

Introduction to Mobile Robotics

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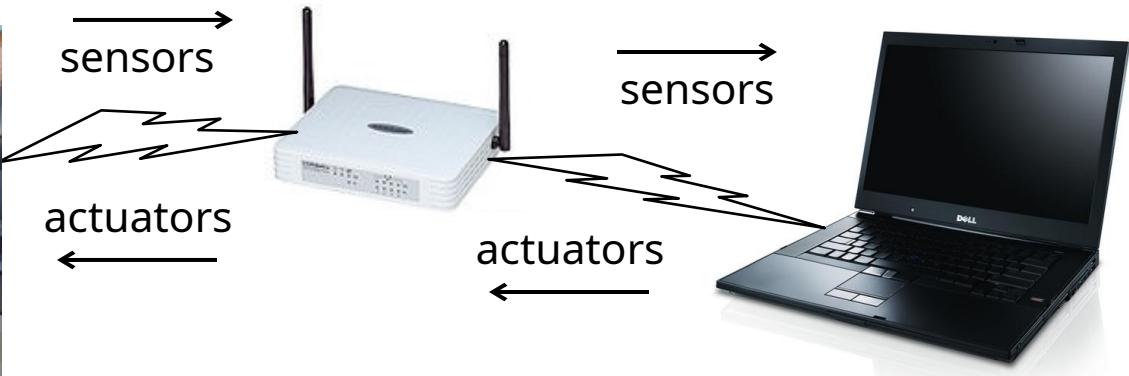


What is a robot ?

Robot = mechatronic system with perception, decision and action skills, capable of carrying out different tasks in the real world, in an autonomous way.



The robot of the day



- 1 raspberry pi3:
 - ubuntu + ROS
- Sensors
 - 1 laserscanner
- Actuators
 - 2 wheels driven by 2 motors + encoders
- 1 PC Ubuntu + ROS
 - In charge of sensor data acquisition, processing & visualization;
 - In charge of controlling actuators.

Outline

1. Sensors and actuators
2. ROS
3. Perception
4. Decision
5. Action
6. Examples of applications
7. Conclusion

Sensor (1/3)

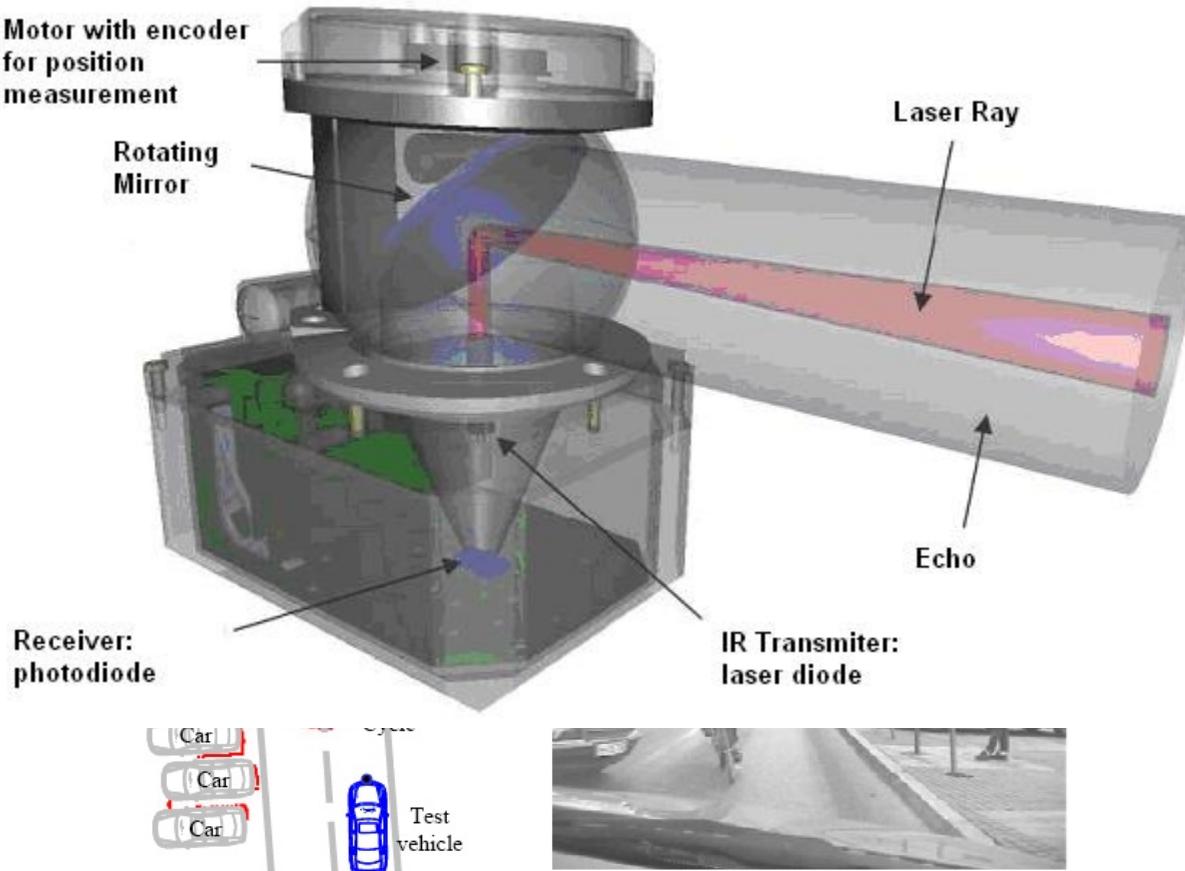
- A **sensor** is an instrument measuring a physical property of the environment;
- Sensors are imprecise and limited;
- The environment of a robot is generally complex, changing, unpredictable and uncertain;
- Understanding the world in which a robot evolves remains a challenge.



