Applicazioni dell'Automatica

Introduction to mobile robotics:
Systems and problems

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module contents

- systems and problems
  a bird's eye view on the world of mobile robotics
- kinematics and modeling of WMRs
  mechanical structure and mobility of typical wheeled mobile robots
- motion control of WMRs
  fundamentals of control problems for wheeled vehicles
- automated lane keeping
  some insight into a specific application

readings

- Siciliano, Sciavicco, Villani, Oriolo, *Robotics: Modelling, Planning and Control*, 3rd Edition, Springer, 2010 (also available in Italian by McGraw-Hill)

- Choset, Lynch, Hutchinson, Kantor, Burgard, Kavraki, Thrun, *Principles of Robot Motion: Theory, Algorithms and Implementations*, MIT Press, 2005

- Siciliano, Khatib, Eds., *Handbook of Robotics*, 2nd Edition, Springer, 2016

- Siegwart, Nourbakhsh, *Introduction to Autonomous Mobile Robots*, MIT Press, 2004

- Tzafestas, *Introduction to Mobile Robot Control*, Elsevier, 2014

other sources of information

- https://spectrum.ieee.org/robotics
- https://robotsguide.com
- https://mars.nasa.gov/mer/, https://mars.nasa.gov/msl/home/, https://mars.nasa.gov/mars2020/
- https://asimo.honda.com
- https://www.bostondynamics.com
- https://www.youtube.com/user/RoboticsLabSapienza

objective

- a short introduction to modeling and controlling autonomous mobile robots
- …they come in many flavors!







outline of this lecture

- why mobile robots
- applications
- gallery
- the key problems of mobile robotics
- autonomy
- a basic underlying functionality: perception
- deliberative architecture
- other architectures

why mobile robots?

- industrial fixed-base robots are fast and accurate in a limited, structured, known, static workspace

- to be useful in the outside world, robots must be able to move freely in large, unstructured, uncertain, dynamic environments

applications of mobile robots

structured environments (service robots)

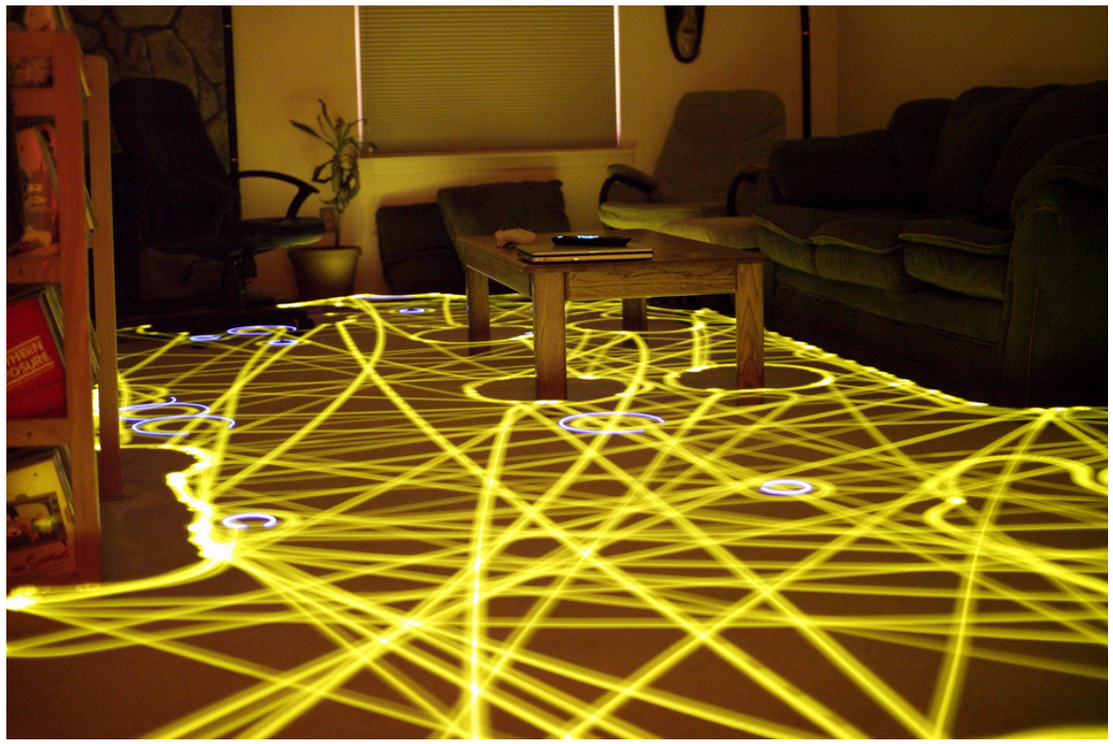
- transportation (industry, logistics)
- cleaning (homes, large buildings, cities)
- customer assistance (museums, shops)
- surveillance
- entertainment

unstructured environments (field robots)

- exploration (sea, space)
- monitoring (sea, forests)
- rescue
- demining
- agriculture
- construction
- transportation
- military :-(

gallery

on wheels/ I



Roomba by iRobot
(cleaning)

