Robotics

Erwin M. Bakker| LIACS Media Lab

1-2 2021

Universiteit Leiden

Bij ons leer je de wereld kennen

Organization and Overview

Period: February 1st – May 10th 2021
Time: Tuesday 16.15 – 18.00
Place: https://smart.newrow.com/#/room/qba-943
Lecturer: Dr Erwin M. Bakker (erwin@liacs.nl)
Assistant: Erqian Tang

NB Register on Brightspace

Schedule:

1-2	Introduction and Overview
8-2	No Class (Dies)
15-2	Locomotion and Inverse Kinematics
22-2	Robotics Sensors and Image Processing
1-3	**Yetiborg Introduction + SLAM Workshop I**
8-3	Project Proposals (presentation by students)
15-3	Robotics Vision
22-3	Robotics Reinforcement Learning
29-3	**Yetiborg Qualification + Robotics Reinforcement Learning Workshop II**
5-4	No Class (Eastern)
12-4	Project Progress (presentations by students)
19-4	**Yetiborg Challenge**
26-4	Project Team Meetings
3-5	Project Team Meetings
10-5	**Online Project Demos**

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.

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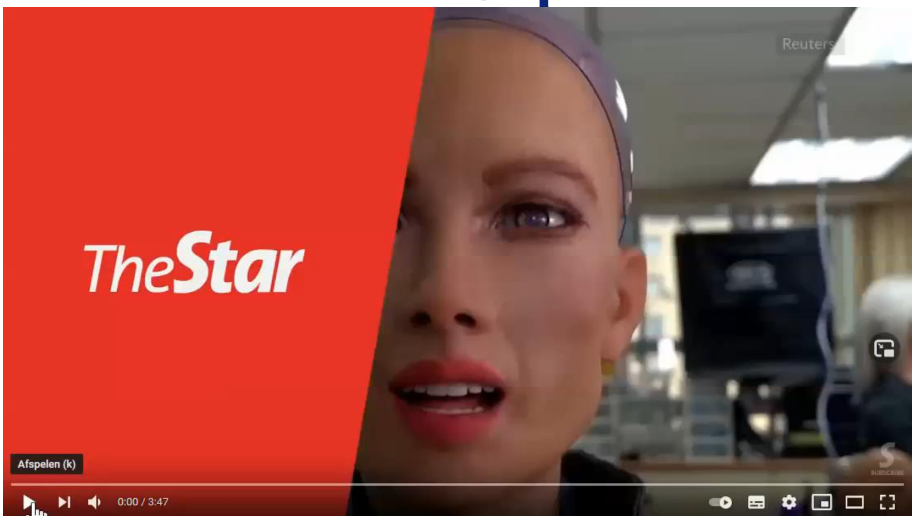
Robotics in the News: Sophia



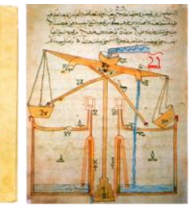
Sophia's creators plan an 'army of robots in 2021.
Jan. 2021, https://www.youtube.com/watch?v=iKpUGYoz2CM

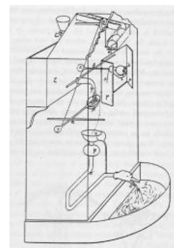
Robotics in the News

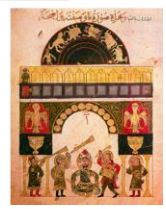
M. Pan et al., Robot Gaze, DisneyResearch, October 2020
https://www.youtube.com/watch?v=D8_VmWWRJgE

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




Leonardo da Vinci (1452 – 1519)

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

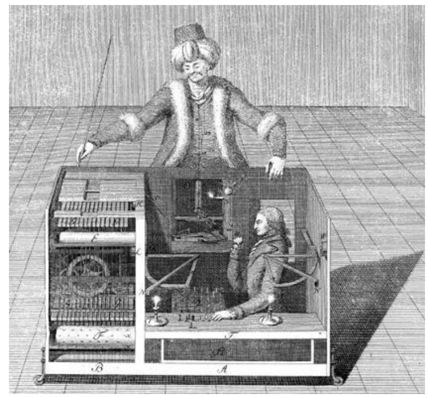




Pictures from:
http://www.leonardo3.net
http://brunelleschi.imss.fi.it

The Turk

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



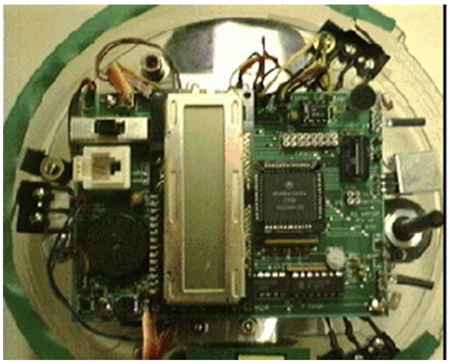
Pictures from:
http://en.wikipedia.org/wiki/The_Turk