Courtesy of sick

Sensor (1/3)

- A **sensor** is an instrument measuring a physical property of the environment;
- Sensors
- The environment is unpre
- Under challenge



Courtesy of sick

Sensor (2/3)

- Robair is equipped with a 2D laser scanner;
- The laser scanner has:
 - a range of about 5.5 meters;
 - a field of view of 240 degrees;
 - an angular resolution of 1/3 degrees.
- Output: a table with 725 elements (r, Θ)
- Laser data are acquired in the trigonometric way
- Polar to cartesian:
 - $X = r \cos (\Theta);$
 - $Y = r \sin (\Theta).$
- Quality of data depends on distance, angle...
- The frequency of acquisition is of about 40 Hz
- The laser scanner costs about 900 euros.



Sensor (3/3)

Polar space:

$(r[i], \theta[i])$ with i in $[0..724]$

Cartesian space:

$(x[i], y[i])$ with i in $[0..724]$

$+\pi/2$
radians

$+2\pi/3$
radians

$r[724], \theta[724]$
 $x[724], y[724]$

0
radian

$r[362], \theta[362]$
 $x[362], y[362]$

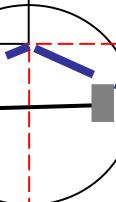
Field Of View
(FOV)

$-\pi/2$
radians

$-2\pi/3$
radians

$r[0], \theta[0]$
 $x[0], y[0]$

$+\pi$ radians = $-\pi$
radians

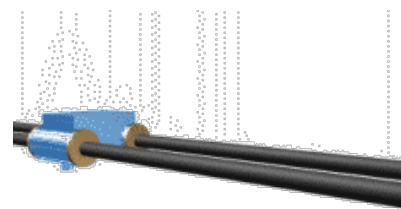
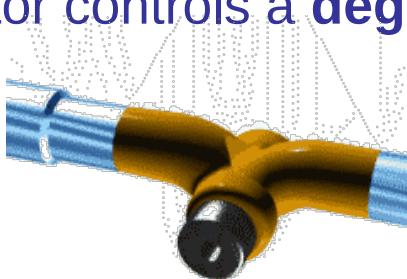


y

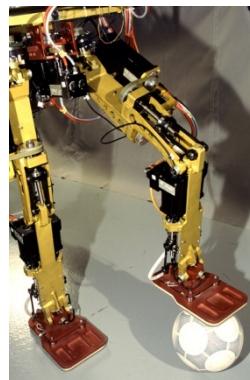
x

Actuators of a mobile robot

- An **actuator** is a component of a machine that is responsible for moving or controlling a mechanism or system;
- An actuator controls a **degree of freedom** (rotation, translation);



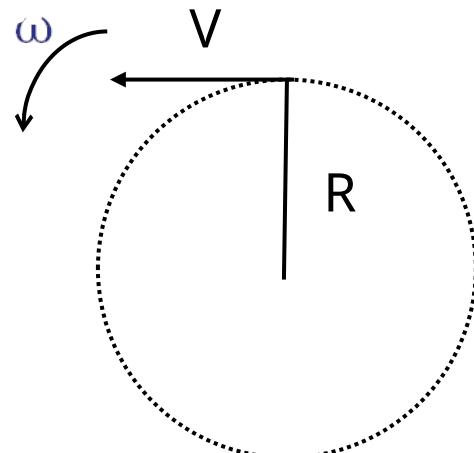
- Actuators could be complex.



Courtesy of Thierry Fraichard

Actuators of robair (1/3)

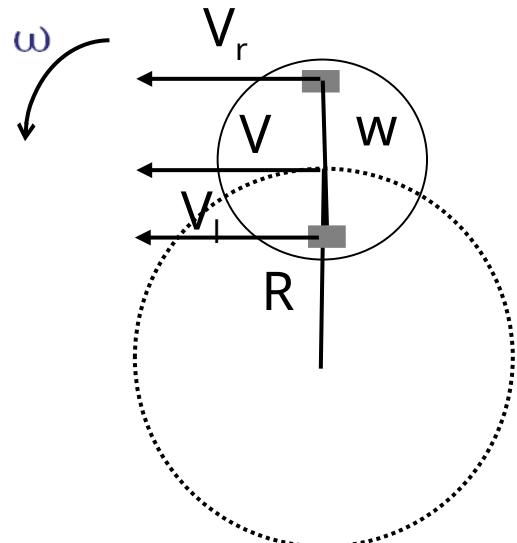
- Robair has 2 wheels controlled by 2 motors;
- Robair is a differential drive robot;
- Simplest and most used kinematic model of robot.



- A **monocycle** describes a virtual circle of radius R ;
- We have $V = R \omega$

Actuators of robair (2/3)

- Robair has 2 wheels controlled by 2 motors;



- We have $V = R \omega$
- We have $V_r = (R + w/2) \omega$
- We have $V_l = (R - w/2) \omega$

- We find:

$$R = \frac{w}{2} \frac{V_r + V_l}{V_r - V_l}$$

Actuators of robair (3/3)

- Finally, we have the direct kinematic model:

$$\omega = \frac{V_r - V_l}{w} \quad (1) \qquad V = \frac{V_l + V_r}{2} \quad (2)$$

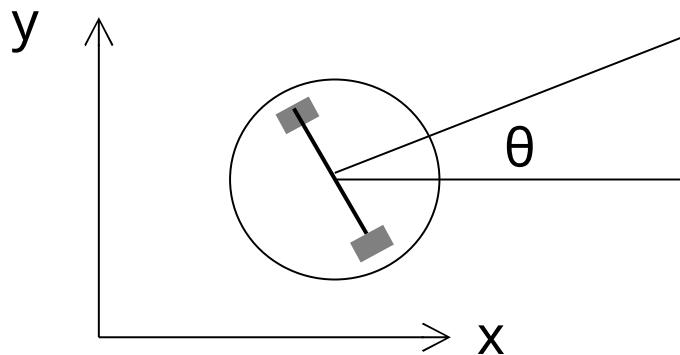
- Controlling (V_l, V_r) , we can determine (V, ω)

$$V_r = V + \frac{w}{2}\omega \qquad V_l = V - \frac{w}{2}\omega$$

- To simplify the control (at the beginning), we will perform translation OR rotation in place

