Welcome to CS 3630!

This year:
- ***All new robots!***
- ***All new experiments!***
- ***A new course outline!***

What this class is about

robotics, AI and perception

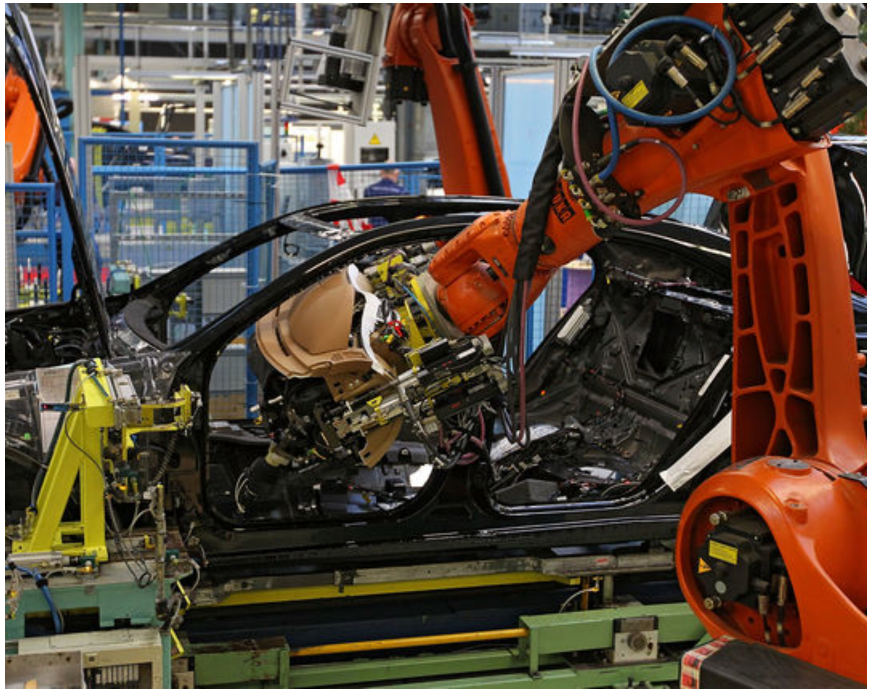
making a robot be (somewhat) intelligent

robot navigation

Robots…

Robot Taxonomy

- **Industrial Robots**
- Service Robots
- Field Robots
- Humanoid Robots
- Medical Robots
- Self-Driving Cars
- Aerial Vehicles



http://www.kuka.com

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http://www.frc.ri.cmu.edu/robots/

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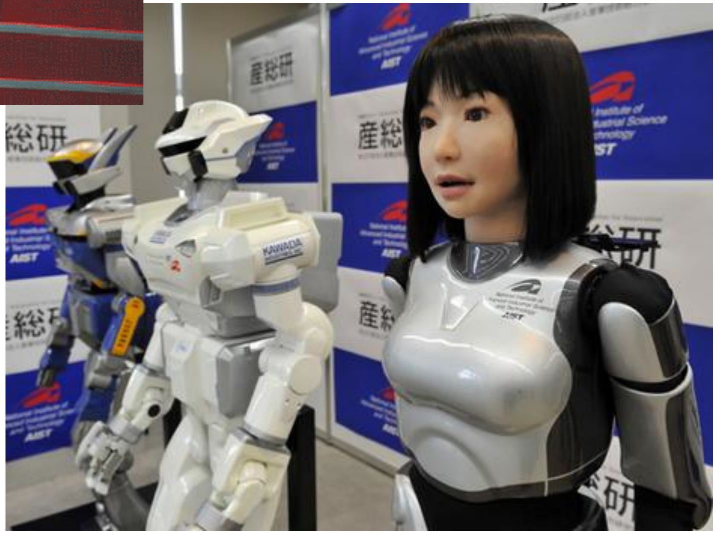

