

Robotics

Erwin M. Bakker | LIACS Media Lab

5-2 2024



Universiteit
Leiden

Bij ons leer je de wereld kennen

Organization and Overview

Lecturer:

Dr Erwin M. Bakker (erwin@liacs.nl)
Room 126a and LIACS Media Lab (LML)

Teaching assistants:

Xia Tian
Aristidou Kyriakos
Dimitrios Kourmidis
Ruilin Ma

Period: February 5th - May 21st 2024

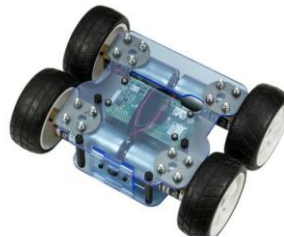
Time: Monday 15.15 - 17.00

Place (Rooms):

a) LMUY Havingazaal

Schedule (tentative, visit regularly):

Date	Subject
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12-2	Locomotion and Inverse Kinematics
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26-2	SLAM + Workshop@Home
4-3	Mobile Robot Challenge Intro
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7-6	Project Deliverables



Grading (6 ECTS):

- Presentations and Robotics Project (60% of grade).
- Class discussions, attendance, assignments (pass/no pass) 2 workshops (0-10) (20% of the grade).
- Mobile Robot Challenge (0-10) (20% of the grade)
- ***It is necessary to be at every class and to complete every workshop and assignment.***

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

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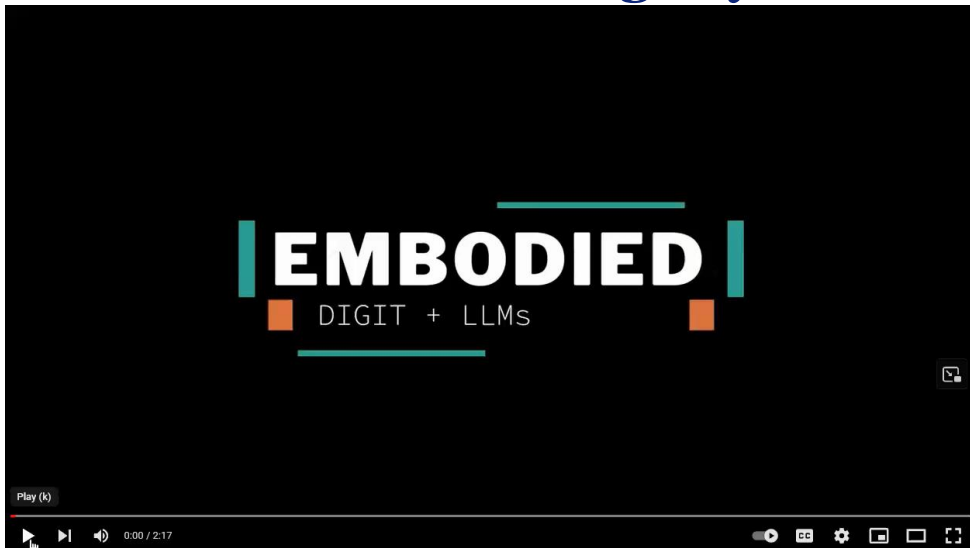
Robotics in the News: Agility Robotics



Cassie sets a Guinness World Record. (No cameras or external sensors.)
 Sept. 28 2022, <https://agilityrobotics.com/news/2022/cassie-sets-a-guinness-world-record>
<https://agilityrobotics.com/news>

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Robotics in the News: Agility Robotics



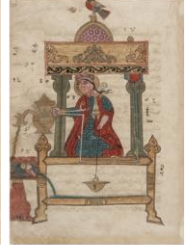
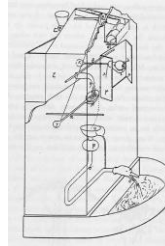
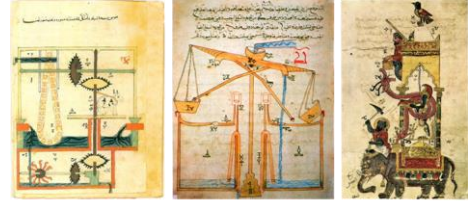
Digit + Large Language Model – Embodied Artificial Intelligence
<https://www.youtube.com/watch?v=CnkMOAecxYA>