Estimation of motion: encoder

- While Robair is moving in its environment, we would like to know its position in this environment;
- Its position is determined by its position (x, y) in the environment + its orientation θ : (x, y, θ)
- **X-axis is aligned with the angle 0 of the laser**



- On each wheel, there is a system (named encoder) able to estimate the distance traveled by each wheel over a short time Δt

Estimation of position: odometry (1/7)

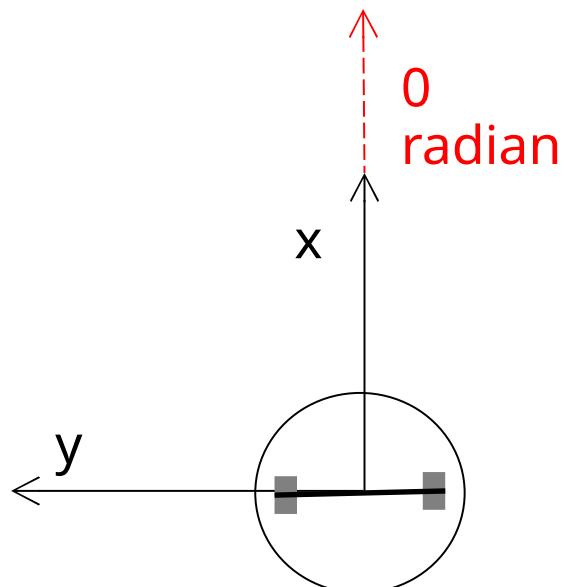
- We call d_l and d_r the distance traveled by each wheel over Δt

$$d = \frac{d_r + d_l}{2} \text{ using (2)} \quad \theta = \frac{d_r - d_l}{w} \text{ using (1)}$$

- $x_t = x_{t-1} + d \cos(\theta)$
- $y_t = y_{t-1} + d \sin(\theta)$
- $\theta_t = \theta_{t-1} + \theta$

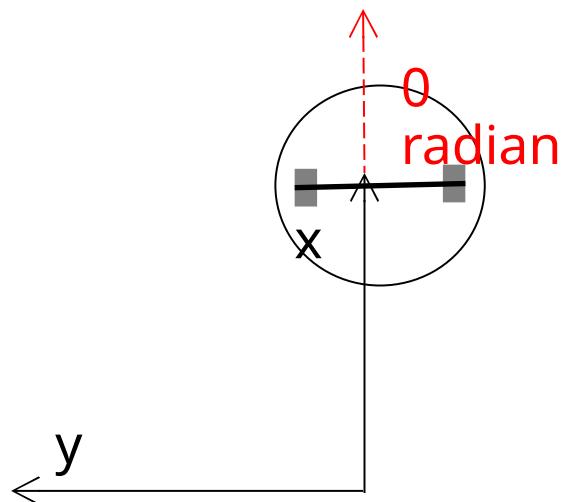
Estimation of position: odometry (2/7)

- When we start robair, odometry is ($x=0m$, $y=0m$,



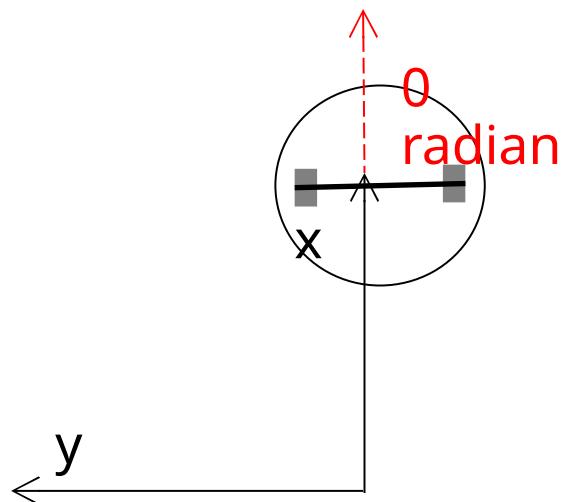
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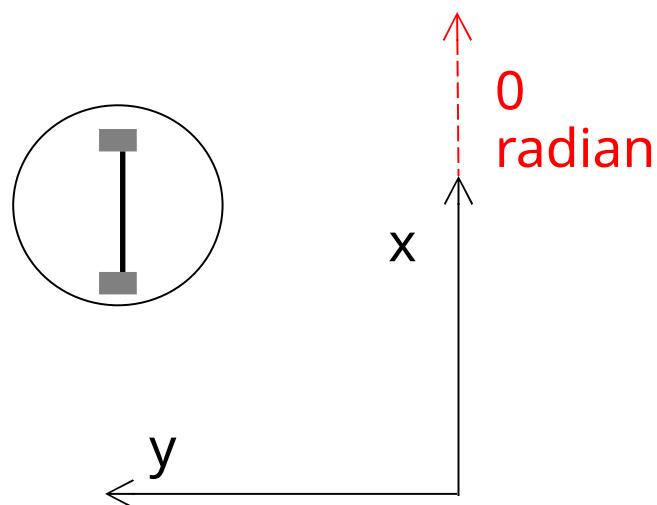
Estimation of position: odometry (4/7)

- When we start robair, odometry is ($x=0m$, $y=0m$,



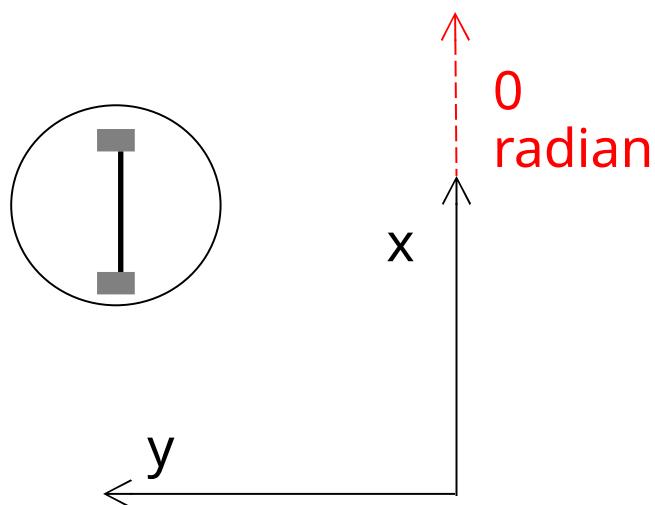
Estimation of position: odometry (5/7)