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Major application areas

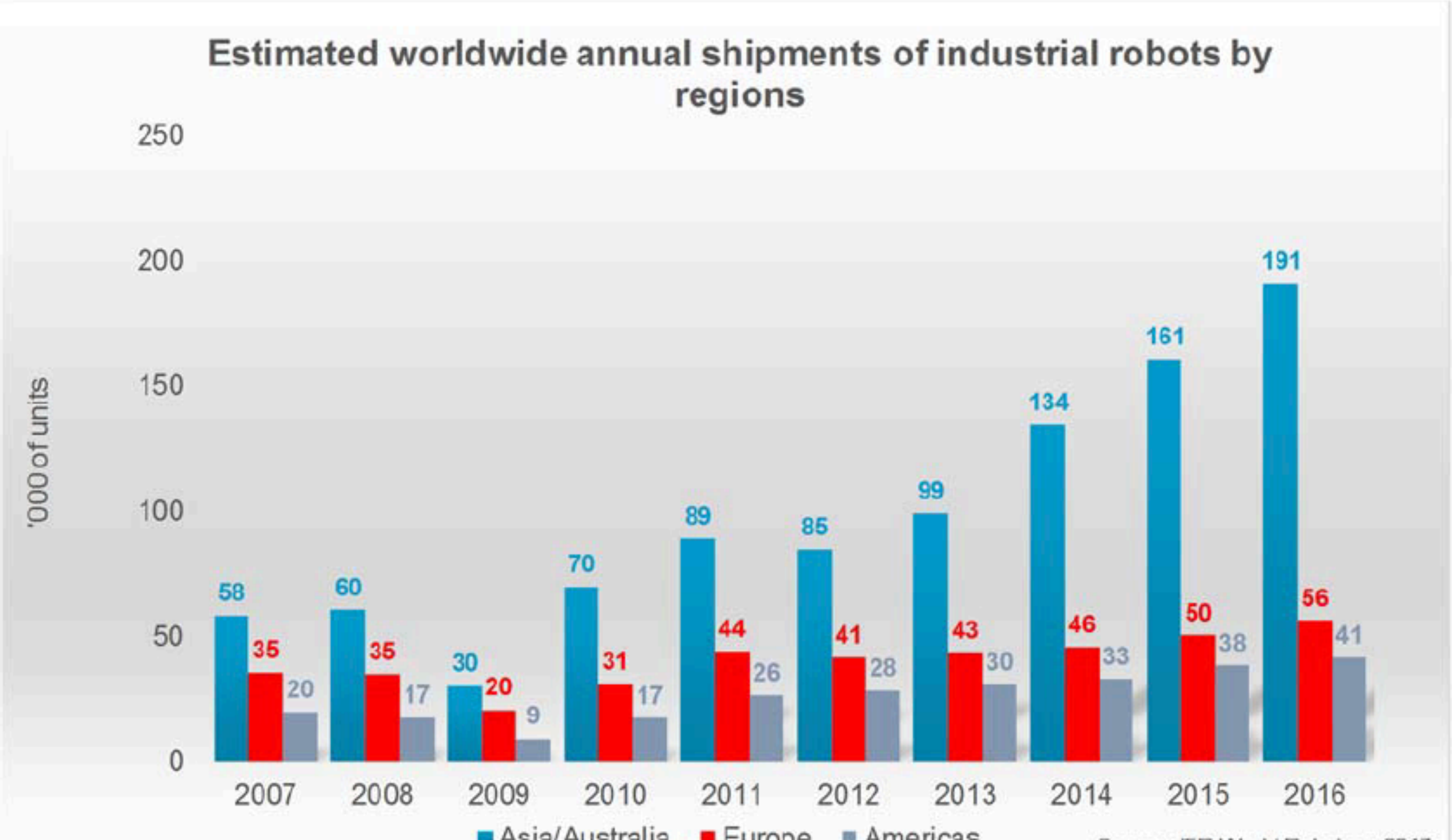
- Manufacturing
- Logistics (inventory, warehouse logistics, packaging)
- Transportation (self-driving cars)
- Consumer and professional services (cleaning, mowing)
- Health, independence and quality of life (exoskeletons, semi-autonomous wheelchairs)
- Agriculture