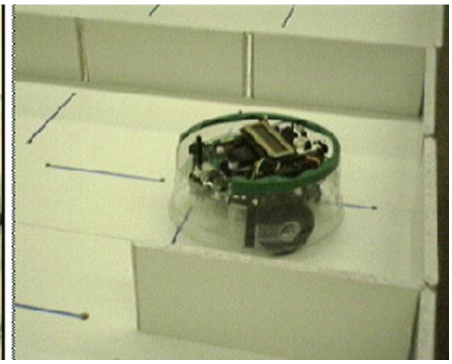
LOCOMOTION & INVERSE KINEMATICS

EARLY ROBOTS

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

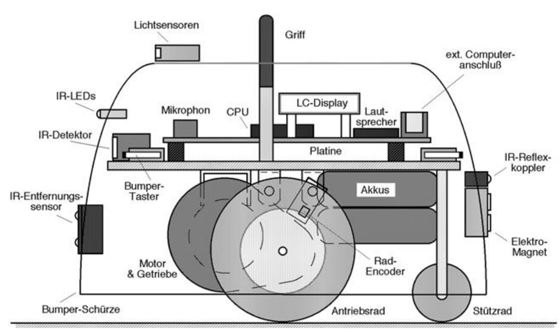
Autonomous Robots for Artificial Life (MIT, T. Braunl, Stuttgart University) 'Rug Warrior'