gallery

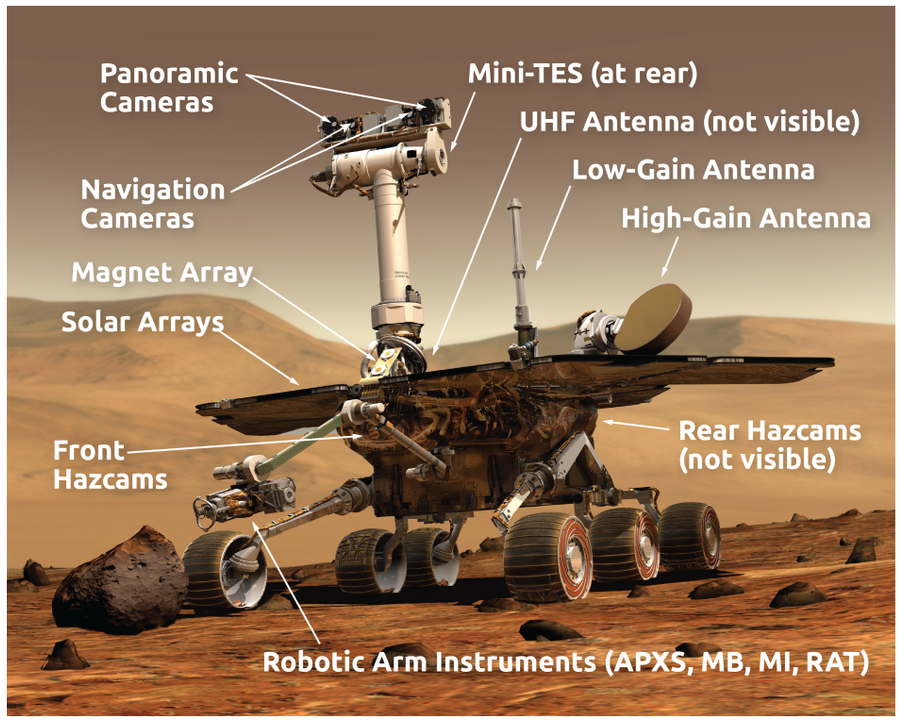
on wheels/2

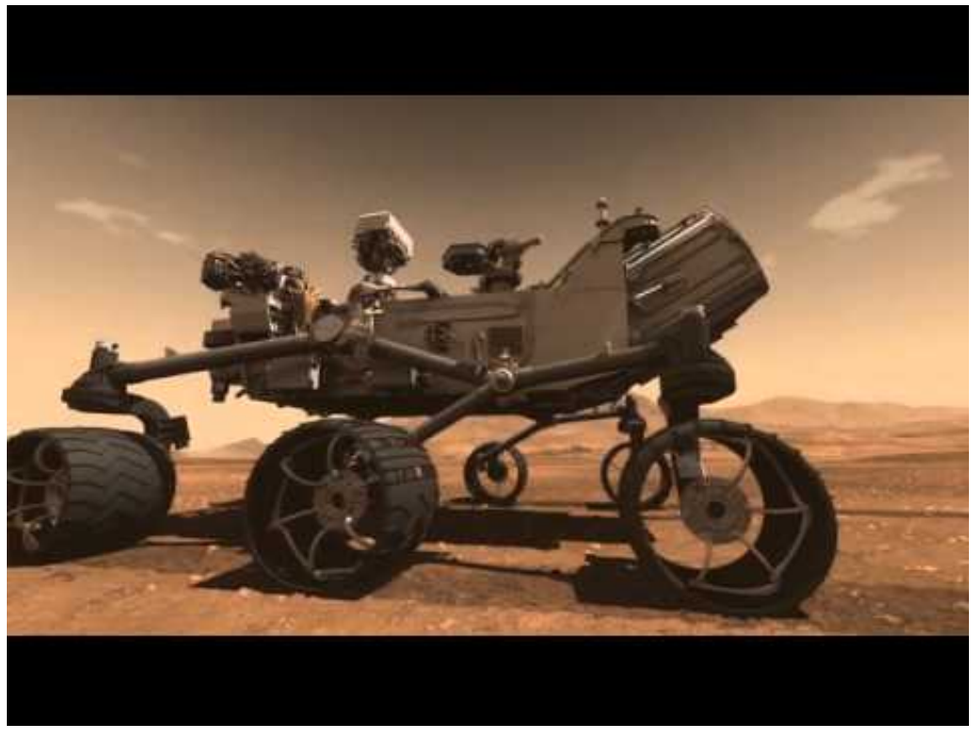
Swisslog SpeciMinder
(healthcare)

gallery

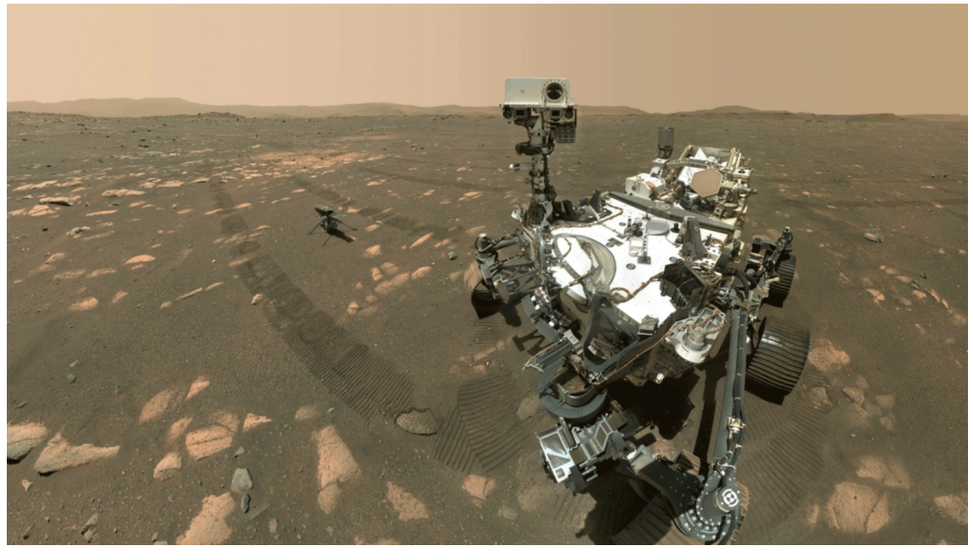
on wheels/3

https://mars.nasa.gov/mer/





Spirit+Opportunity, Curiosity,
Perseverance+Ingenuity
by NASA
(planetary exploration)



gallery

on wheels/4

https://yapemobility.it

Yape by e-Novia
(urban transportation)

gallery

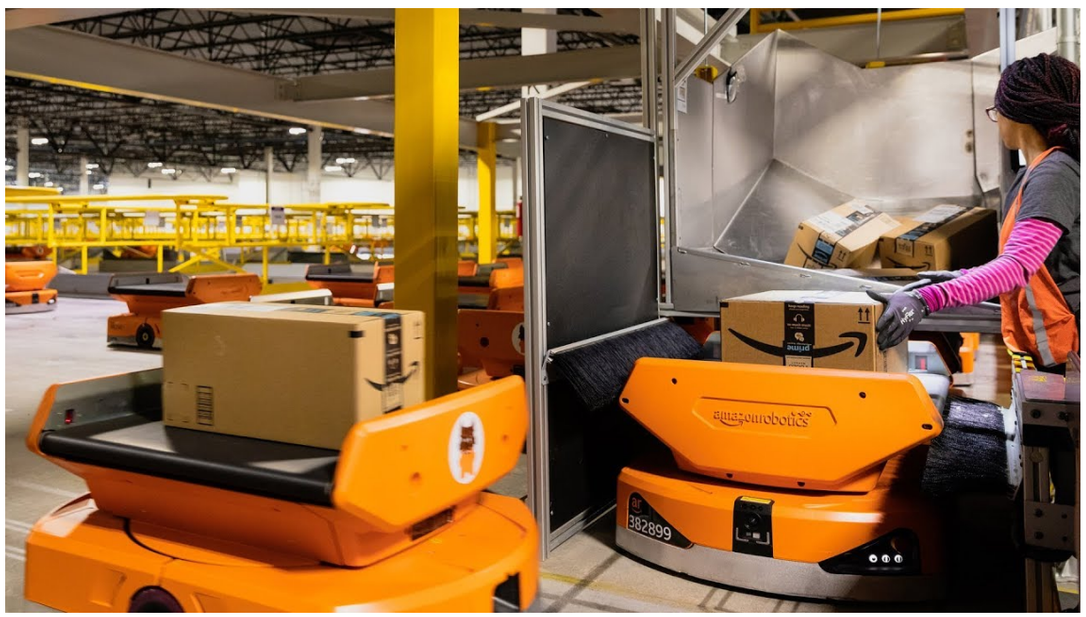
on wheels/5

https://mygita.com

Gita by Piaggio
(urban transportation)