INDUSTRIAL ROBOTS

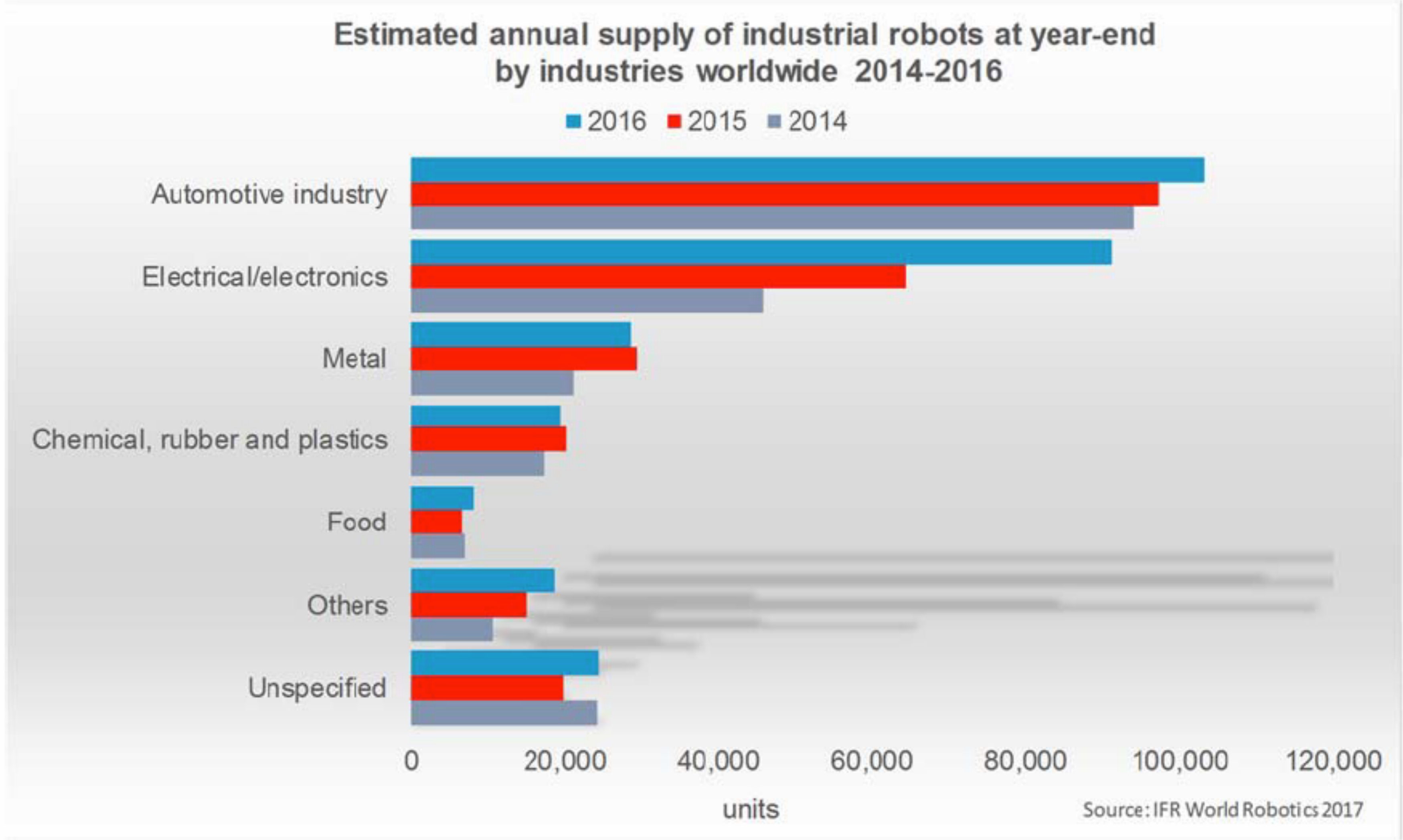
Industrial Robots

IFR International Federation of Robotics

ifr.org



What Are They Doing?



Where Are They?

Estimated annual shipments of multipurpose industrial robots in selected countries. Number of units

Country	2015	2016	2017*	2018*	2019*	2020*	2017/ 2016	CAGR 2018 - 2020
America	**38,134**	**41,295**	**48,000**	**50,900**	**58,200**	**73,300**	**16%**	**15%**
North America	36,444	39,671	46,000	48,500	55,000	69,000	16%	14%
- United States	27,504	31,404	36,000	38,000	45,000	55,000	15%	15%
- Canada	3,474	2,334	3,500	4,500	3,000	5,000	50%	13%
- Mexico	5,466	5,933	6,500	6,000	7,000	9,000	10%	11%
Brazil	1,407	1,207	1,500	1,800	2,500	3,500	24%	33%
Rest of South America	283	417	500	600	700	800	20%	17%
Asia/Australia	**160,558**	**190,542**	**230,300**	**256,550**	**296,000**	**354,400**	**21%**	**15%**
China	68,556	87,000	115,000	140,000	170,000	210,000	32%	22%
India	2,065	2,627	3,000	3,500	5,000	6,000	14%	26%
Japan	35,023	38,586	42,000	44,000	45,000	48,000	9%	5%
Republic of Korea	38,285	41,373	43,500	42,000	44,000	50,000	5%	5%
Taiwan	7,200	7,569	9,000	9,500	12,000	14,000	19%	16%
Thailand	2,556	2,646	3,000	3,500	4,000	5,000	13%	19%
other Asia/Australia	6,873	10,741	14,800	14,050	16,000	21,400	38%	13%
Europe	**50,073**	**56,043**	**61,200**	**63,950**	**70,750**	**82,600**	**9%**	**11%**
Central/Eastern Europe	6,136	7,758	9,900	11,750	13,900	17,500	28%	21%
France	3,045	4,232	4,700	4,500	5,000	6,000	11%	8%
Germany	19,945	20,039	21,000	21,500	23,500	25,000	5%	6%
Italy	6,657	6,465	7,100	7,000	7,500	8,500	10%	6%
Spain	3,766	3,919	4,300	4,600	5,100	6,500	10%	15%
United Kingdom	1,645	1,787	1,900	2,000	2,300	2,500	6%	10%
other Europe	8,879	11,843	12,300	12,600	13,450	16,600	4%	11%
Africa	**348**	**879**	**800**	**850**	**950**	**1,200**	**-9%**	**14%**
not specified by countries**	4,635	5,553	6,500	7,000	8,000	9,400	17%	13%
TOTAL	253,748	294,312	346,800	379,250	433,900	520,900	18%	15%