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);
  }
}
```

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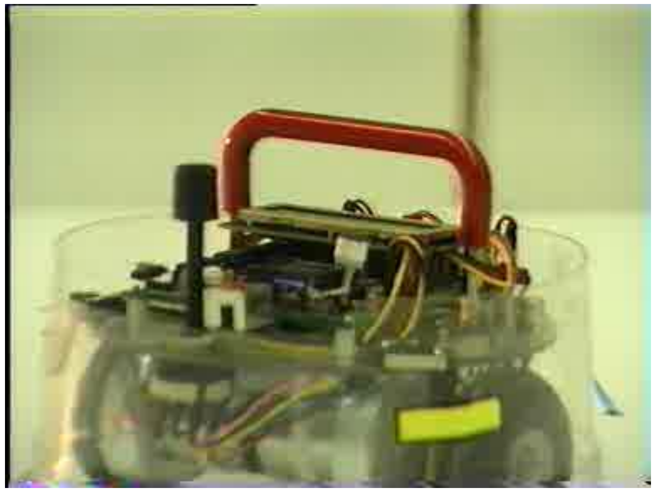
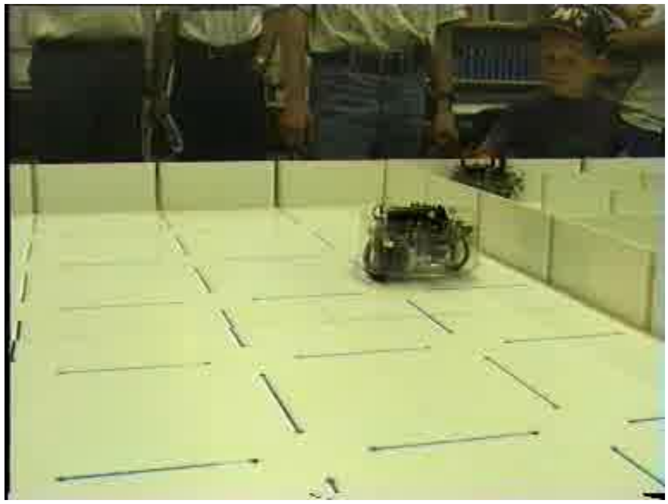
Finding the Light



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



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

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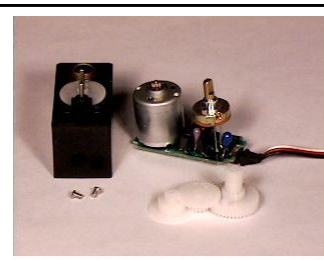
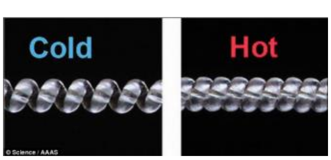
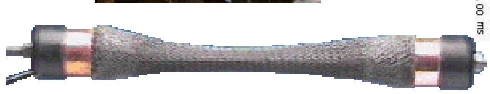
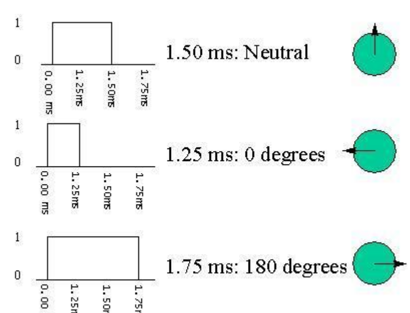
Robotics Actuators

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









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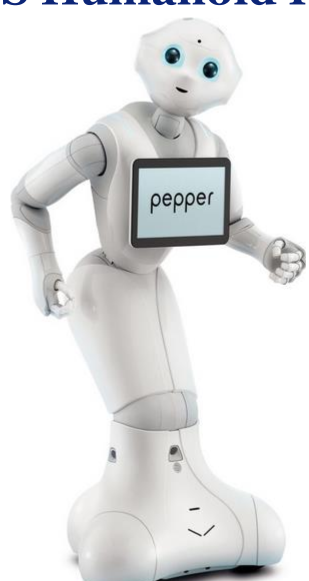
Humanoid Research Platforms

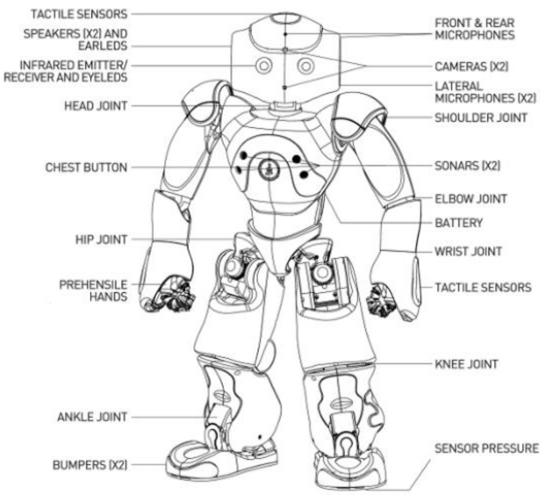
LIACS Humanoid Research Platforms

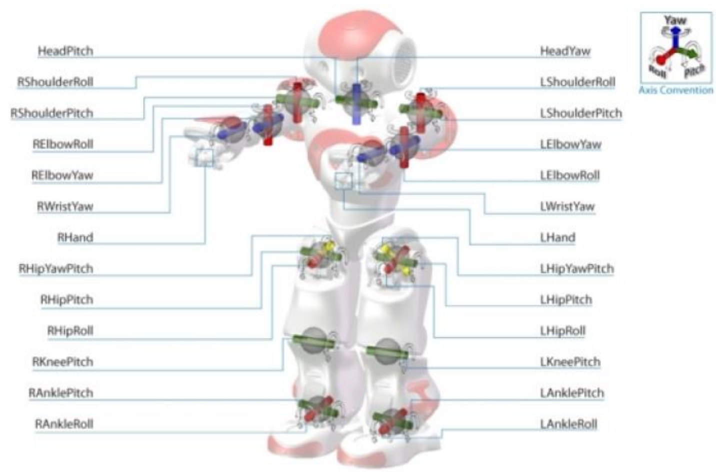


LML

LIACS
MEDIA
LAB

NAO