- When we start robair, odometry is ($x=0m$, $y=0m$,



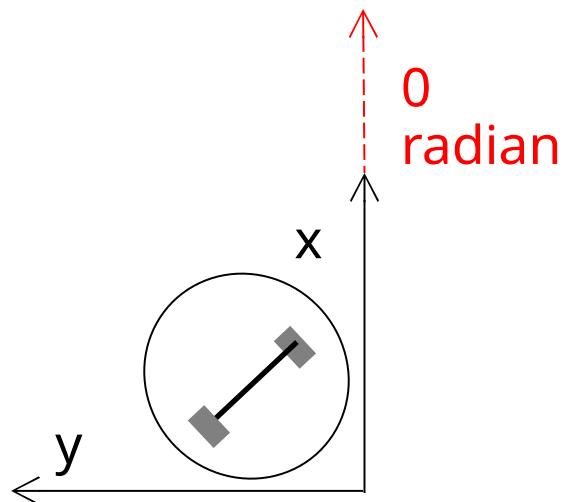
Estimation of position: odometry (6/7)

- When we start robair, odometry is ($x=0m$, $y=0m$,



Estimation of position: odometry (7/7)

- When we start robair, odometry is ($x=0m$, $y=0m$,



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ROS in a nutshell

- **ROS (Robot Operating System)** is a middleware for controlling robotic components from a PC: robots.ros.org;
- ROS is open source and a standard for software architecture development in robotics;
- ROS is based on 2 important concepts:
 1. A number of independent nodes;
 2. Messages (or topics) that are published by some nodes and subscribed by some nodes;
=> Messages are used to exchange information between nodes;

ROS in a nutshell

- **ROS (Robot Operating System)** is a middleware for controlling robotic components from a PC;
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 1. A number of independent nodes;
 2. Messages (or topics) that are published by some nodes and subscribed by some nodes;
- Next slides introducing ROS are based on [89-685: Introduction to Robotics \(biu.ac.il\)](#) (lecture 1, slide 8-11)

Robots using ROS

- <http://wiki.ros.org/Robots>



[Fraunhofer IPA Care-O-bot](#)



[Videre Erratic](#)



[TurtleBot](#)



[Aldebaran Nao](#)



[Lego NXT](#)



[Shadow Hand](#)



[Willow Garage PR2](#)



[iRobot Roomba](#)



[Robotnik Guardian](#)



[Merlin miabotPro](#)



[AscTec Quadrotor](#)



[CoroWare Corobot](#)



[Clearpath Robotics Husky](#)



[Clearpath Robotics Kingfisher](#)



[Festo Didactic Robotino](#)

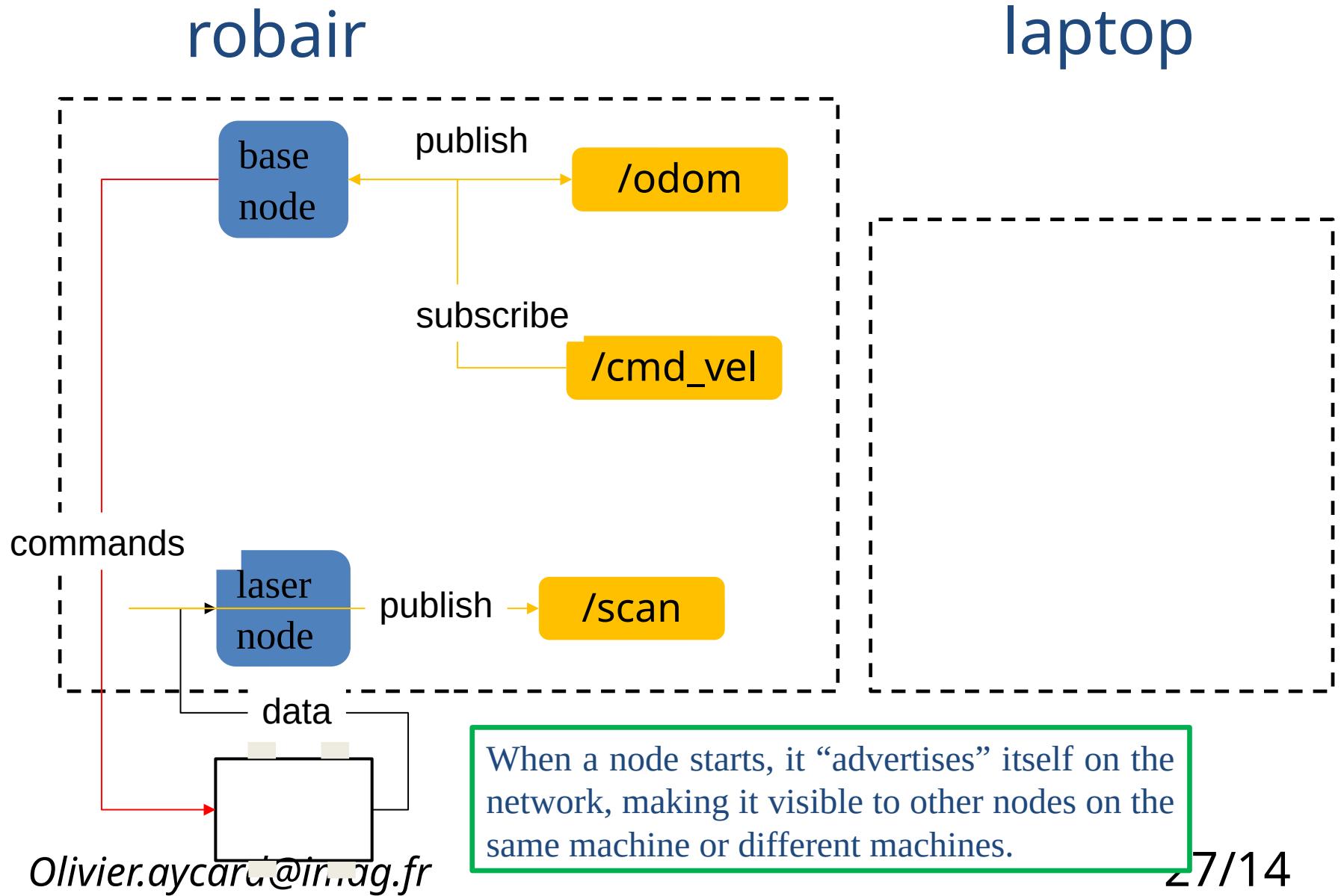
ROS nodes

- Single-purposed executable programs
 - e.g. sensor driver(s), actuator driver(s), mapper, planner, UI, etc.
- Individually compiled, executed, and managed
- Nodes are written using a ROS **client library**
 - C++ client library
 - python client library (not provided in this course)
- Nodes can publish or subscribe to a Topic