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



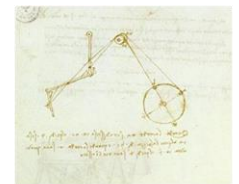
- Mechanisms and methods for automation
- Water-raising machines
- Clocks
- Automata
 - Drink-serving waitress
 - Hand-washing automaton with flush mechanism
 - Peacock fountain with automated servants
 - Musical robot band



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Leonardo da Vinci (1452 – 1519)

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

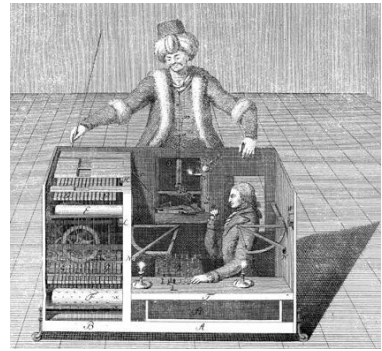
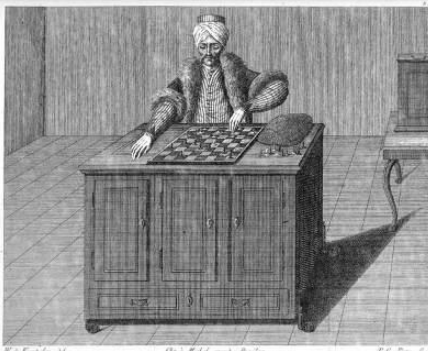


Pictures from:
<http://www.leonardog.net>
<http://brunelleschi.imss.fi.it>

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The Turk

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



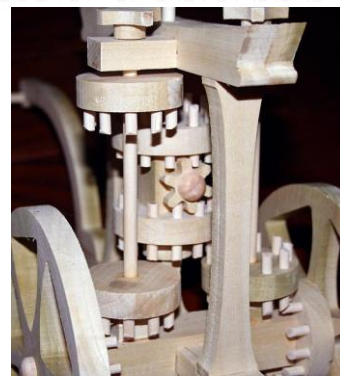
Pictures from:
http://en.wikipedia.org/wiki/The_Turk

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LOCOMOTION & INVERSE KINEMATICS



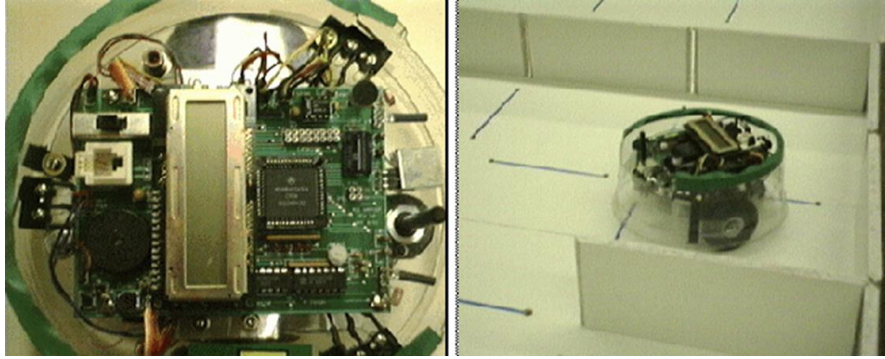
EARLY ROBOTS



[South Pointing Chariot](#)
by [Ma Jun](#) (circa 200–265)
was the first reliably documented version.

