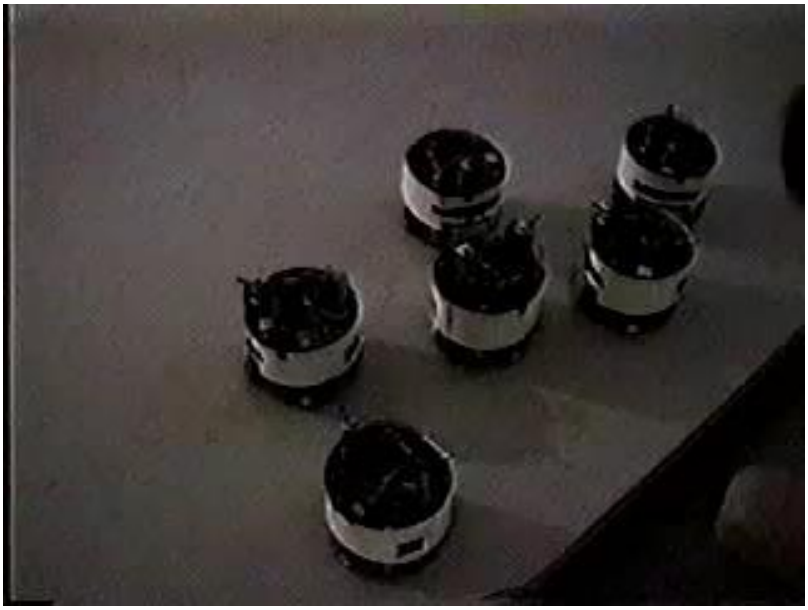
Robotics Actuators

- Electro motors
- Servo’s
- Stepper Motors
- Brushless motors
- Solenoids
- Hydraulic, pneumatic actuator’s
- Magnetic actuators
- Artificial Musscles
- Etc.






A robot balanced on a ball
Tohoku gakuin univ.
Robot development engineering lab.



Caltech’s Leonardo

Caltech’s Leonardo, Oct. 2021
https://www.youtube.com/watch?v=fh1AsW22Iks

Humanoid Research Platforms

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LIACS Humanoid Research Platforms

LML

LIACS
MEDIA
LAB

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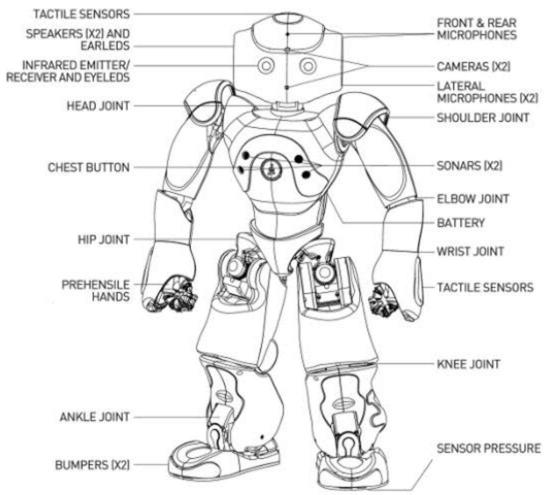
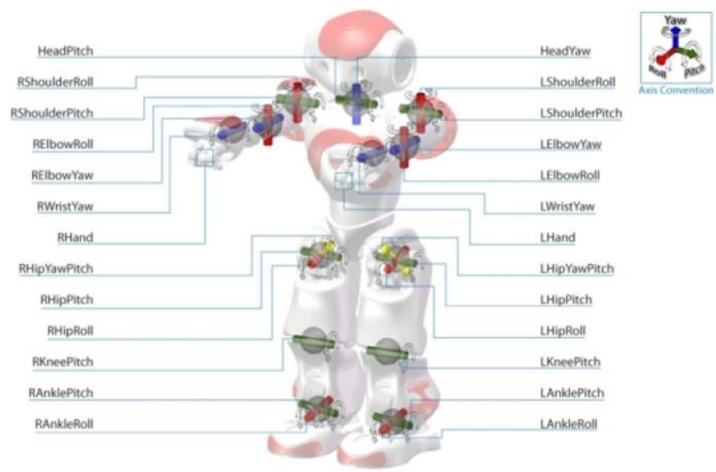
NAO