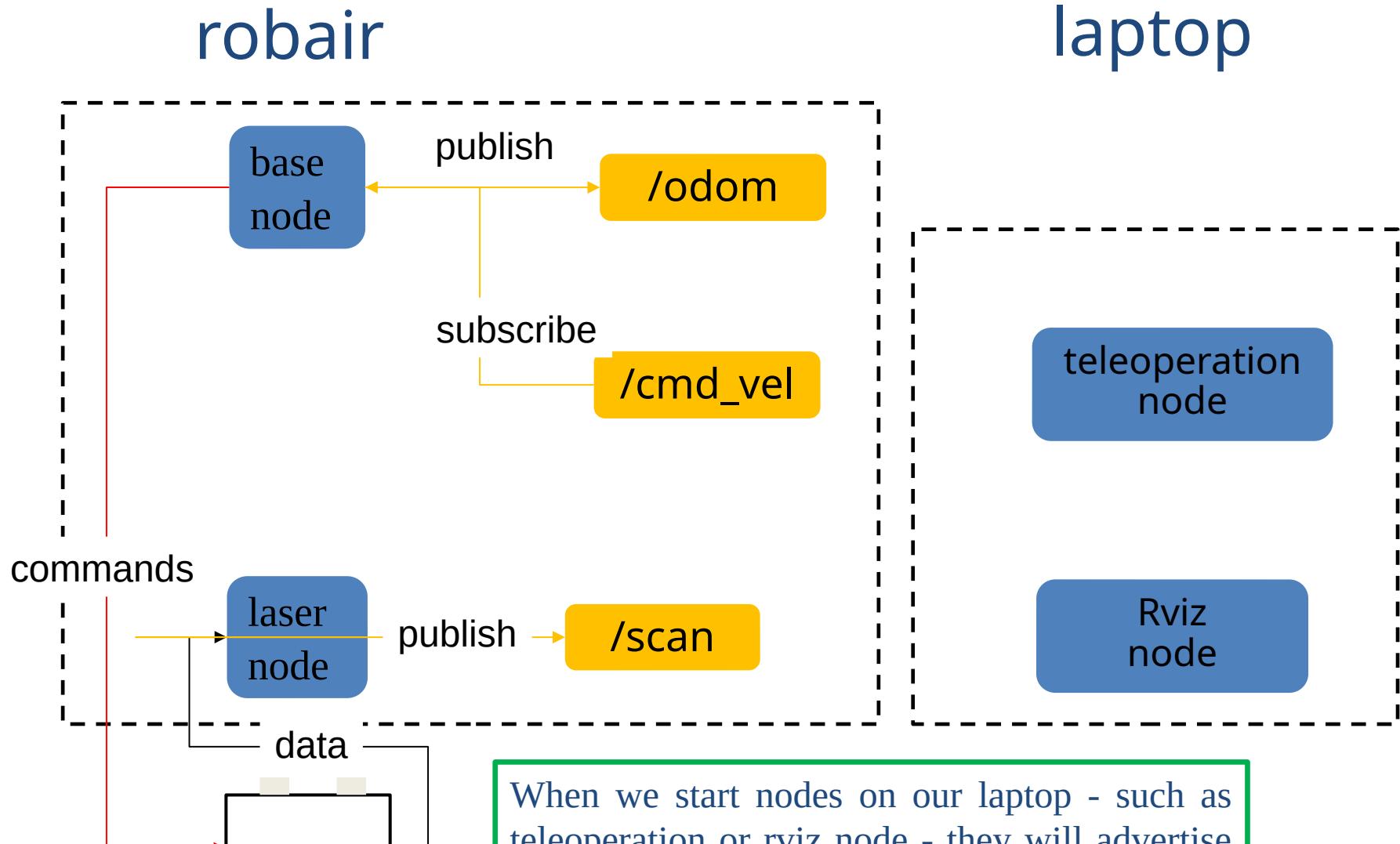
ROS topics

- A topic is a name for a stream of messages with a defined type
 - e.g., data from a laser range-finder might be sent on a topic called scan, with a message type of LaserScan
- Nodes communicate with each other by publishing messages to topics
- Publish/Subscribe model

ROS on robair (2/5)