gallery

on wheels/6

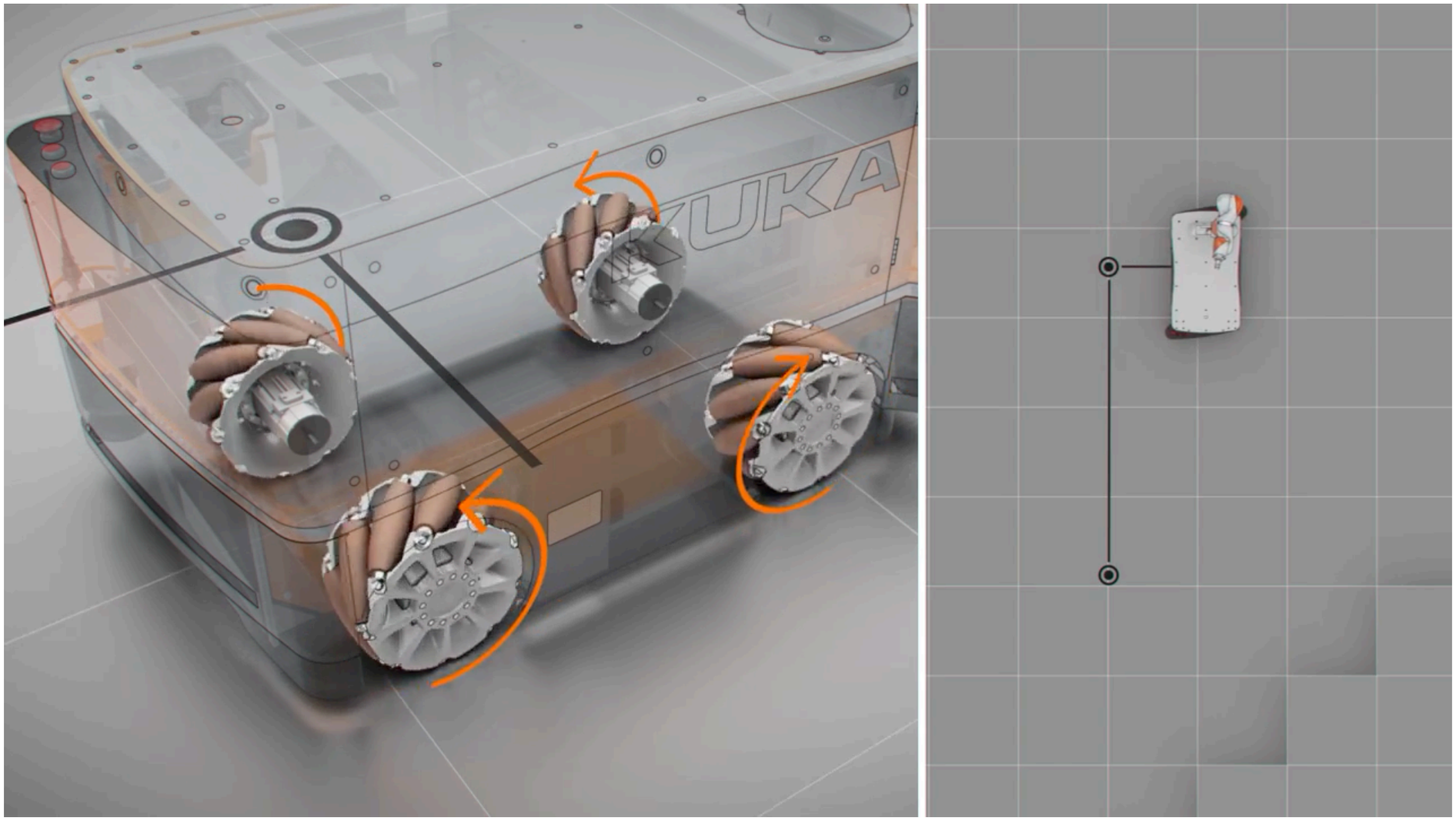


Amazon Robotics
ex-KIVA
(internal logistics)

gallery

on wheels/7

https://www.kuka.com

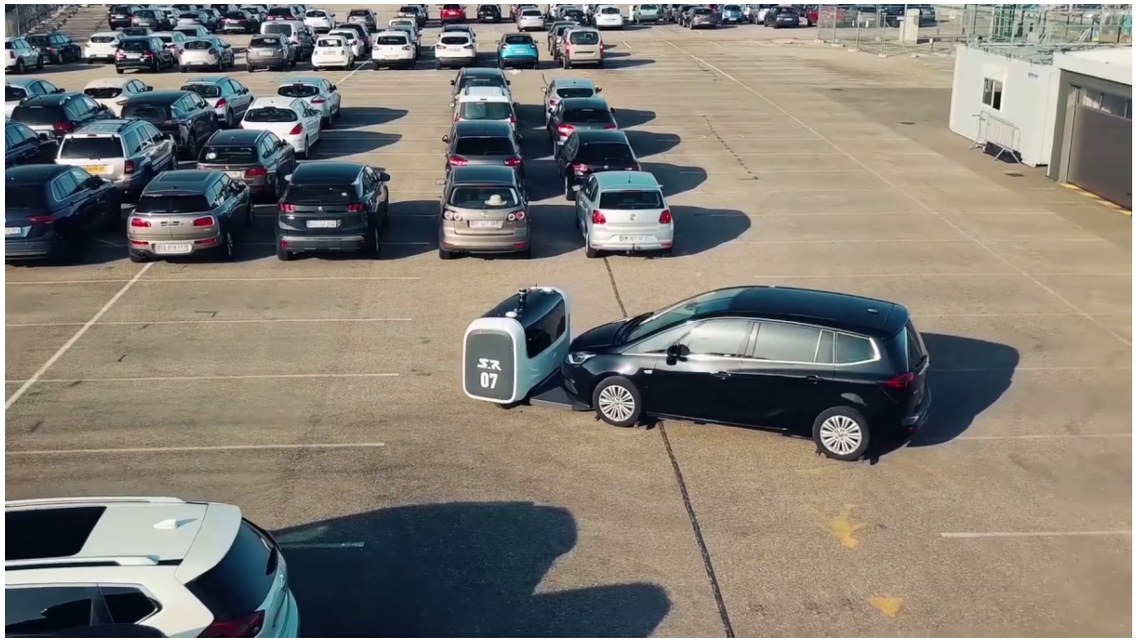


omniMove by KUKA
(internal logistics)