http://doc.aldebaran.com/2-1/family/nao_dcm/actuator_sensor_names.html

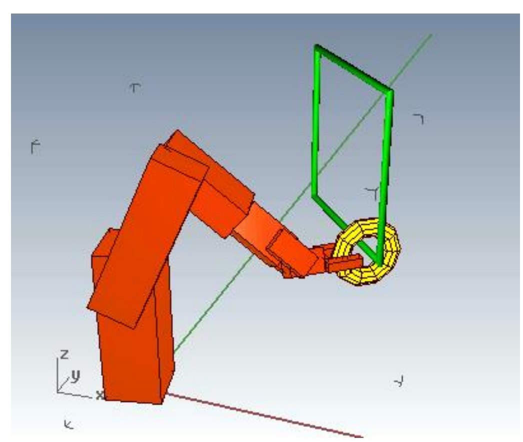
How to move to a goal?

Problem: How to move to a goal?

- Grasp, Walk, Stand, Dance, Follow, etc.

Solution:

- Program step by step.
- Inverse kinematics: take end-points and move them to designated points.
- Trace movements by specialist, human, etc.
- **Learn the right movements:**
  Reinforcement Learning, give a reward when the movement resembles the designated movement.



https://pybullet.org/wordpress/

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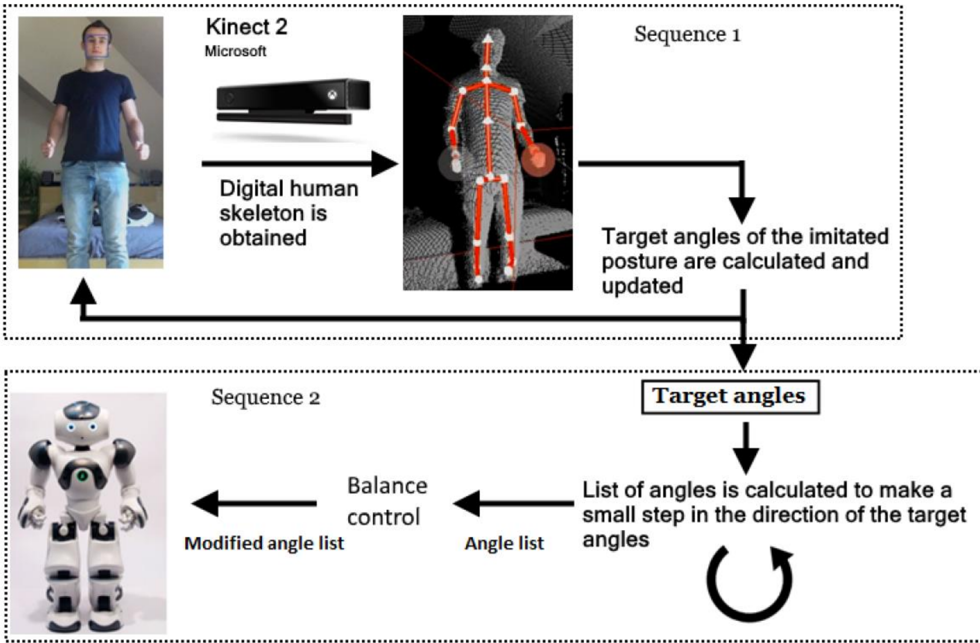


From: Robin Borst, Robust self-balancing robot mimicking, Bachelor Thesis, August 2017