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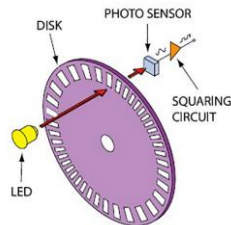
Autonomous Robots for Artificial Life (MIT, T. Braunl, Stuttgart University) 'Rug Warrior'



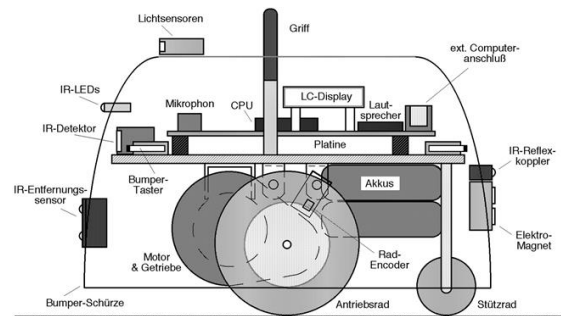
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Autonomous Robots for Artificial Life

- Motorola MC68HC11 microcontroller
- Sensors
- Bumper
- Photoresistors (2)
- Infrared Obstacle Detectors w. 2 infrared LED's
- Microphone
- Two Shaft-Encoders



<https://www.analogictips.com/rotary-encoders-part-1-optical-encoders/>



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

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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](#) (2012⁺): 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., written in C++. Python, or LISP www.ros.org

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Autonomous Robots for Artificial Life



Straight ahead

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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"); }

```

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Straight Ahead

```

void fahre_geradeaus() // Adapt left and right speed
{ int d; // to get same number of
  while(TRUE) // clicks for each wheel
  { 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);
  }
}

```

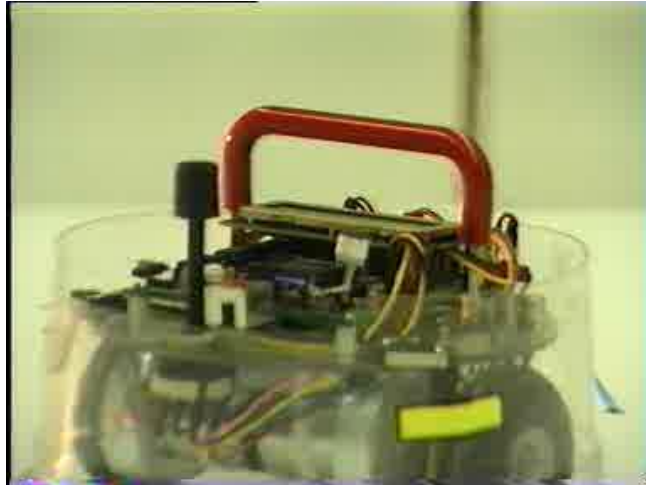
```

void clicks() // Continuously read out odometer clicks
{ 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);
  }
}

```

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Finding the Light



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Finding the Light

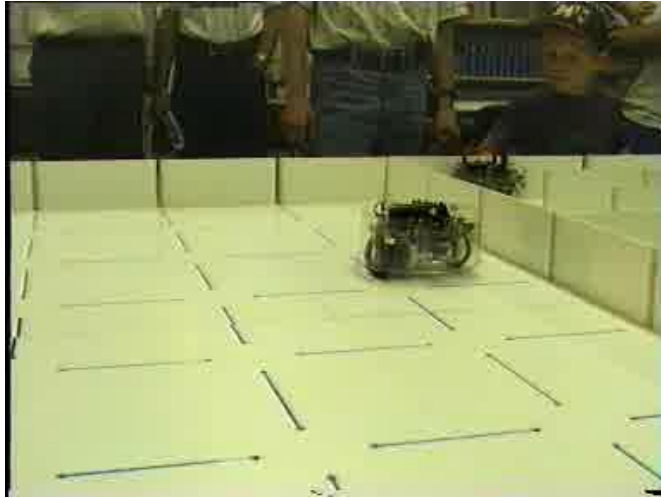
```