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

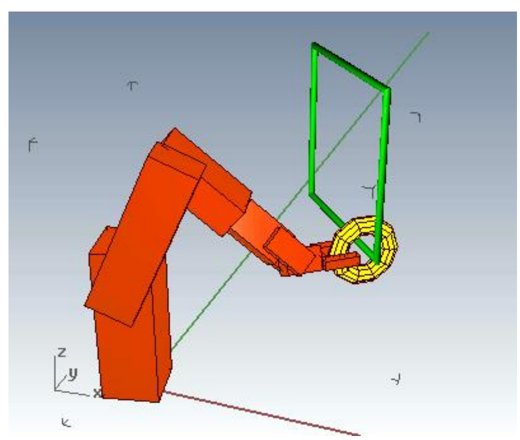
How to move to a goal?

Problem: How to move to a goal?

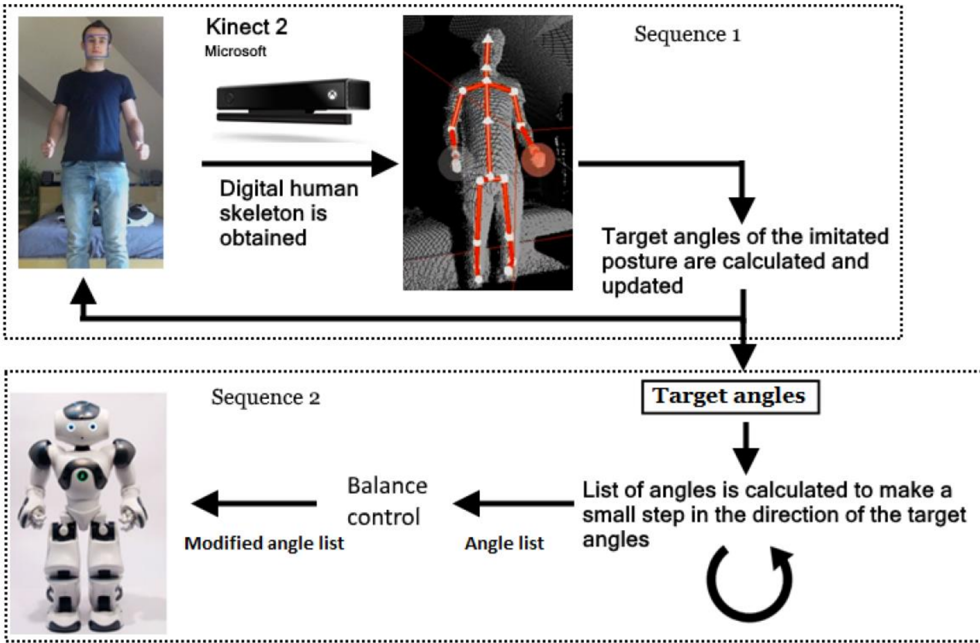
- Grasp, Walk, Stand, Dance, Follow, etc.

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/



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

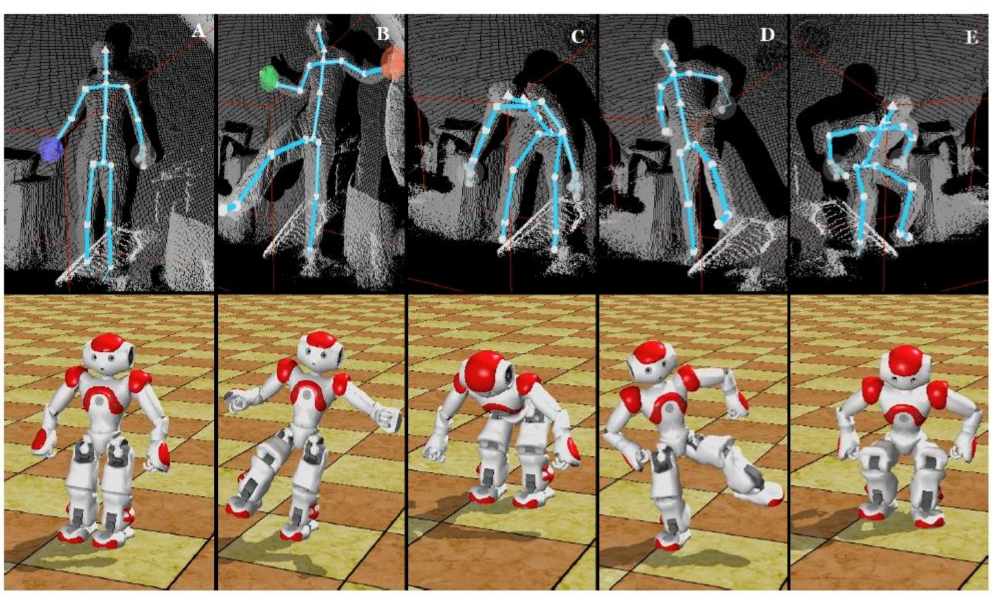


Figure 5.4: The five poses that have been selected to evaluate the effect of the balance controller.

OPNNAR

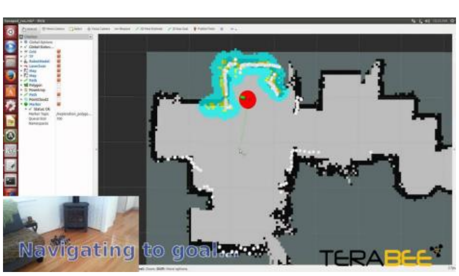
(a) *Start state* (b) *Raise Arm* (c) *Swipe*

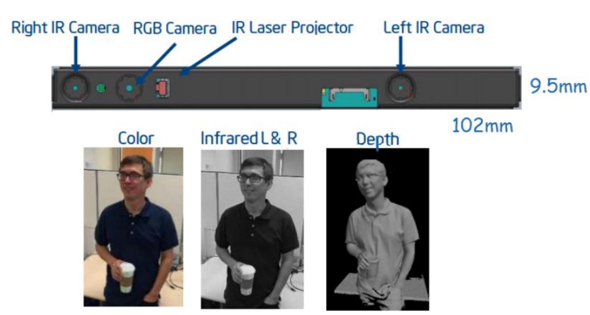
K. Maas, Full-Body Action Recognition from Monocular RGB-Video:
A multi-stage approach using OpenPose and RNNs, BSc Thesis, 2021.

ROBOTICS SENSORS

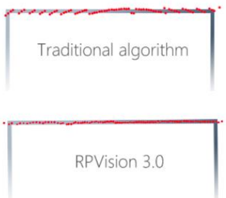
- Bumper switches
- Acceleration, Orientation, Magnetic
- IR/Visible Light
- Pressure, Force
- Ultrasonic, Lidar, Radar