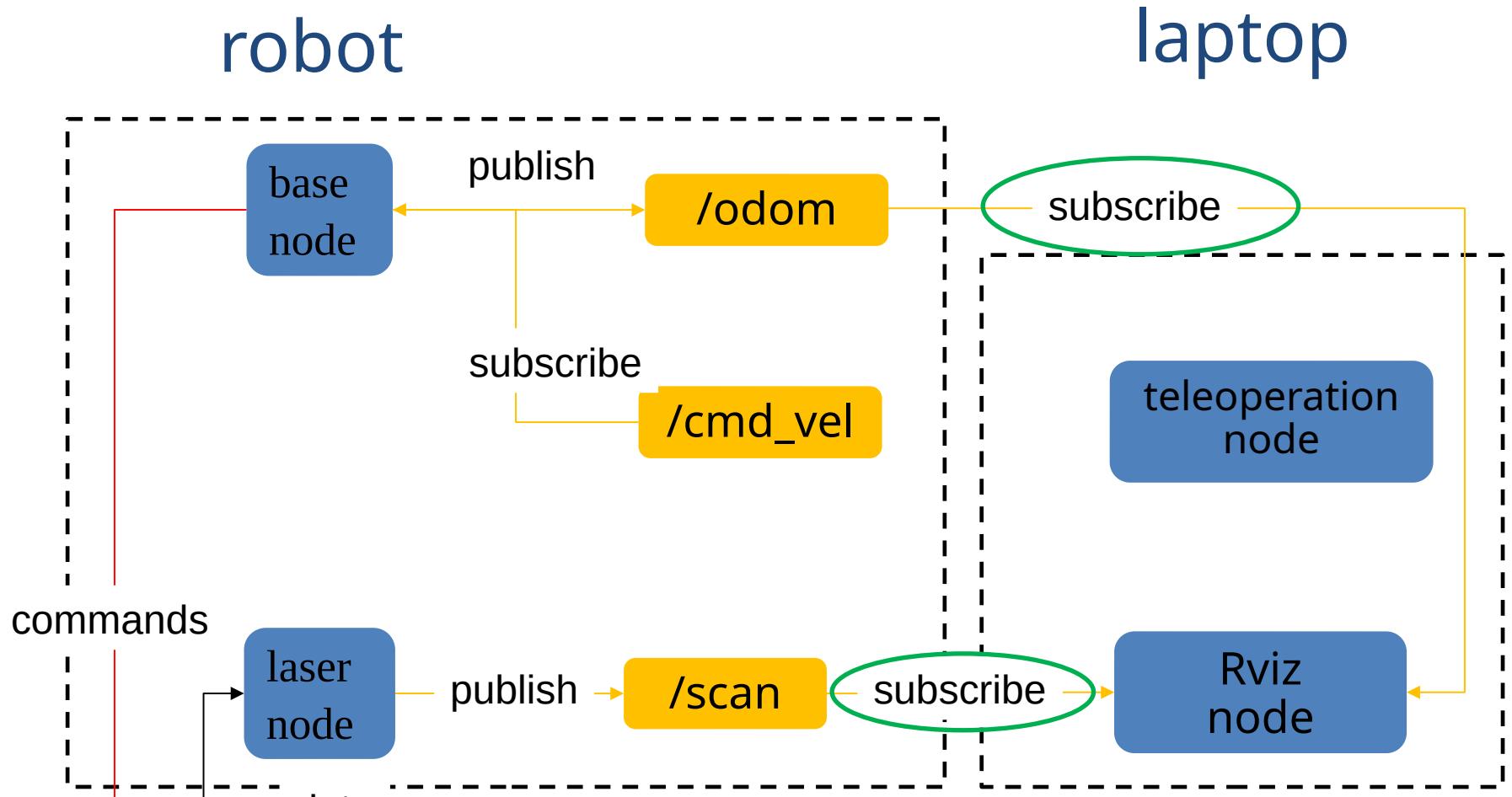


ROS on robair (3/5)



When we start nodes on our laptop - such as teleoperation or rviz node - they will advertise themselves, and see the nodes and topics running on RobAIR.

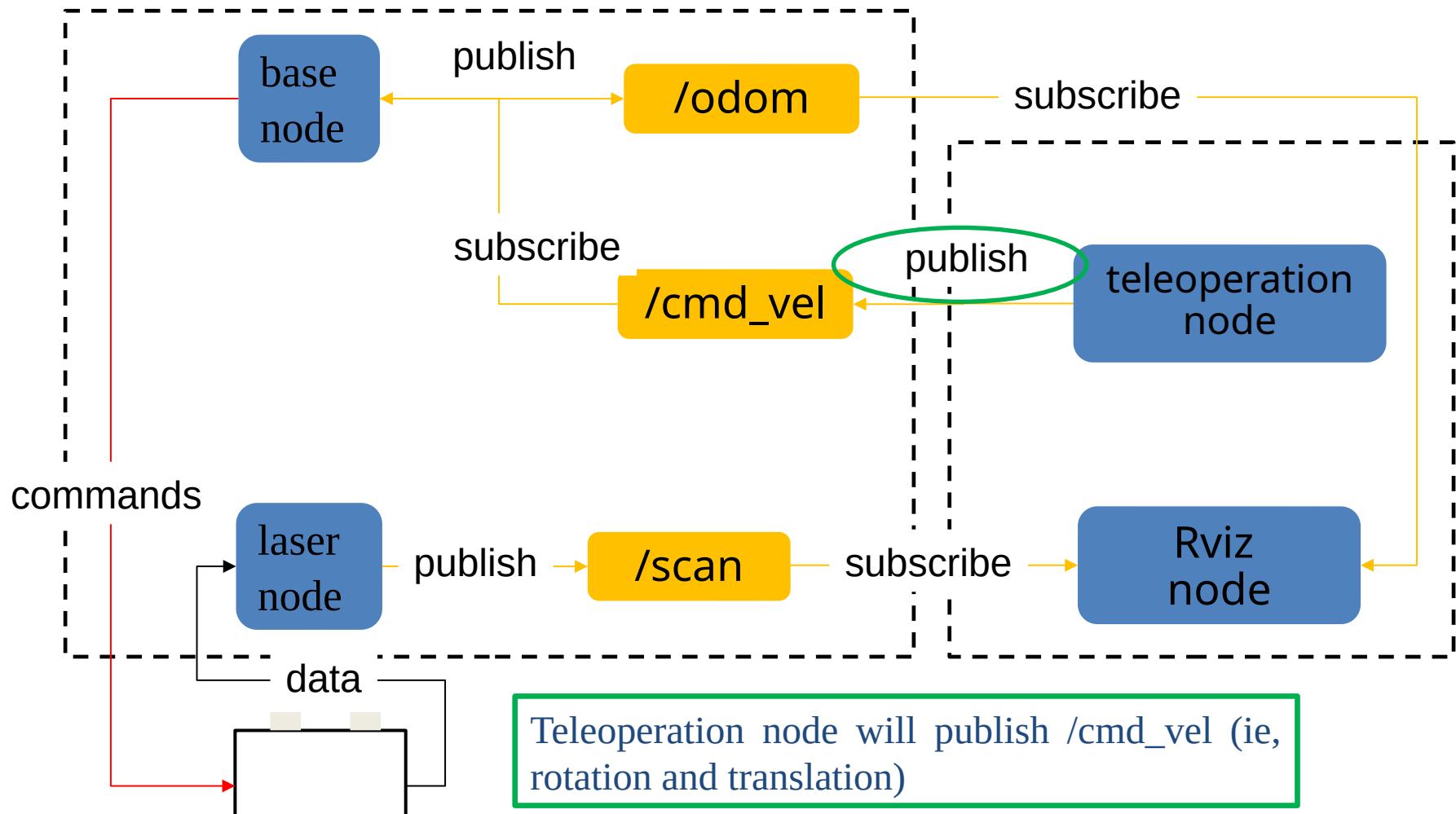
ROS on robair (4/5)