gallery

on wheels/8

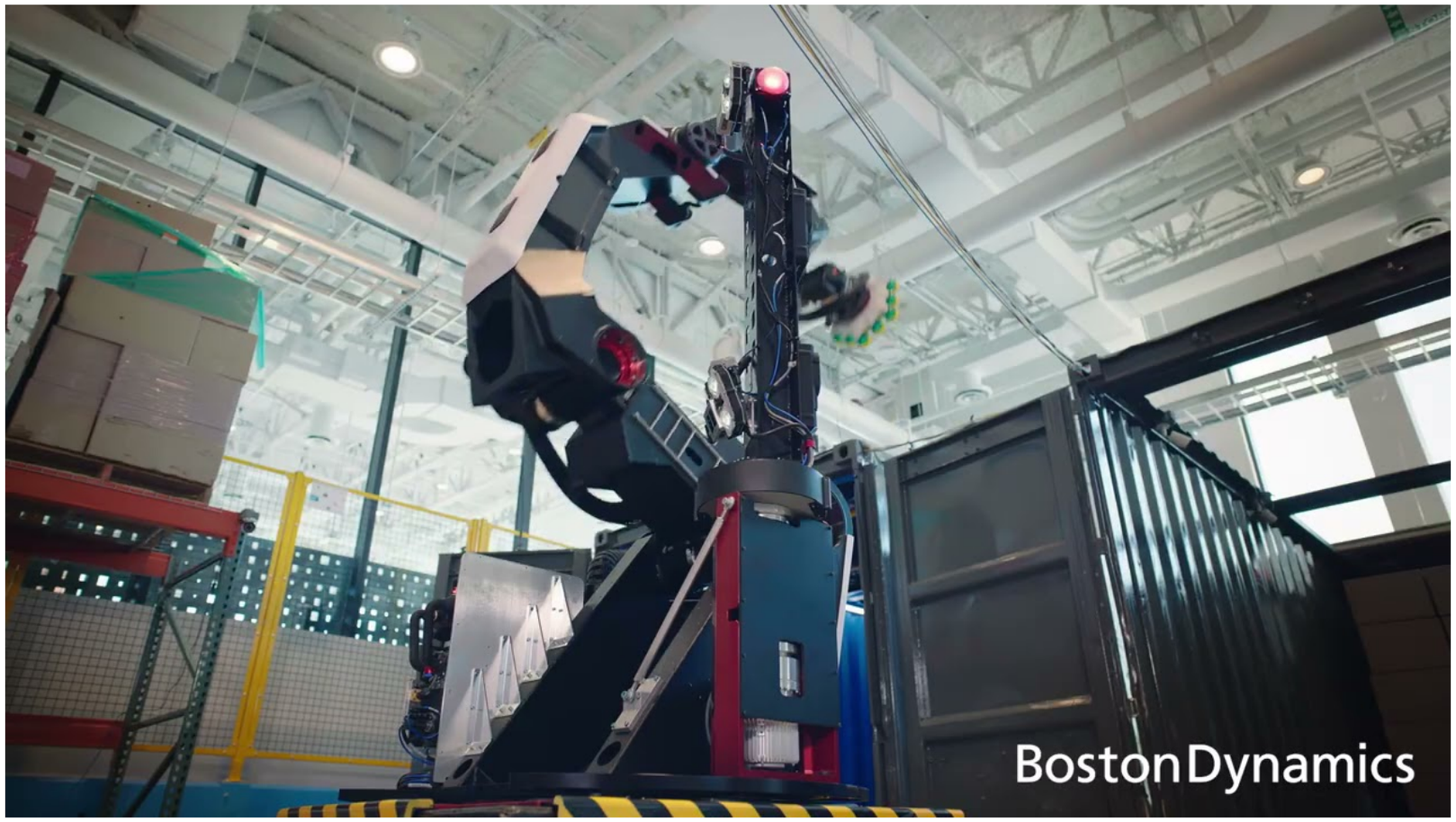
https://stanley-robotics.com



Stan by Stanley Robotics
(automated parking)

gallery

on wheels/9



Stretch by Boston Dynamics
(internal logistics)

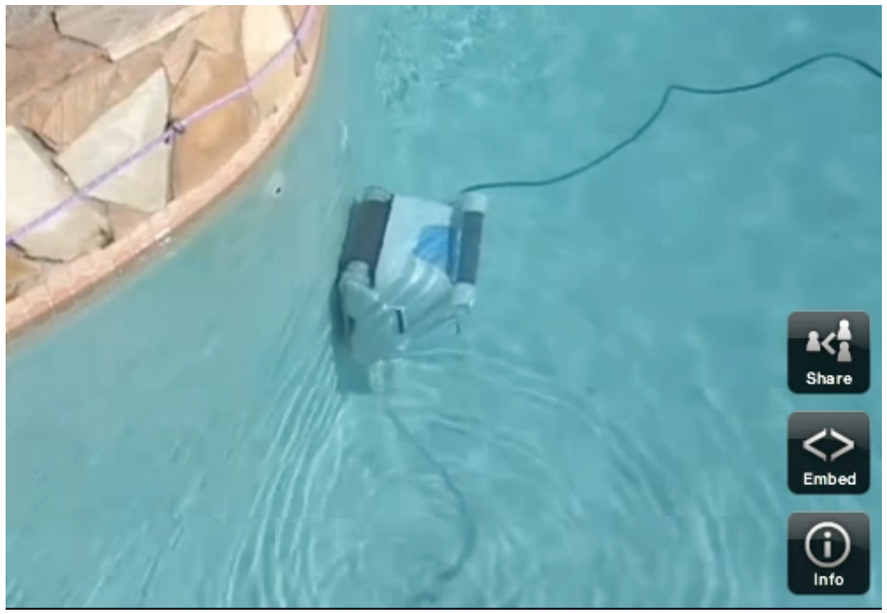
gallery

on wheels/10

Handle by Boston Dynamics
(internal logistics)

gallery

on tracks



Verro by iRobot
(pool cleaning)

MAXXII by Robodyne
(all-terrain navigation)

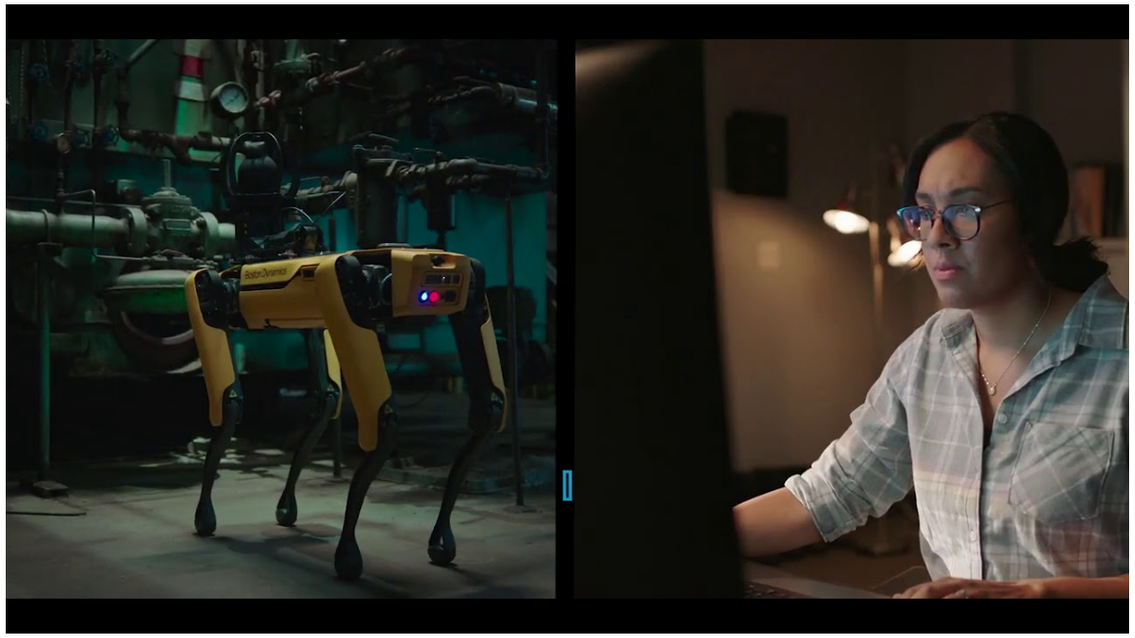
gallery

on legs/1

BigDog and LS3
by Boston Dynamics
(military transportation)