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);
}

```

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Finding the Light 2



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Mechanical Tortoise (1951)



British Pathé, 1951.

YouTube: <https://www.youtube.com/watch?v=wQE82derooc&t=14s>

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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.



TurtleBot 4



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Vacuum Cleaner & Lawn Mower



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TurtleBot4 with ROS



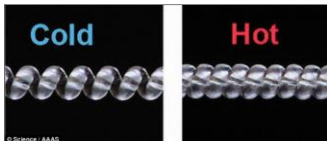
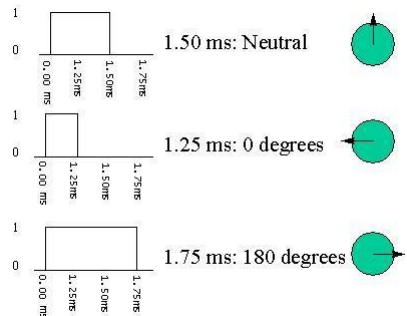
www.ros.org

TurtleBot 4	TurtleBot 4 Lite
341 x 339 x 351 mm	341 x 339 x 192 mm
3.9 kg	3.3 kg
15 kg & 0.31 m/s	15 kg & 0.31 m/s
2.5 - 4.0 hrs (load dependent)	2.5 - 4.0 hrs (load dependent)
OAK-D-PRO	OAK-D-LITE
RPLIDAR-A1	RPLIDAR-A1
Yes	No
Yes	No
Yes	No
ROS 2	ROS 2
Raspberry Pi 4B (4 GB)	Raspberry Pi 4B (4 GB)

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Robotics Actuators

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



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A robot balanced on a ball

*Tohoku gakuin univ.
Robot development engineering lab.*

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Caltech's Leonardo



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