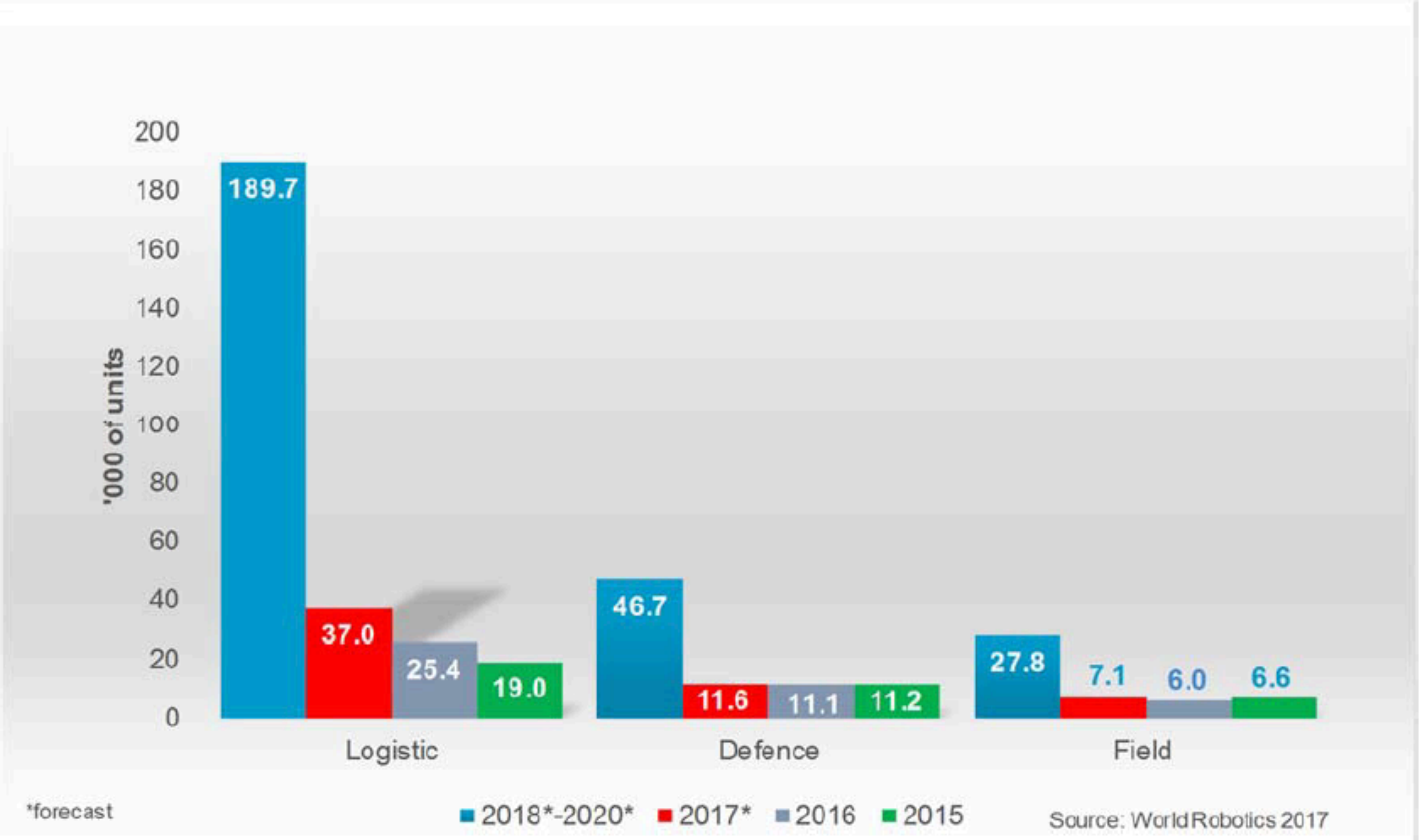
Sources: IFR, national associations

*forecast

** reported and estimated sales which could not be specified by countries

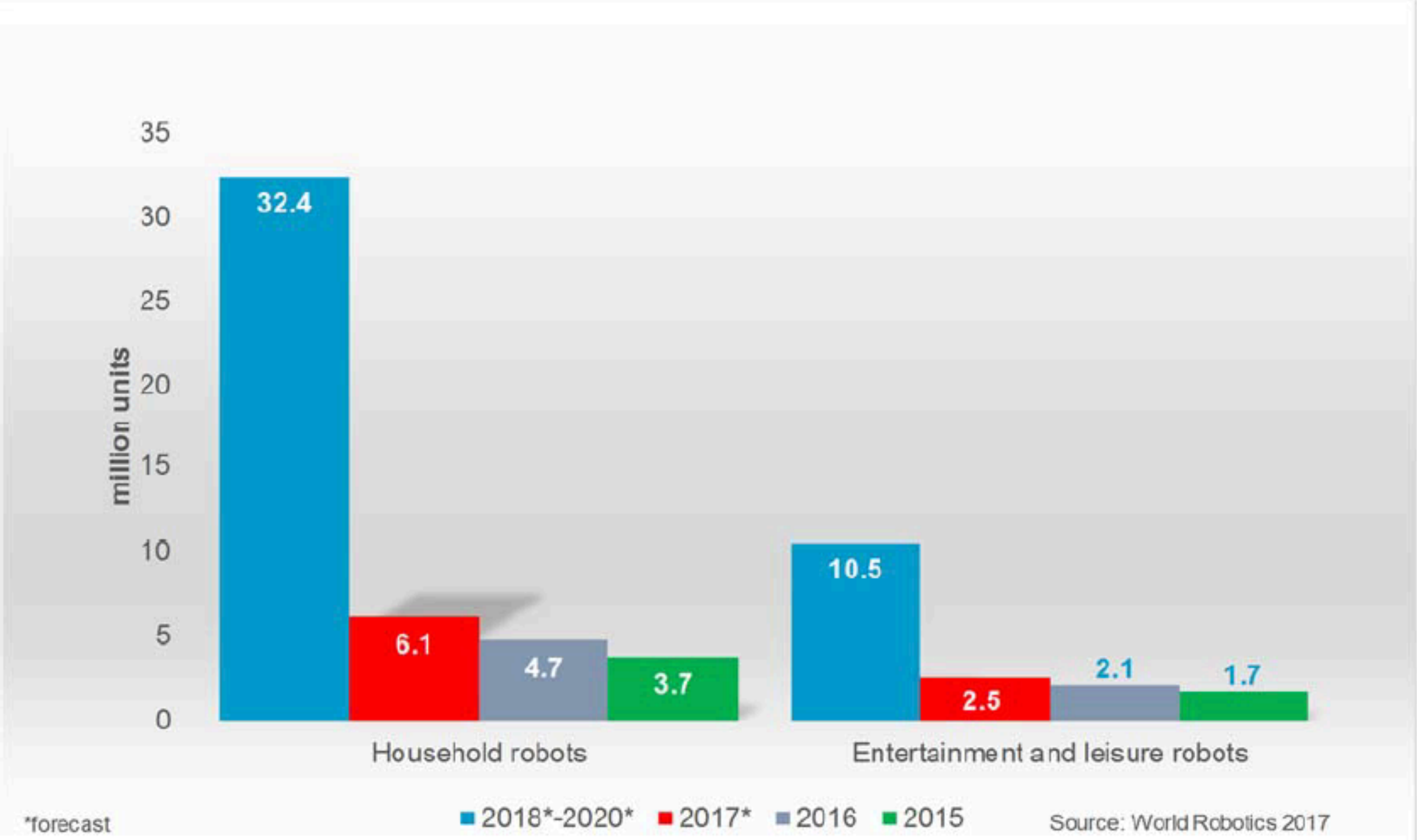
SERVICE ROBOTS

Service Robots



Service Robots

Service Robots



What is a service robot?

Start-up examples (I): Service robotics in agriculture

Fresh fruit picking robot

FF Robotics (Israel)

Platform for vineyard maintenance

WALL-YE (France)

Robotic weeder for vegetable farms

Naïo Technologies (France)

Source: FF Robotics, WALL-YE, Naio Technologies

IFR International Federation of Robotics

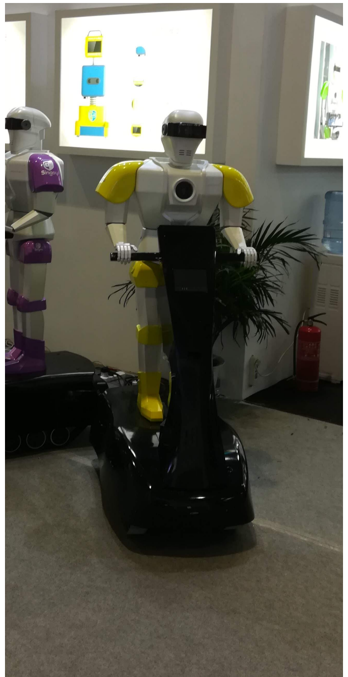
Start-up examples (II): Service robots in public-relations

Unity Robotics (D)

Bots and us (UK)

Promobot (RU)