gallery

on legs/2

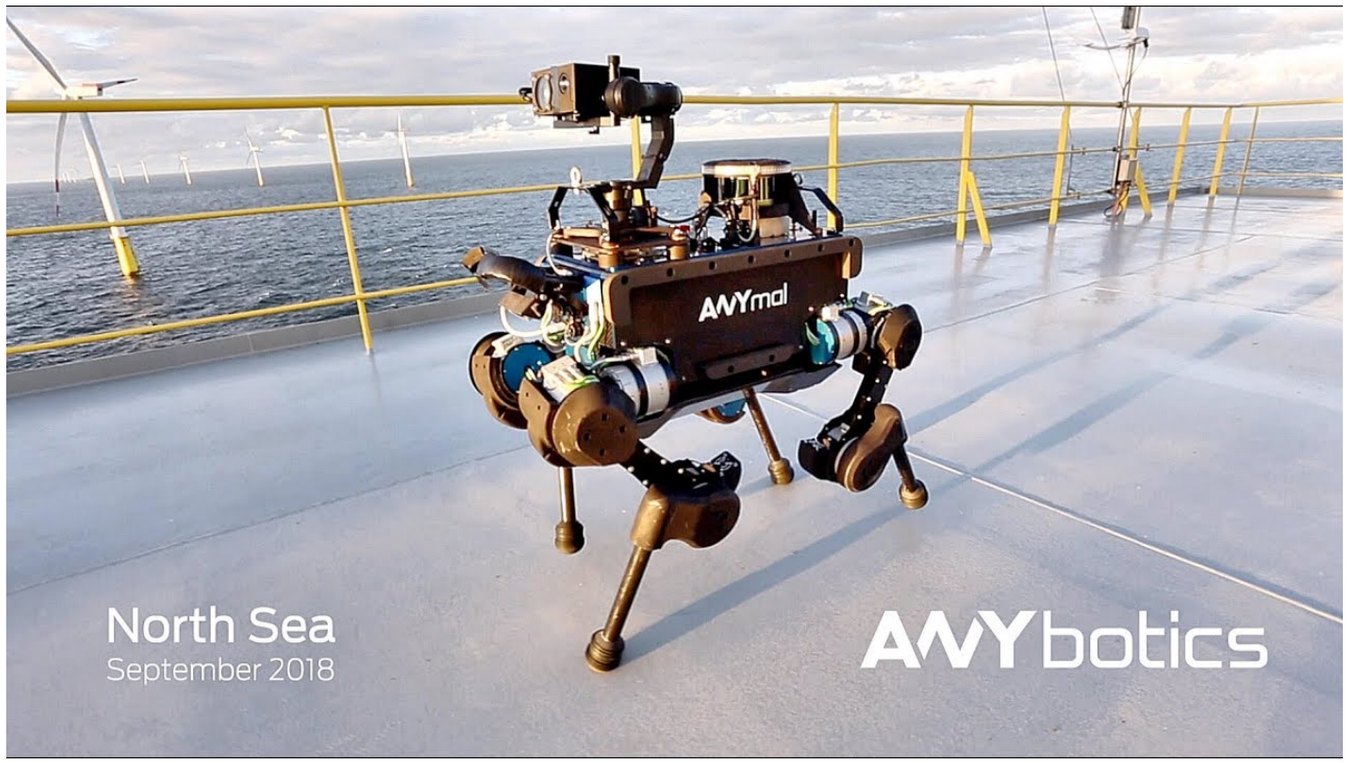


Spot by Boston Dynamics
(remote monitoring
and intervention)

gallery

on legs/3

Cheetah
by MIT
(research)



ANYmal
by ANYbotics
(inspection)

gallery

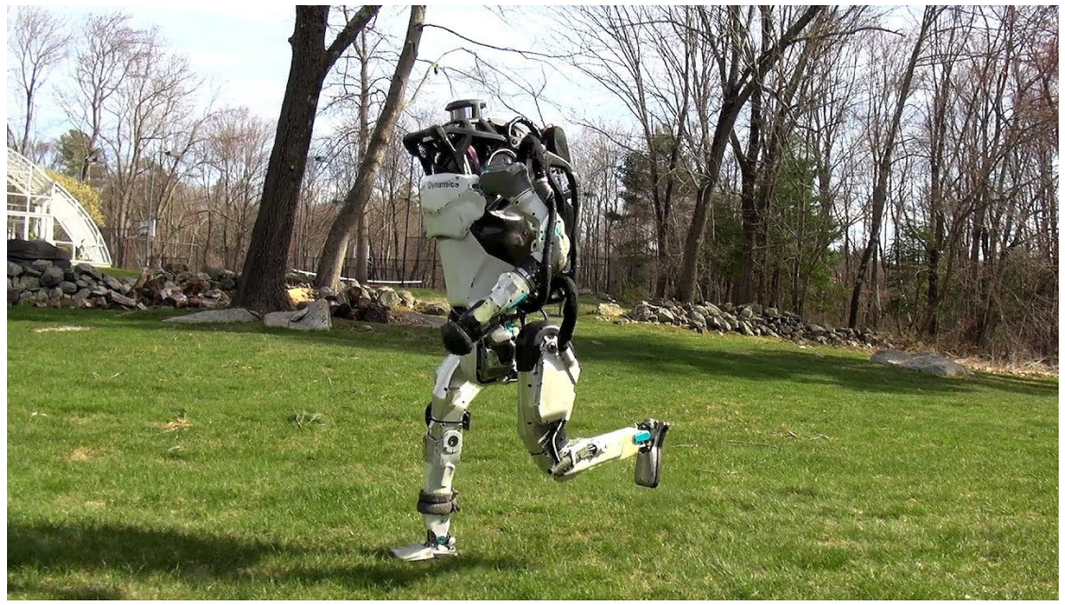
on legs/4

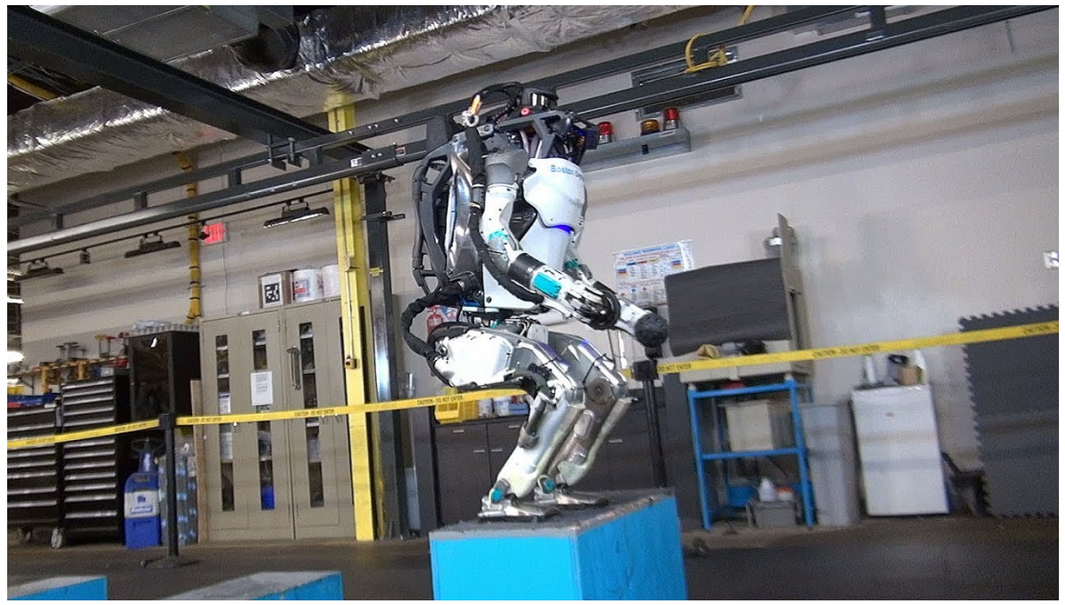
ASIMO by Honda
(research)