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Humanoid Research Platforms



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LIACS Humanoid Research Platforms

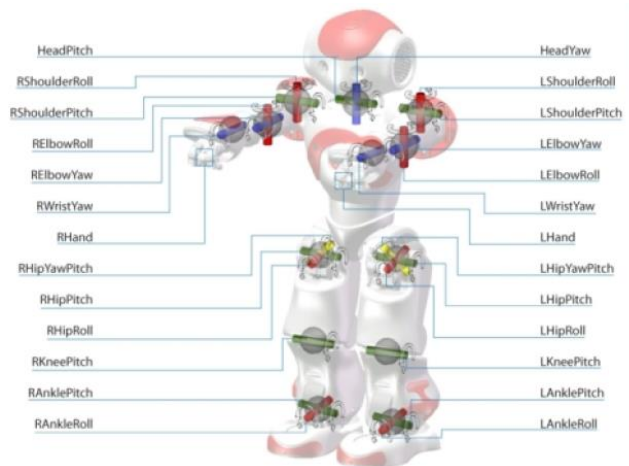
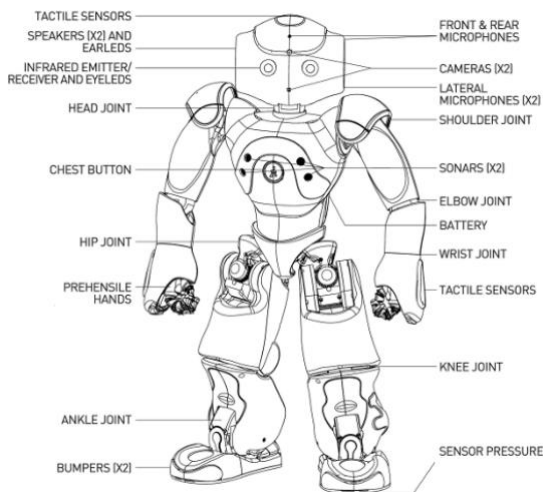


LML

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NAO



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

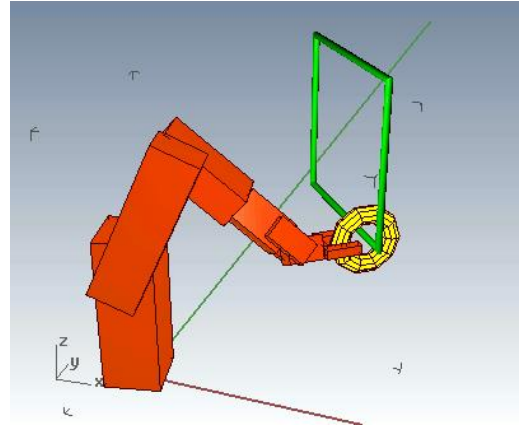
How to move to a goal?

Problem: How to move to a goal?

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

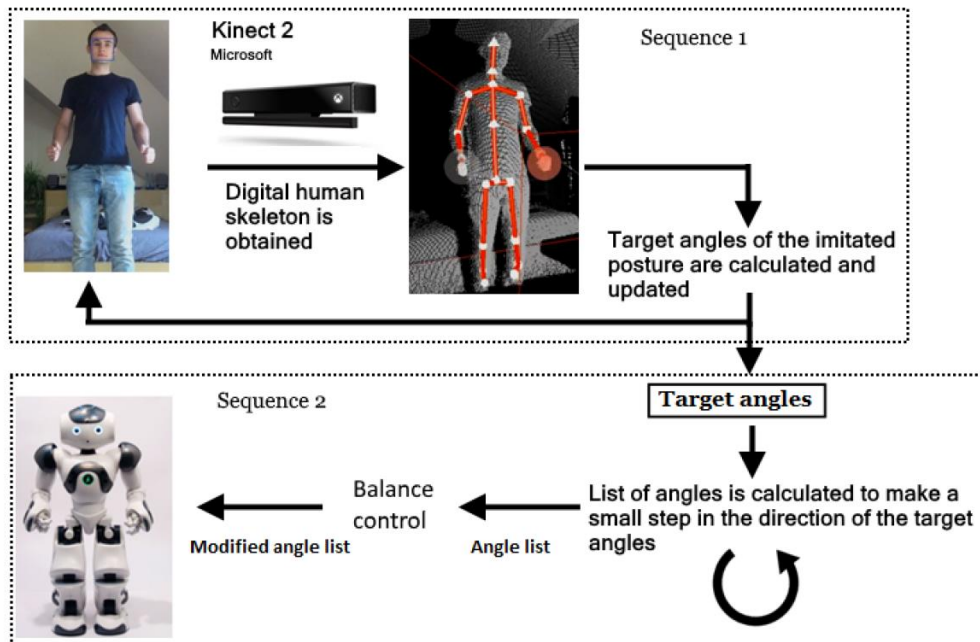
Solution:

- 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

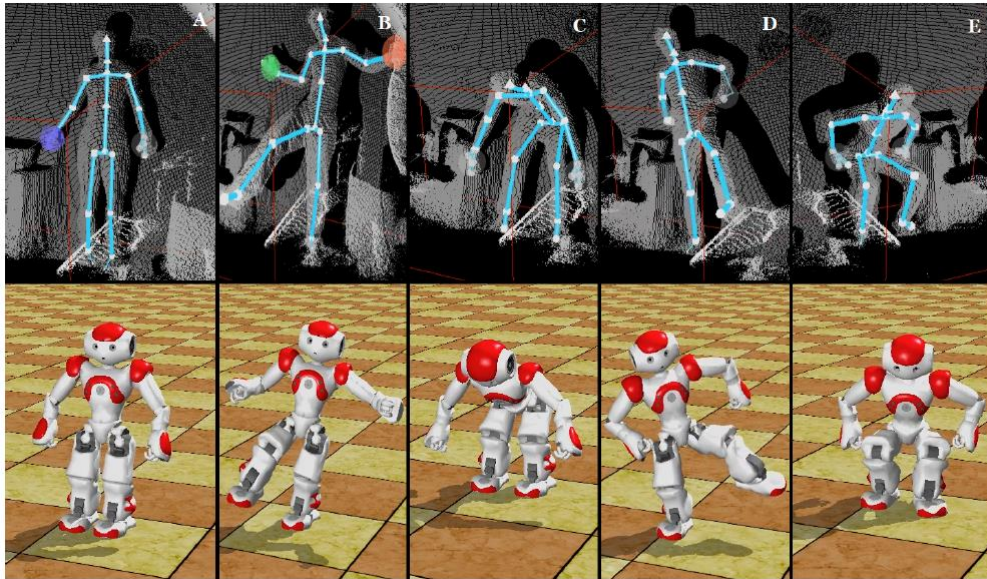


Figure 5.4: The five poses that have been selected to evaluate the effect of the balance controller.

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

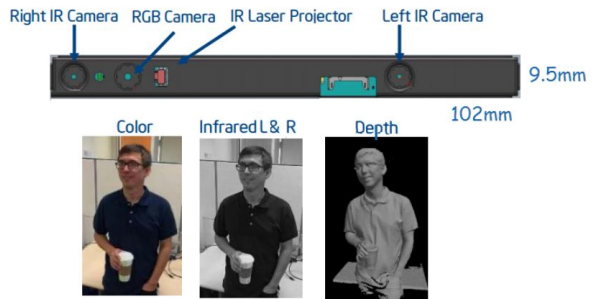
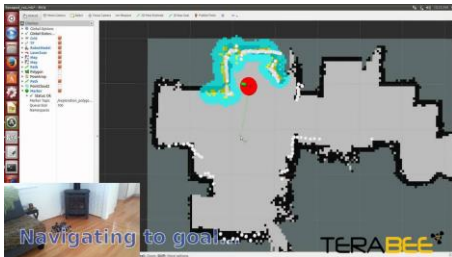
- Bumper switches
- Acceleration, Orientation, Magnetic
- IR/Visible Light
- Pressure, Force
- Ultrasonic, Lidar, Radar
- Camera's, stereo camera's
- Structured Light Camera's

The perfect anti-collision solution for any environment

Technology Comparison

distance sensors for robotics

	Ultrasonic	Infrared Triangulation	Laser	TeraRanger Time of Flight
High reading frequency	✗	✗	✓	✓
Long range	✗	✗	✓	✓
Minimal weight	✓	✓	✗	✓
Small form factor	✓	✓	✗	✓
Eye safety	✓	✓	Class I hazard only	✓
Use with multiple sensors	✗	✗	✗	✓