- Camera's, stereo camera's
- Structured Light Camera's

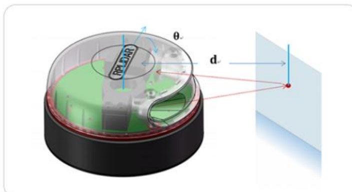
	Ultrasound	Infrared Triangulation	Laser	TeraRanger Time-of-Flight
High reading frequency	✗	✗	✓	✓
Long range	✗	✗	✓	✓
Minimal weight	✓	✓	✗	✓
Small form factor	✓	✓	✗	✓
Eye safety	✓	✓	Class 1 lasers only	✓
Use with multiple sensors	✗	✗	✗	✓



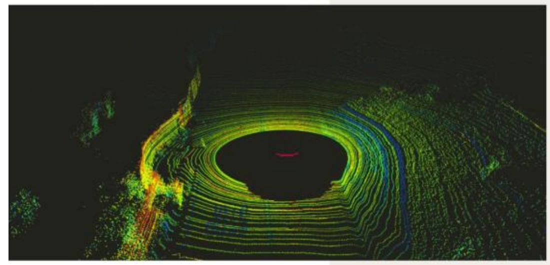


LIDAR Explanation

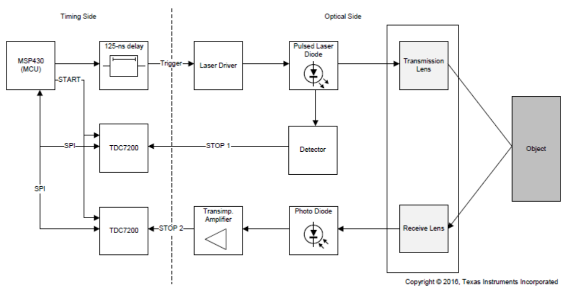




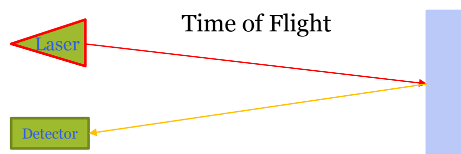
http://www.slamtec.com/en/lidar/A3



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
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Robotics Homework I

Assignment:

Give a link to the coolest, strangest, most impressive, most novel, or technologically inspirational robot you could find.

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

Due: Monday 8-2 at 14.00 PM.

Email your link to erwin@liacs.nl with subject 'Robotics2021'.