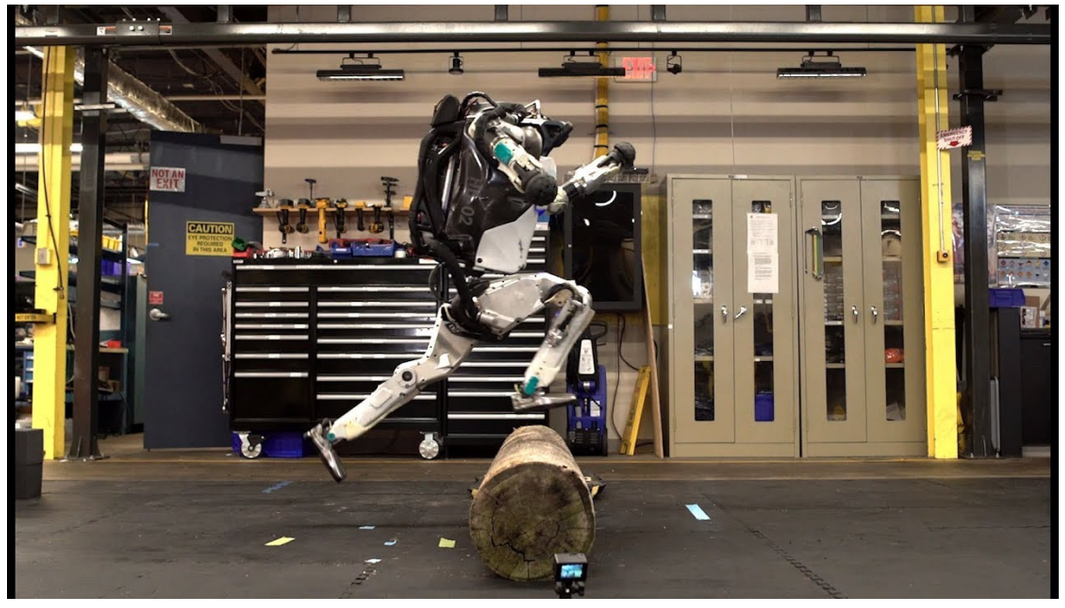
gallery

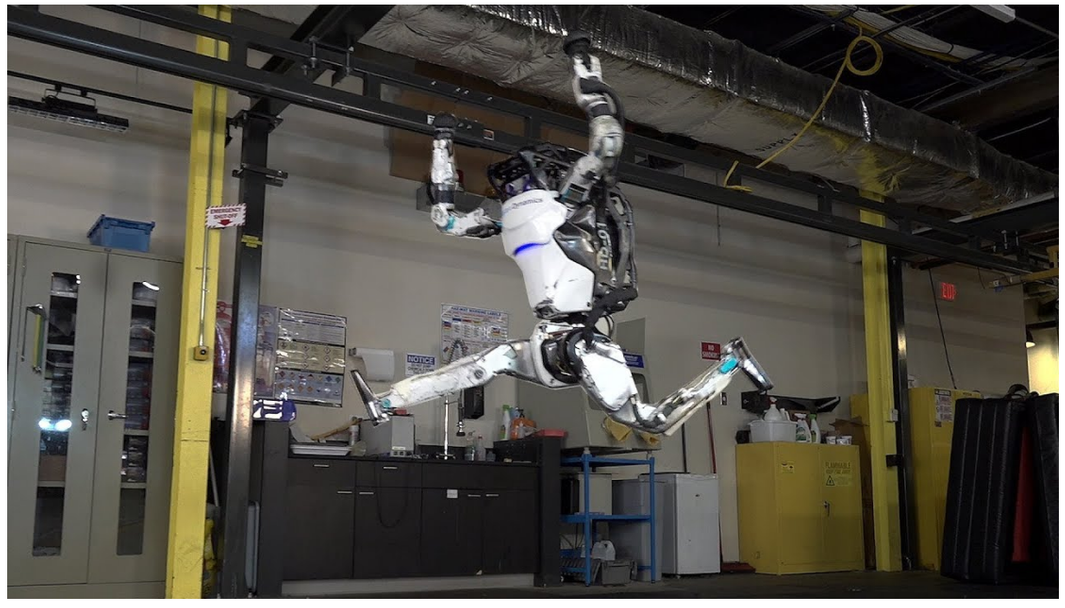
on legs/5

ATLAS by Boston Dynamics (research)









gallery

flying

Skydio 2 by Skydio
(aerial cinematography)

Amazon Prime Air
(delivery)

gallery

underwater

Seagoo ROV
(inspection)

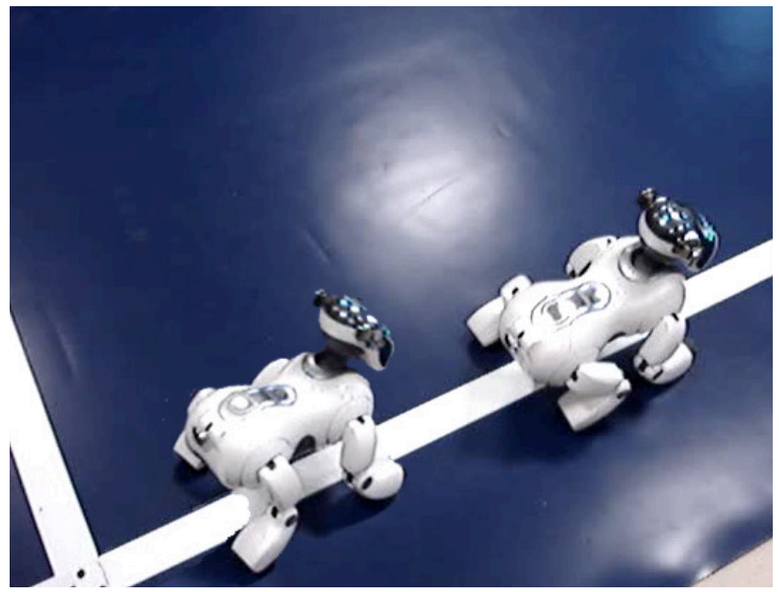
Aquanaut by
Houston Mechatronics
(underwater operation)