WRC Exhibition - Beijing 2018

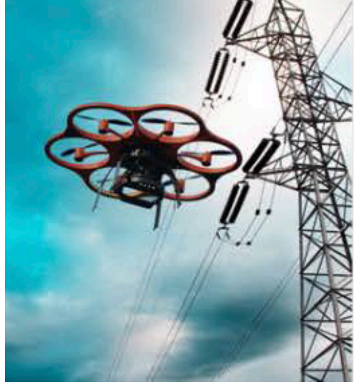


Start-up examples (III): Service robots in logistics


Mobile Industrial Robots MiR (DK)


Fetch Robotics (USA)


Robotnik (ES)





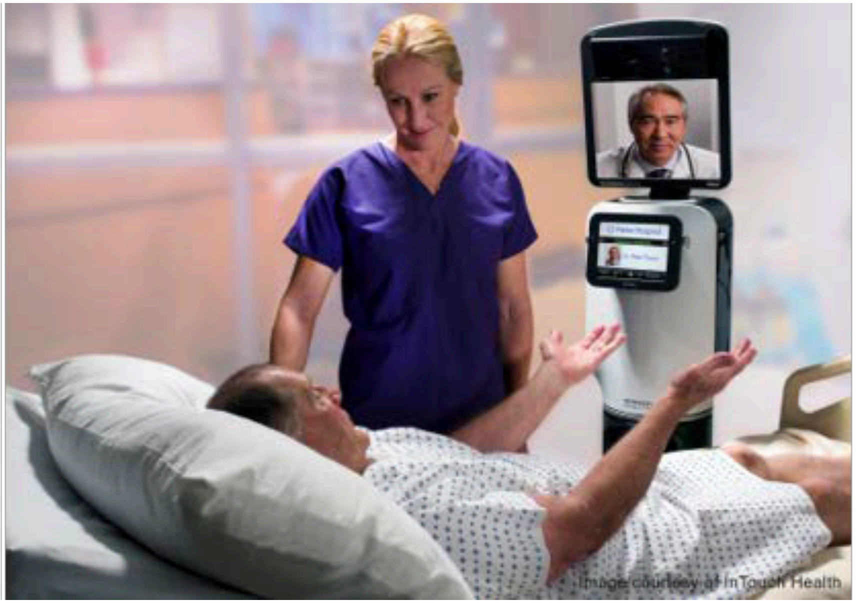


Image courtesy of InTouch Health





JOHN DEERE

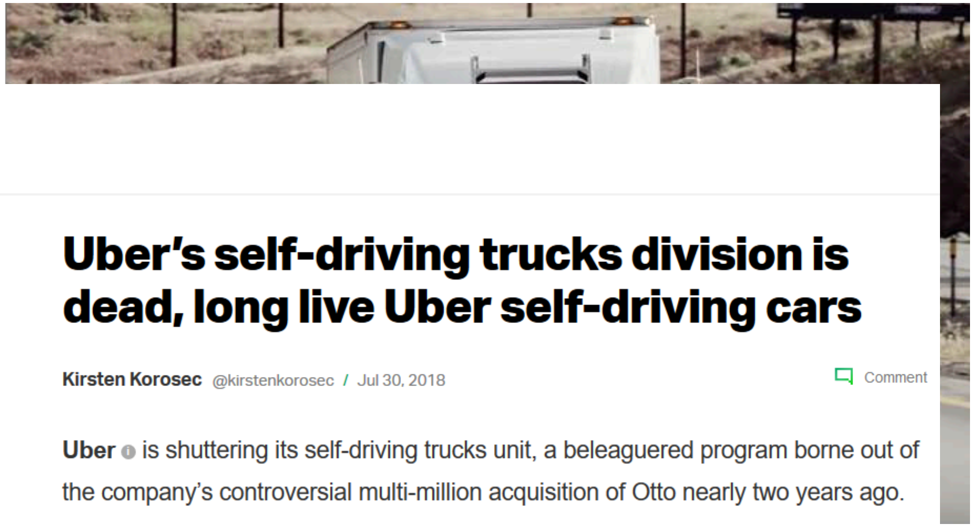
What’s possible today?