ROS on robair (5/5)

robot

laptop



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Perception

Goal

- Robot perception in dynamic environments
- **Laser scanner**
- Speed and robustness



Present Focus: interpretation of raw and noisy sensor data

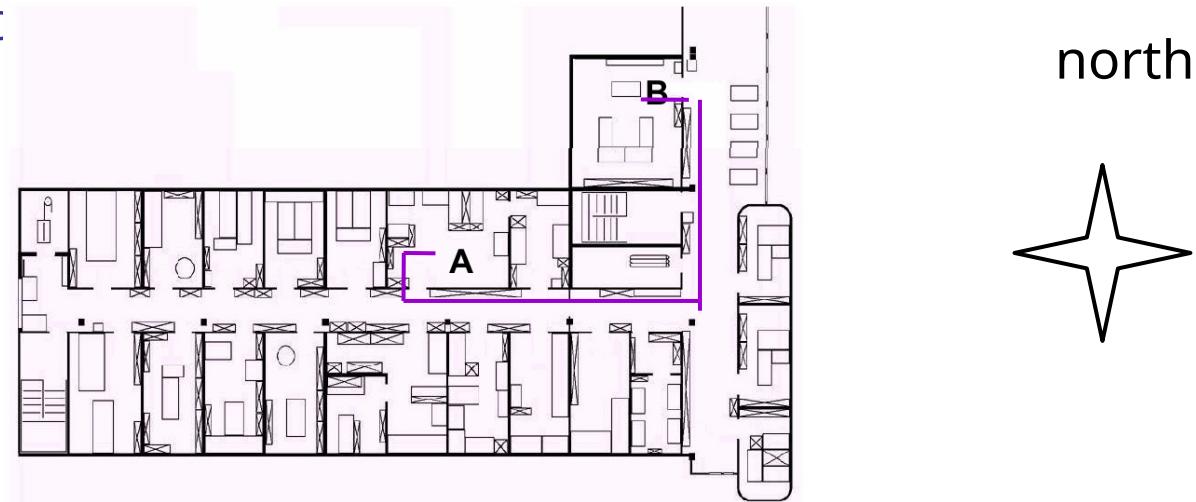
- Identify static and dynamic part of sensor data
- Modeling dynamic part of the environment
 - **Detection And Tracking of Moving Objects (DATMO)**
- Modeling static part of the environment
 - **Simultaneous Localization And Mapping (SLAM)**

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Decision/Plan of future actions

- Most of the time, a mobile robot has to move in its environment:
 - It needs to plan its future actions
- The mobile robot has a map and it knows where it is in the map (position A for instance);
- It should reach an other position in the map (position B for instance)
- **Question:** How to get there ?
- Answer: sequence of actions to go from A to B that is feasible and without collision



West, South, East (12 times), North (6 times), West (twice)

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Action/control/navigation

- The mobile robot has a sequence of actions to execute, to reach its goal: it has to execute this sequence of actions:
 - Typical action in our case: “move to (x, y)”;
 - Monitoring of execution: we monitor what happen and react if needed.
 - We need to be able to estimate actions/motions of the mobile robot;
 - Collision detection/avoidance: the mobile robot should be able to detect (and avoid) collision.

Examples of applications(1/3)

- Advanced driver assistant system (ADAS) or autonomous vehicles



Darpa Urban Challenge 2007



IP Prevent 2008

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Google car



Google car

2016

37/41

Examples of applications(2/3)

- Service robotics



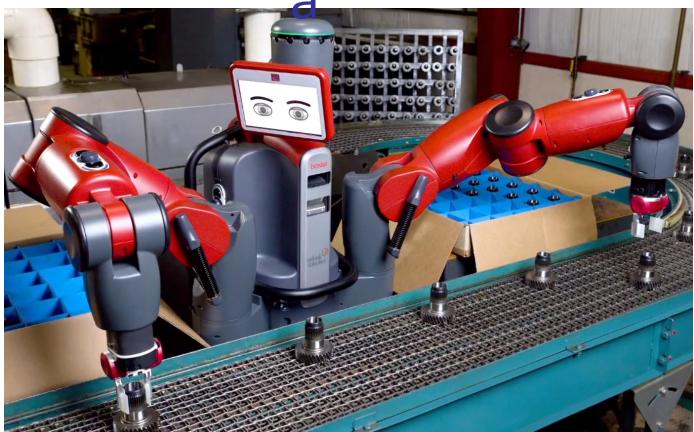
Roomb



Robomo



Dyia One



Baxter



Staubli

Examples of applications(3/3)