gallery

at DIAG Robotics Lab

Kheperas

tractor-trailer prototype

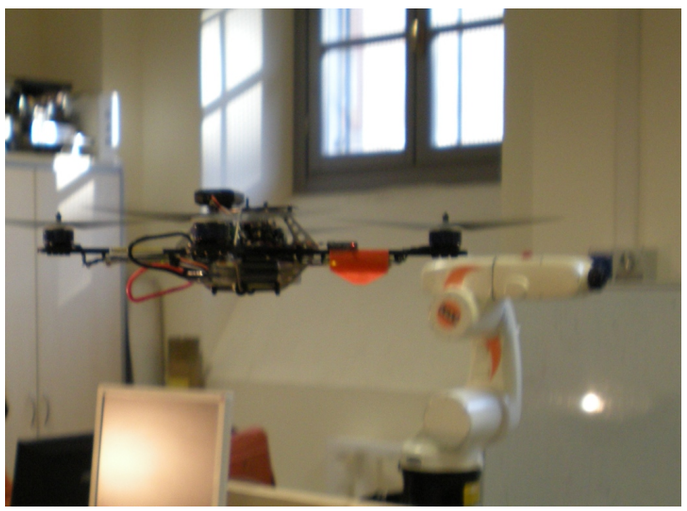


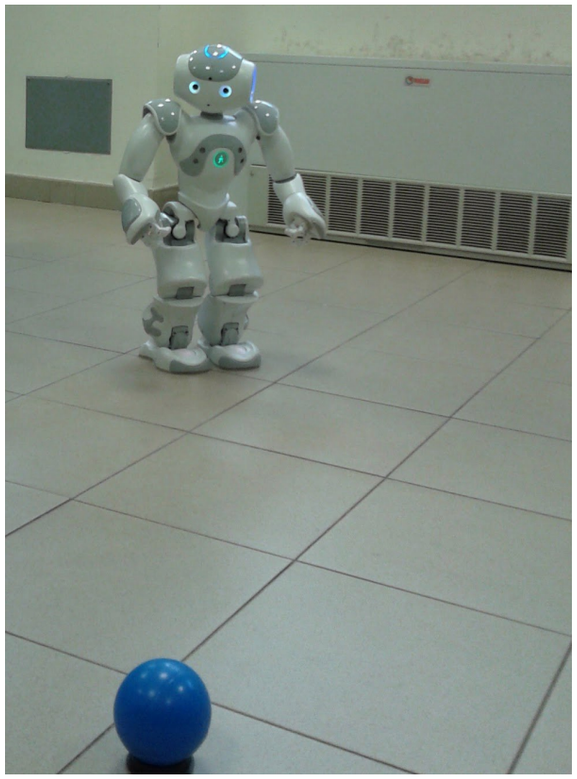
AIBOs

NAOs

MagellanPro

Hummingbird, Pelican





gallery

at DIAG Robotics Lab

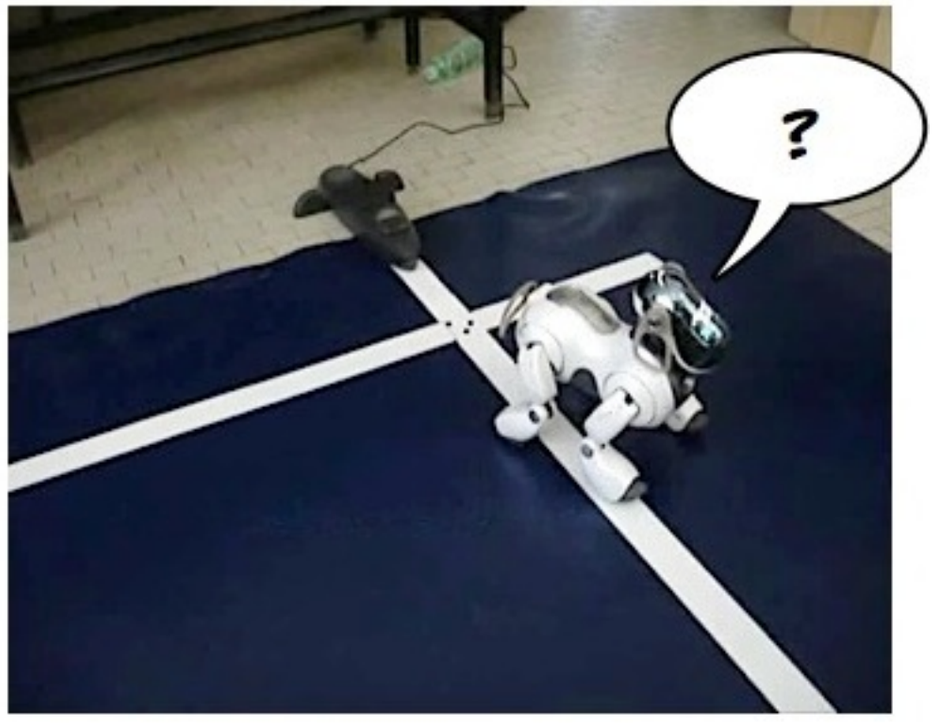
TIAGo

Duckietown

Robotis OP3

the key problems of mobile robotics

1. where am I?
2. how am I supposed to get to the goal?
3. how do I actually move?



1: localization (with or without initial guess, map,...)

2: path/trajectory/motion planning (respectively: only geometric motion, with time, among obstacles)

3: motion control (feedback techniques)

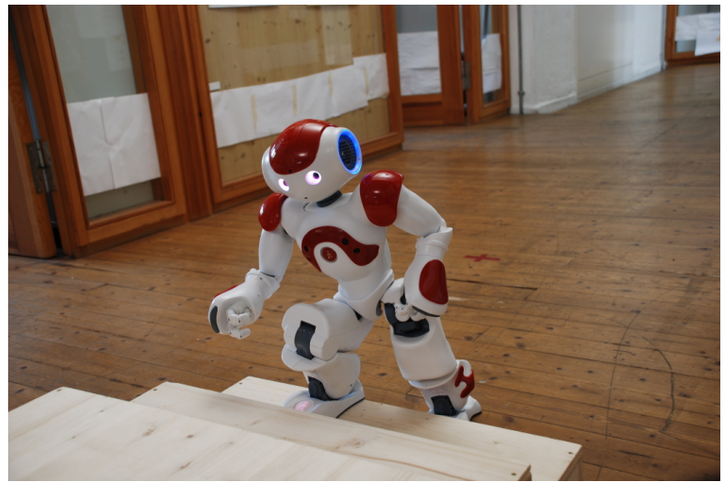
	fixed-base manipulators	single-body wheeled mobile robots
1. localization	easy (thanks to fixed-base and joint encoders)	difficult
2a. path/trajectory planning	easy (all paths are feasible)	difficult (not all paths are feasible)
2b. motion planning	difficult (many dof's)	more difficult (as above)
3. motion control	difficult (nonlinear)	more difficult (nonlinear & no smooth stabilizer)

$\Rightarrow$ multi-body mobile robots are a real challenge!

articulated vehicles

mobile manipulators

humanoids

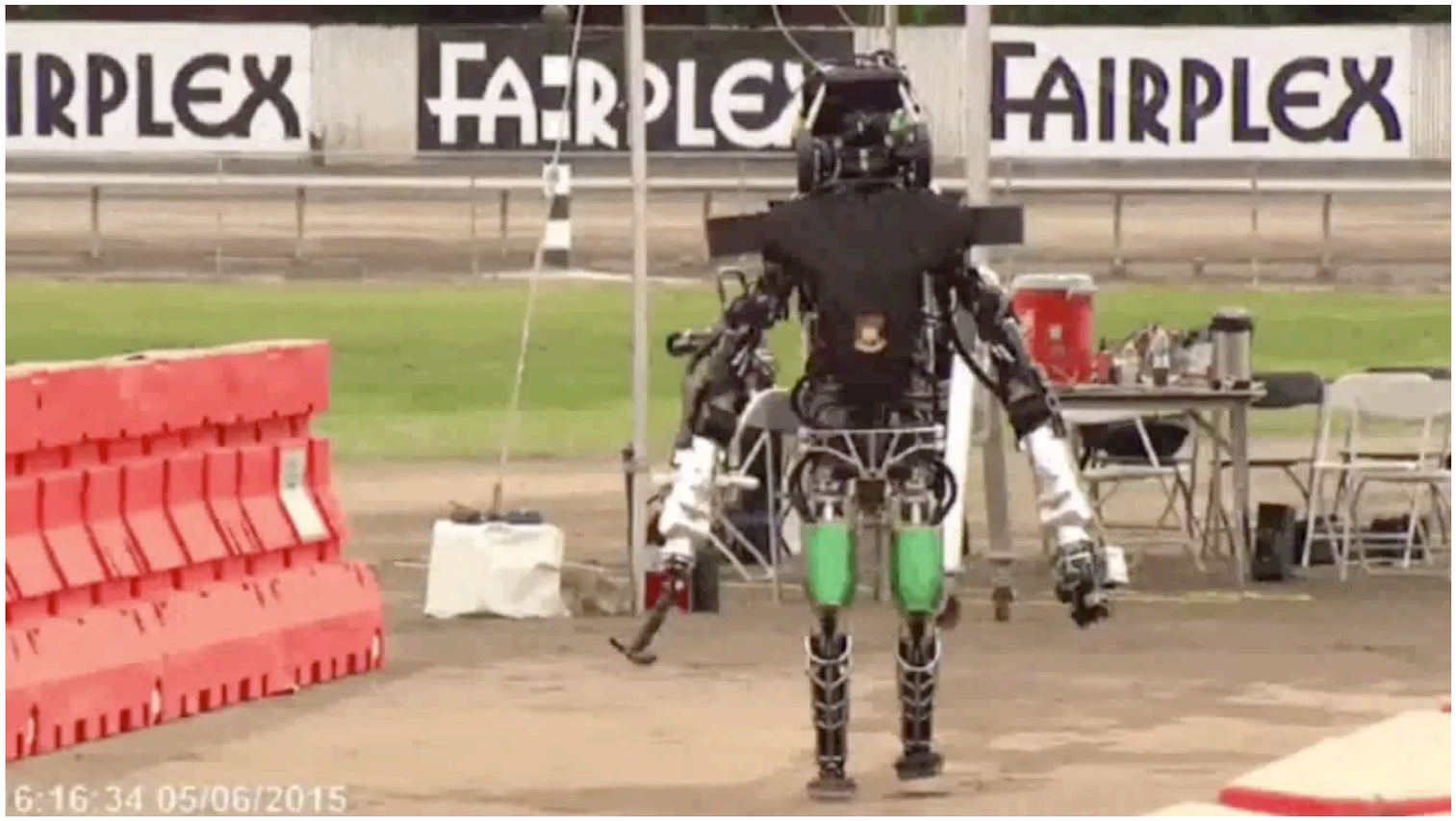


autonomy

can be defined as (or better, requires) the ability to solve problems 1, 2, 3 in unstructured environments and uncertain, possibly dynamic operating conditions