- Single-arm manipulation works well in known/constrained environments
- Navigation is mostly solved on flat(ish) terrain
- Aerial vehicles work well in open spaces but with significant power and computing constraints

Challenges:

- Combining navigation and manipulation (mobile manipulation)
- Operation in dynamic, unconstrained environments
- Humans
- …

Hottest Markets



TC

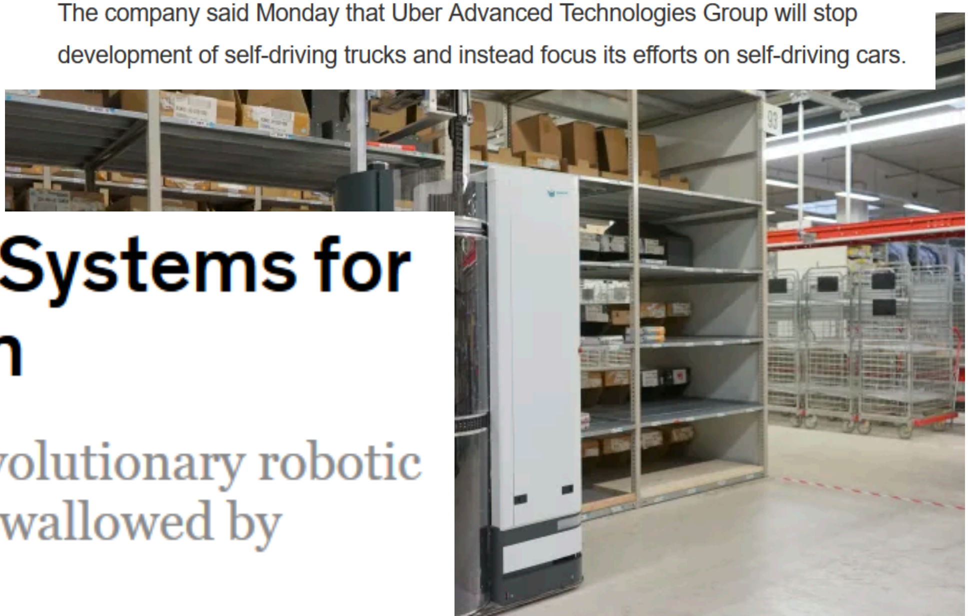
Startups
Apps
Gadgets
Events
Videos
—
Crunchbase
More

Uber's self-driving trucks division is dead, long live Uber self-driving cars

Kirsten Korosec @kirstenkorosec / Jul 30, 2018 Comment

Uber is shuttering its self-driving trucks unit, a beleaguered program borne out of the company's controversial multi-million acquisition of Otto nearly two years ago.

The company said Monday that Uber Advanced Technologies Group will stop development of self-driving trucks and instead focus its efforts on self-driving cars.



Amazon Acquires Kiva Systems for $775 Million

Kiva Systems, which invented a revolutionary robotic warehouse system, is being swallowed by Amazon.com