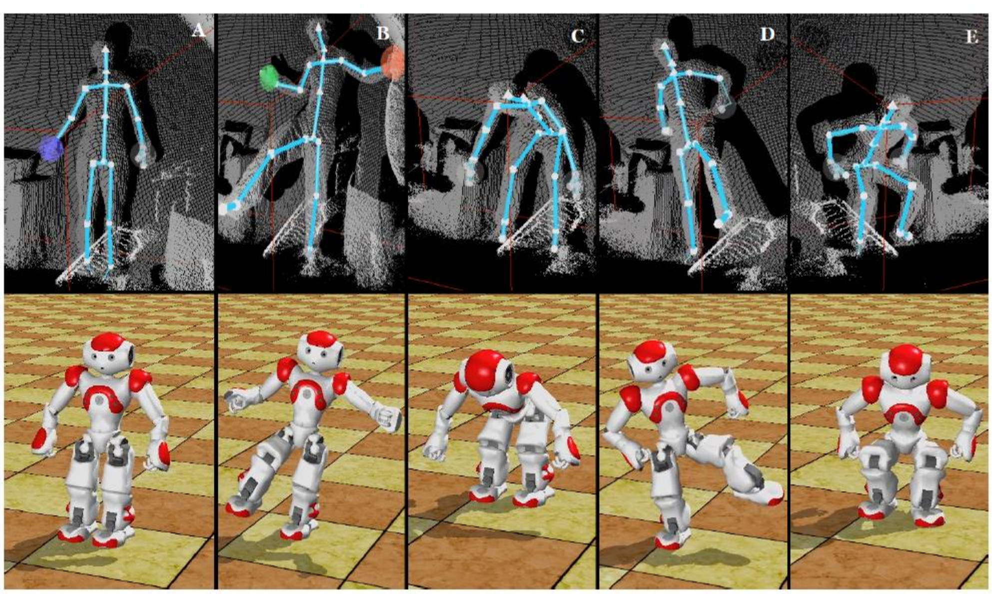


Figure 5.4: The five poses that have been selected to evaluate the effect of the balance controller.

OPNNAR

(a) *Start state*

(b) *Raise Arm*

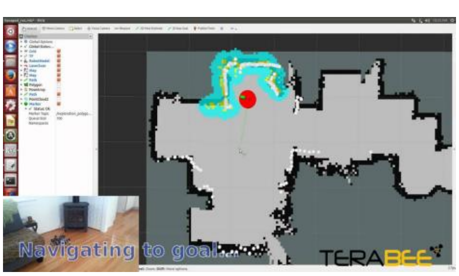
(c) *Swipe*

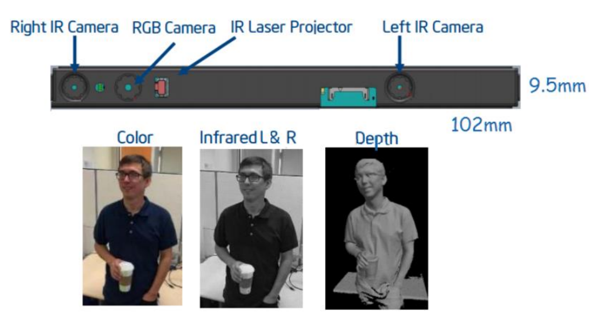
K. Maas, Full-Body Action Recognition from Monocular RGB-Video:
A multi-stage approach using OpenPose and RNNs, BSc Thesis, 2021.

ROBOTICS SENSORS

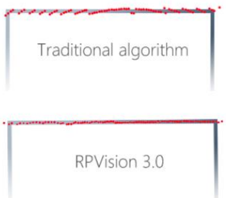
- Bumper switches
- Acceleration, Orientation, Magnetic
- IR/Visible Light
- Pressure, Force
- Ultrasonic, Lidar, Radar
- Camera's, stereo camera's
- Structured Light Camera's

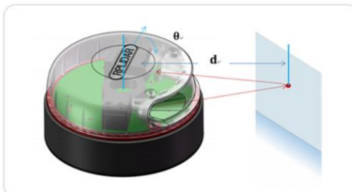
	Ultrasound	Infrared Triangulation	Laser	TeraRanger Time-of-Flight
High reading frequency	✗	✗	✓	✓
Long range	✗	✗	✓	✓
Minimal weight	✓	✓	✗	✓
Small form factor	✓	✓	✗	✓
Eye safety	✓	✓	Class 1 lasers only	✓
Use with multiple sensors	✗	✗	✗	✓