DARPA
Grand Challenge
2005

that was 2005, this is one decade later



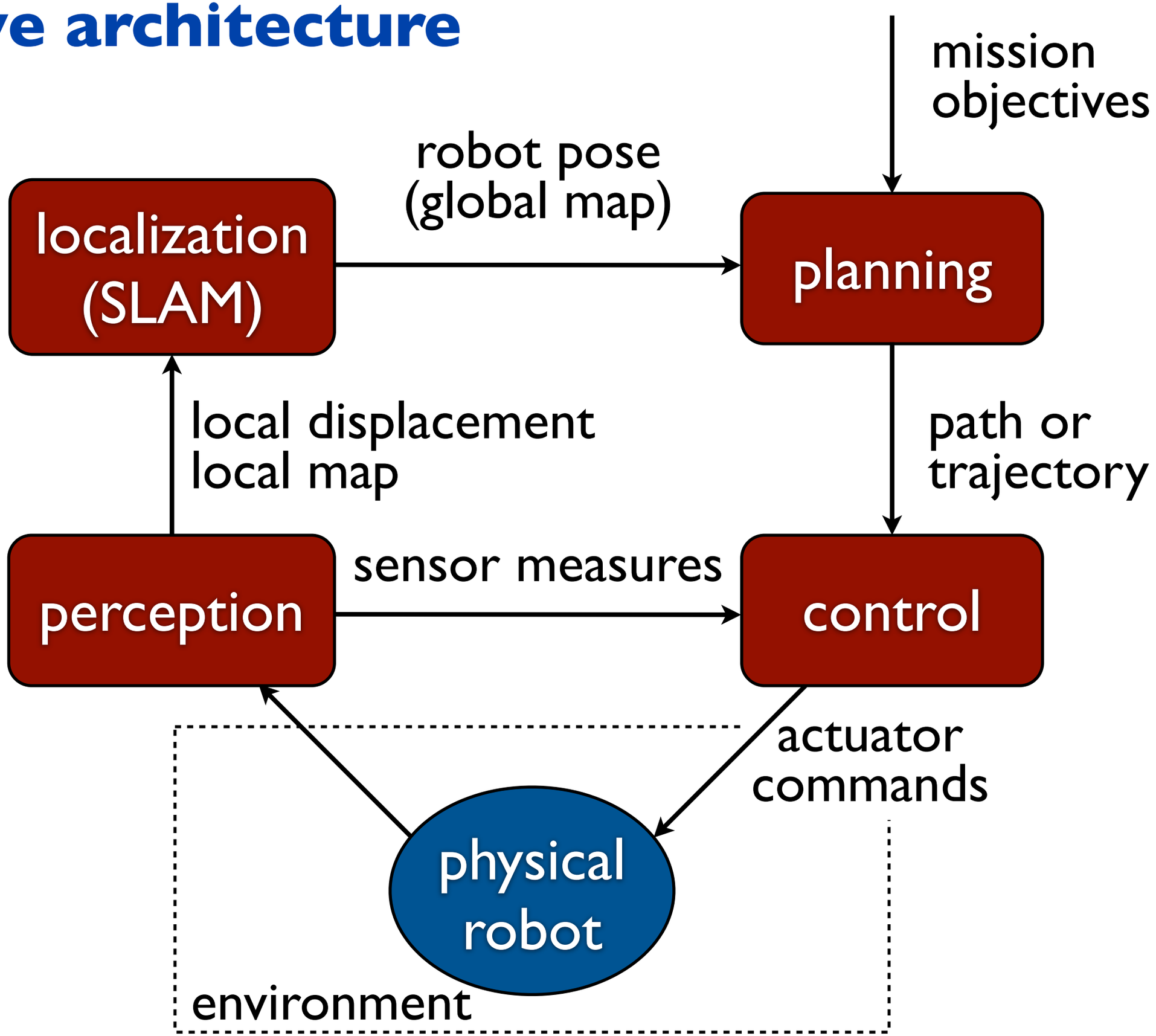
DARPA Robotics Challenge 2015

real autonomy (especially if you want to do more than drive) is not around the corner: still a long way to go

a basic underlying functionality: perception

- sensing + interpretation
- proprioceptive: perception of the robot itself (position, orientation, velocity, etc, in a certain frame)
- exteroceptive: perception of the environment surrounding the robot (obstacles, robots, people, etc)
- essential in unstructured environments
- performed via a variety of sensors:
  - encoders, INS, GPS (proprioception)
  - rangefinders, cameras, tactile sensors (exteroception)

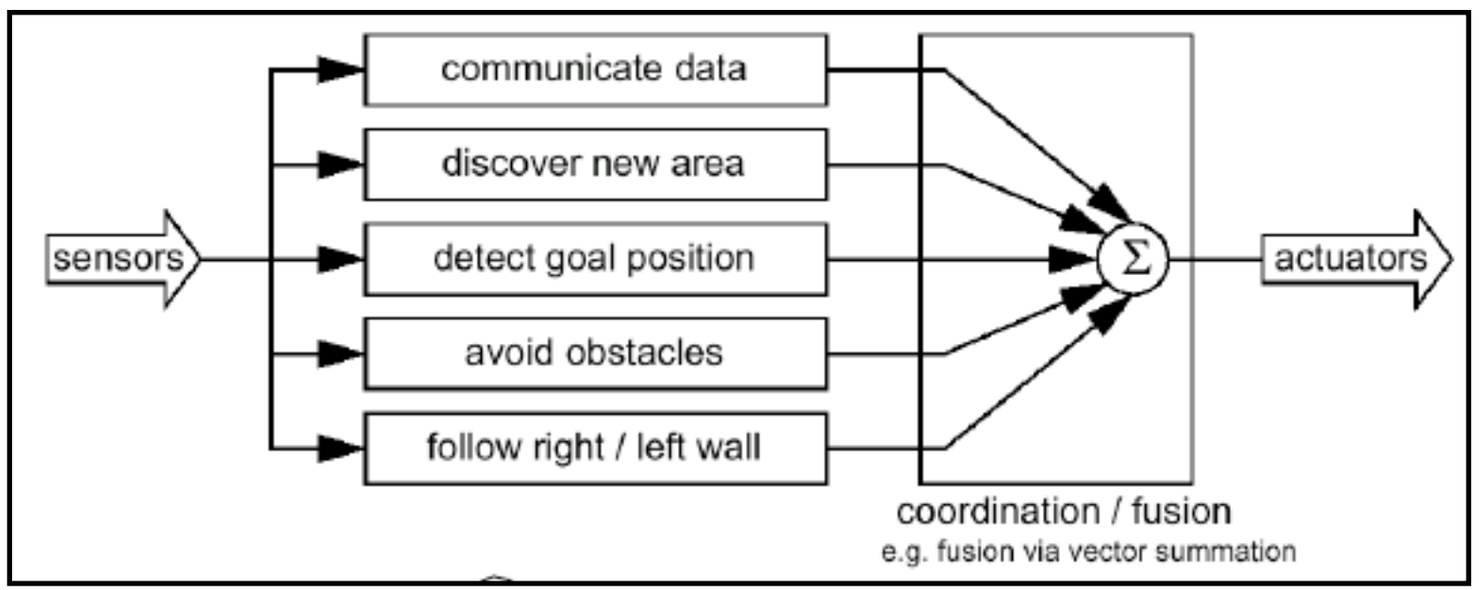
deliberative architecture



"think, then act"

other architectures

- reactive architecture ("don't think, (re)act")
- hybrid architecture ("think and act concurrently")
- behavior-based architecture ("think the way you act"), e.g.



taken from "Introduction to Autonomous Mobile Robots"