- Companion robots



Paro



Aibo



Buddy



Nao



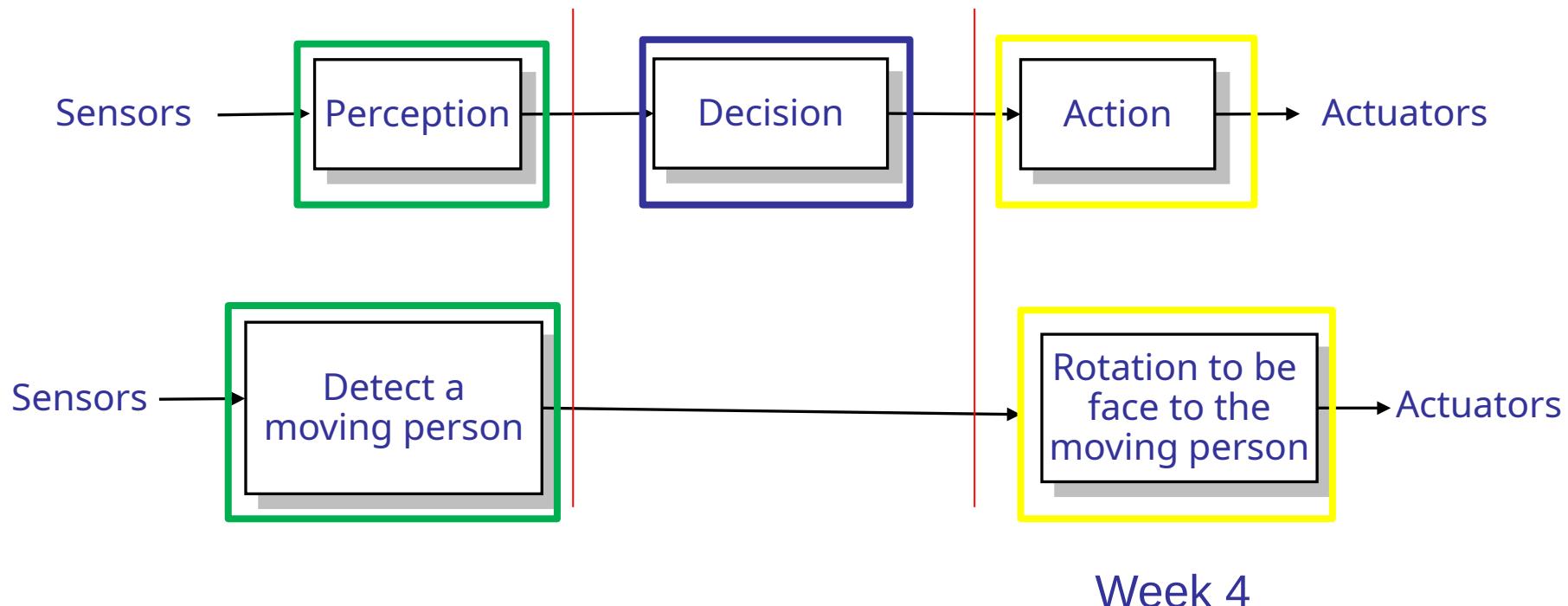
Pepper

Conclusion

- A mobile robot is equipped with 2 kind of sensors:
 - **Exteroceptive sensors** that give information about the environment (ie, laser scanner);
 - **Proprioceptive sensors** that give information about the internal state of the robot (ie, odometer);
- A mobile robot is equipped with some actuators characterized by their degree of freedom;
 - Robair is a differential drive robot;
- Sensors and actuators are imprecise and limited;
- The environment of a robot is generally complex, changing, unpredictable and uncertain.

Follow me behavior (1/2)

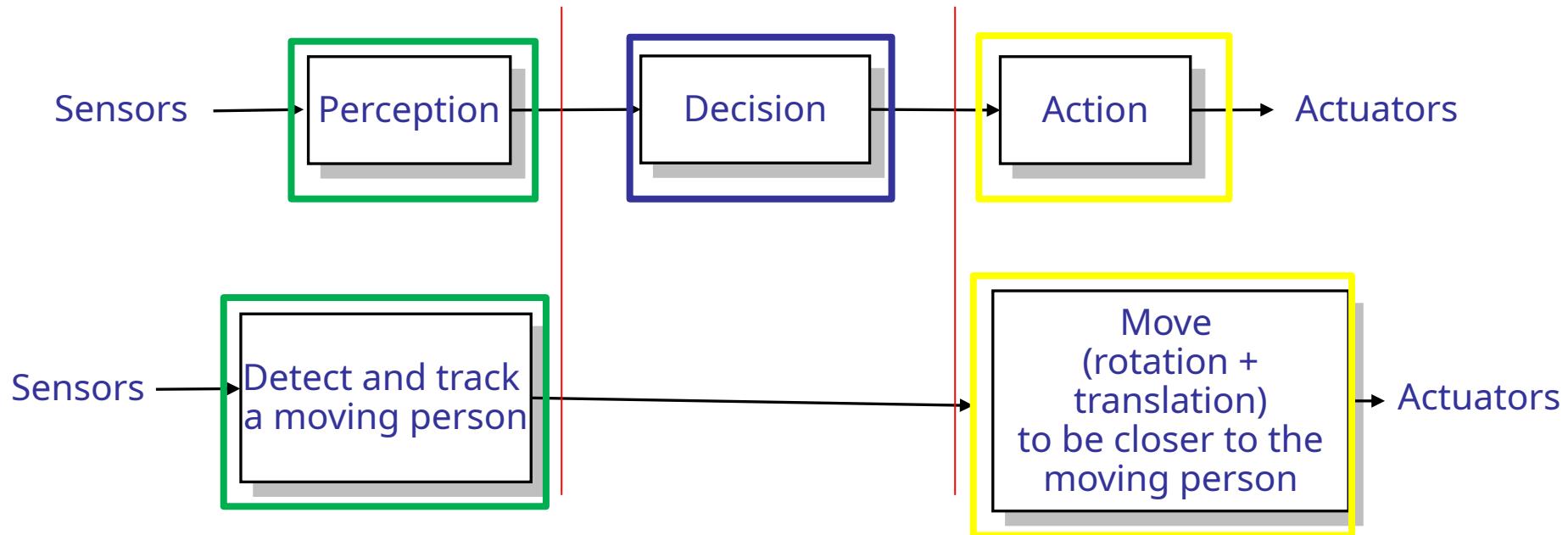
- We design, implement and test a simple “follow me” behavior in the next weeks in 2 steps



- 1st release of “follow me” behavior

Follow me behavior (2/2)

- We design, implement and test a simple “follow me” behavior in the next weeks in 2 steps



- 2nd release of “follow me” behavior