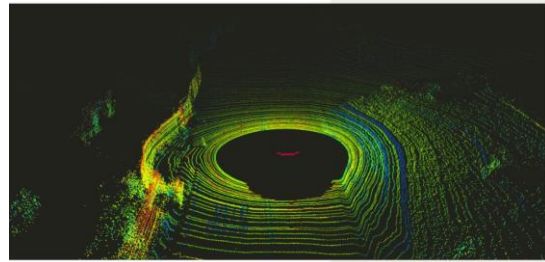


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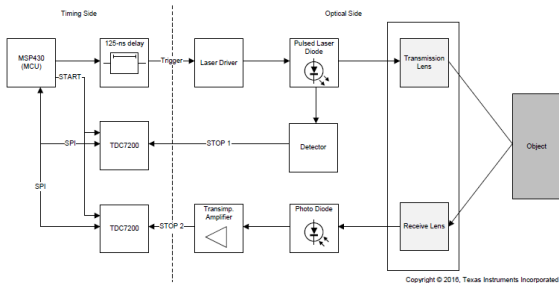
LIDAR Explanation



<http://www.slamec.com/en/lidar/A3>

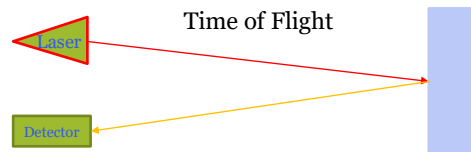


<https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff>



Copyright © 2010, Texas Instruments Incorporated

Texas Instruments LIDAR Pulsed Reference Design



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

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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

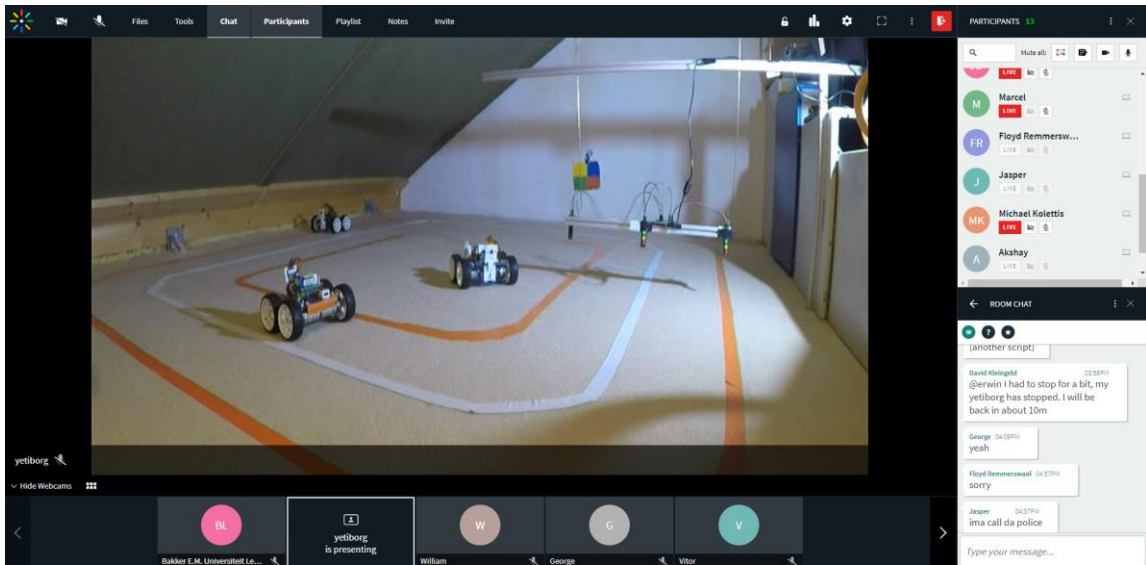
OpenCV.org

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PiBorg: Yetiborg v2



YetiBorg Challenge 2021



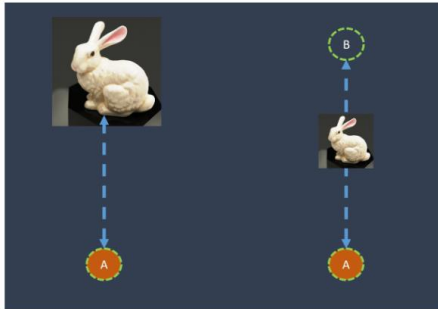
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YetiBorg Challenge 2022

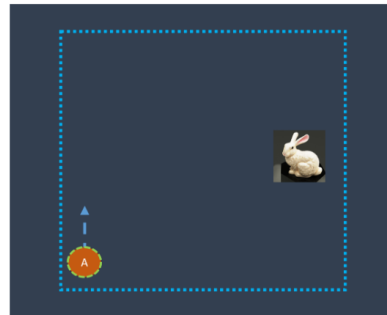


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YetiBorg Challenge 2023



Unknown object detection,
distance estimation and avoidance.



Unknown object search.

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Hand Gesture Recognition on the JetRacer (2022) by Bosong Ding, Nan Sai, Yingjie Li, Zilantian Zhu

JetRacer

- Nvidia Jetson Nano
 - CPU Quad-core ARM A57
 - GPU: 128-core Maxwell
- Yolov3 for detecting objects and hand gestures
- Following objects



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https://www.youtube.com/watch?v=yX_F-Th_Bz4

Autonomous Driving: Real Time Kinematic (RTK) GPS



ZED-F9P Base Station



ZED-F9P Rover

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Organization and Overview

Lecturer:

Dr Erwin M. Bakker (erwin@liacs.nl)
Room 126a and LIACS Media Lab (LML)

Teaching assistants:

Xia Tian
Aristidou Kyriakos
Dimitrios Kourmtidis
Ruilin Ma

Period: February 5th - May 21st 2024

Time: Monday 15.15 - 17.00

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a) LMUY Havingazaal

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

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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 Foresight 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, Atıl İscen, 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.

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Robotics



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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. And describe in a short paragraph (< 100 words) why you selected this robot and what its scientific novelty is. Also give, if possible, a reference to a scientific paper related to the robot.

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

Grading: Pass/No Pass

Due: Monday 12-2 2024

See BrightSpace Assignment(s) to upload your answer in a pdf file,

NB Add a good title, date, your name, email-address and study.