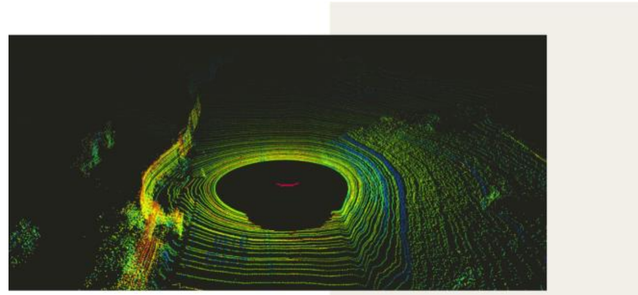


LIDAR Explanation

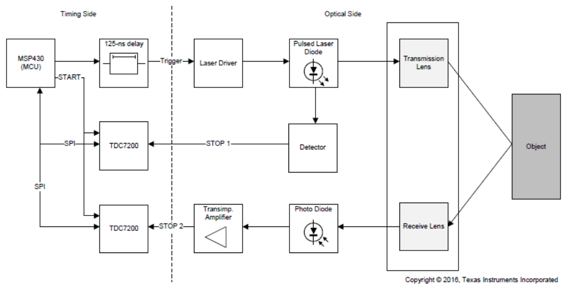




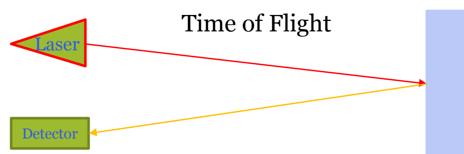
http://www.slamtec.com/en/lidar/A3



https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff



Texas Instruments LIDAR Pulsed Reference Design



- Speed of light ~ 3 x 10^8 m/s
- In 1 picosecond (= 10^{-12} sec) light travels ~ 3 x 10^{-4} m = 0.3 mm
- During 33 picoseconds light travels ~ 1cm

Location & Navigation

Problem:

How to locate yourself? How to navigate?

- In unknown or known environment.

With sensors:

- internal, passive, active, gps, beacons, etc.

With or without reference points.

Solution:

- Collect data to determine starting position, or determine your location.
- Move around while collecting data from your environment.
- Sensor data is noisy => location and map building is a stochastic process.
- SLAM

OpenCV.org

PiBorg: Yetiborg v2

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References

1. L. Pinto, J. Davidson, R. Sukthankar, A. Gupta, Robust Adversarial Reinforcement Learning, arXiv:1703.02702, March 2017.
2. S. Gu, E. Holly, T. Lillicrap, S. Levine, Deep Reinforcement Learning for Robotic Manipulation with Asynchronous Off-Policy Updates, arXiv:1610.00633v2 [cs.RO], October 2016.
3. C. Finn, S. Levine, Deep Visual Forsight for Planning Robot Motion, arXiv:1610.00696, ICRA 2017, October 2016.
4. L. Pinto, J. Davidson, A. Gupta, Supervision via Competition: Robot Adversaries for Learning Tasks, arXiv:1610.01685, ICRA 2017, October 2016.
5. K. Bousmalis, N. Silberman, D. Dohan, D. Erhan, D. Krishnan, Unsupervised Pixel–Level Domain Adaptation with Generative Adversarial Networks, arXiv:1612.05424, CVPR 2017, December 2016.
6. A. Banino et al., Vector-based navigation using grid-like
7. representations in artificial agents, https://doi.org/10.1038/s41586-018-0102-6, Research Letter, Nature, 2018.
8. R. Borst, Robust self-balancing robot mimicking, Bachelor Thesis, August 2017
9. Jie Tan, Tingnan Zhang, Erwin Coumans, Atil Iscen, Yunfei Bai, Danijar Hafner, Steven Bohez, and Vincent Vanhoucke, Sim-to-Real: Learning Agile Locomotion For Quadruped Robots, https://arxiv.org/pdf/1804.10332.pdf , RSS 2018.

Robotics

Universiteit Leiden

Robotics Homework I

Assignment:

Give a link to the coolest, strangest, most impressive, most novel, or technologically inspirational robot you could find. And describe in a short paragraph (< 100 words) why you selected this robot.

NB Boston Dynamics Robot are excluded this time (I know they are very cool).

Grading: Pass/No Pass

Due: Monday 14-2 2022

See BrightSpace Assignment(s) to upload your answer.