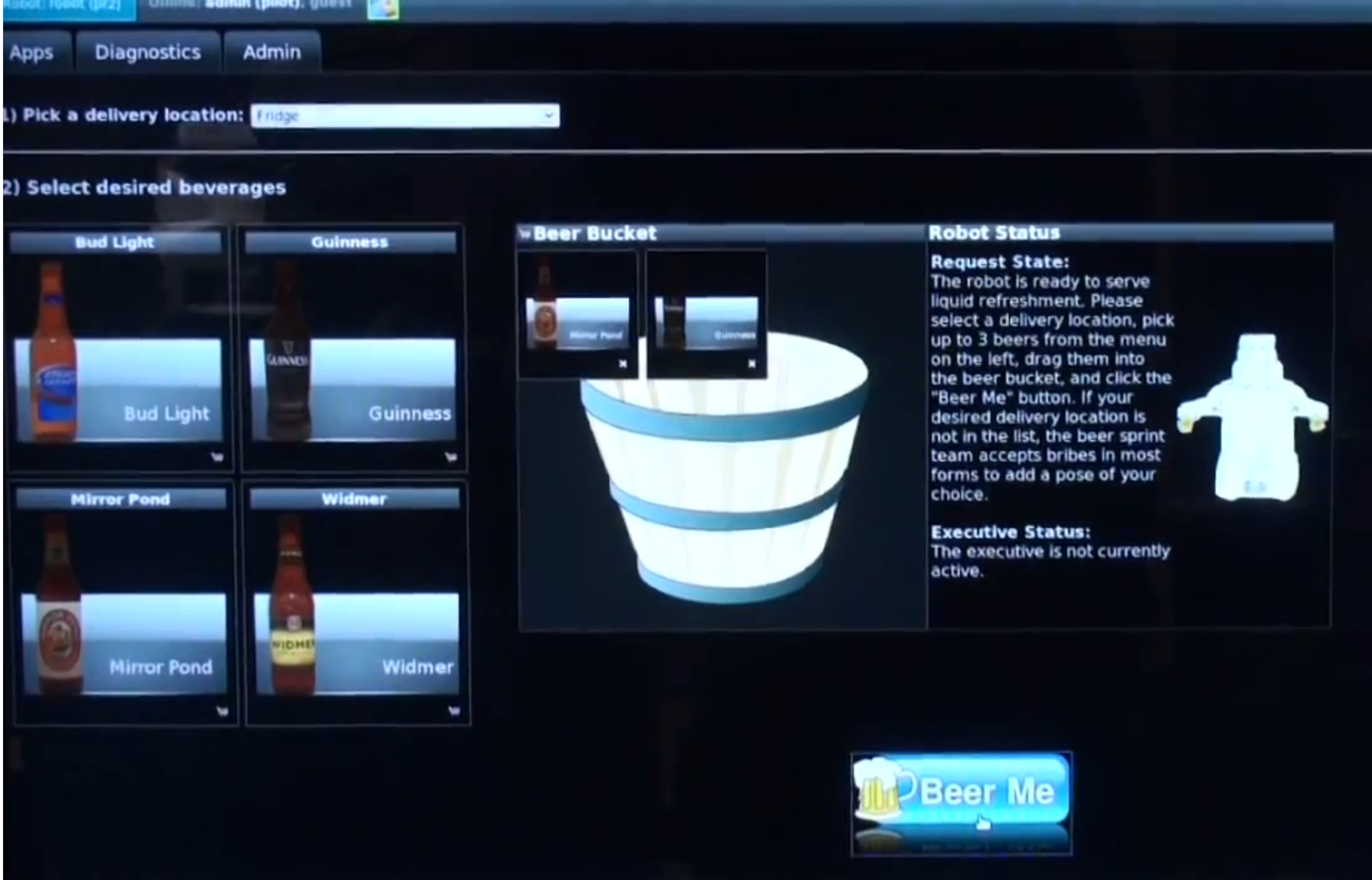
Autonomous (Wheeled) Vehicles

Things that are difficult:

- Perception
- Understanding the environment
- Dealing with uncertainty
- Decision making
- Antogonistic/adversarial drivers

Things that are less difficult

- Managing vehicle dynamics
- Low-level control


Apps
Diagnostics
Admin
1) Pick a delivery location:
Fridge
2) Select desired beverages
Bud Light
Guinness
Mirror Pond
Widmer
Beer Bucket
Robot Status
Request State:
The robot is ready to serve liquid refreshment. Please select a delivery location, pick up to 3 beers from the menu on the left, drag them into the beer bucket, and click the "Beer Me" button. If your desired delivery location is not in the list, the beer sprint team accepts bribes in most forms to add a pose of your choice.
Executive Status:
The executive is not currently active.
Beer Me

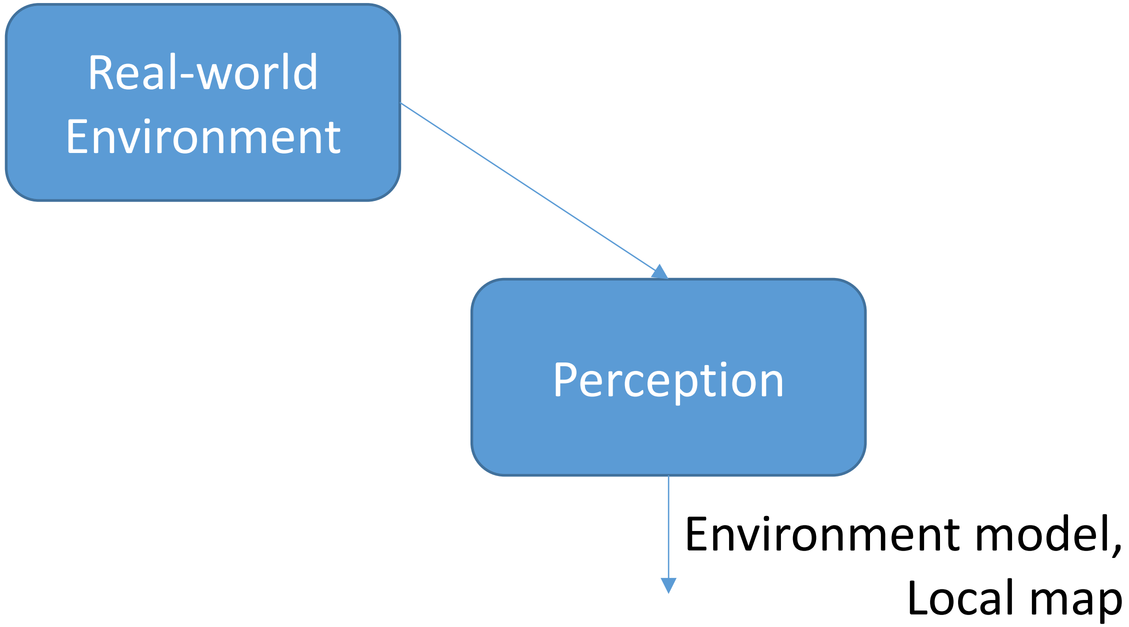
In this class we'll use the general problem of ***sensor-based mobile robot navigation*** to:

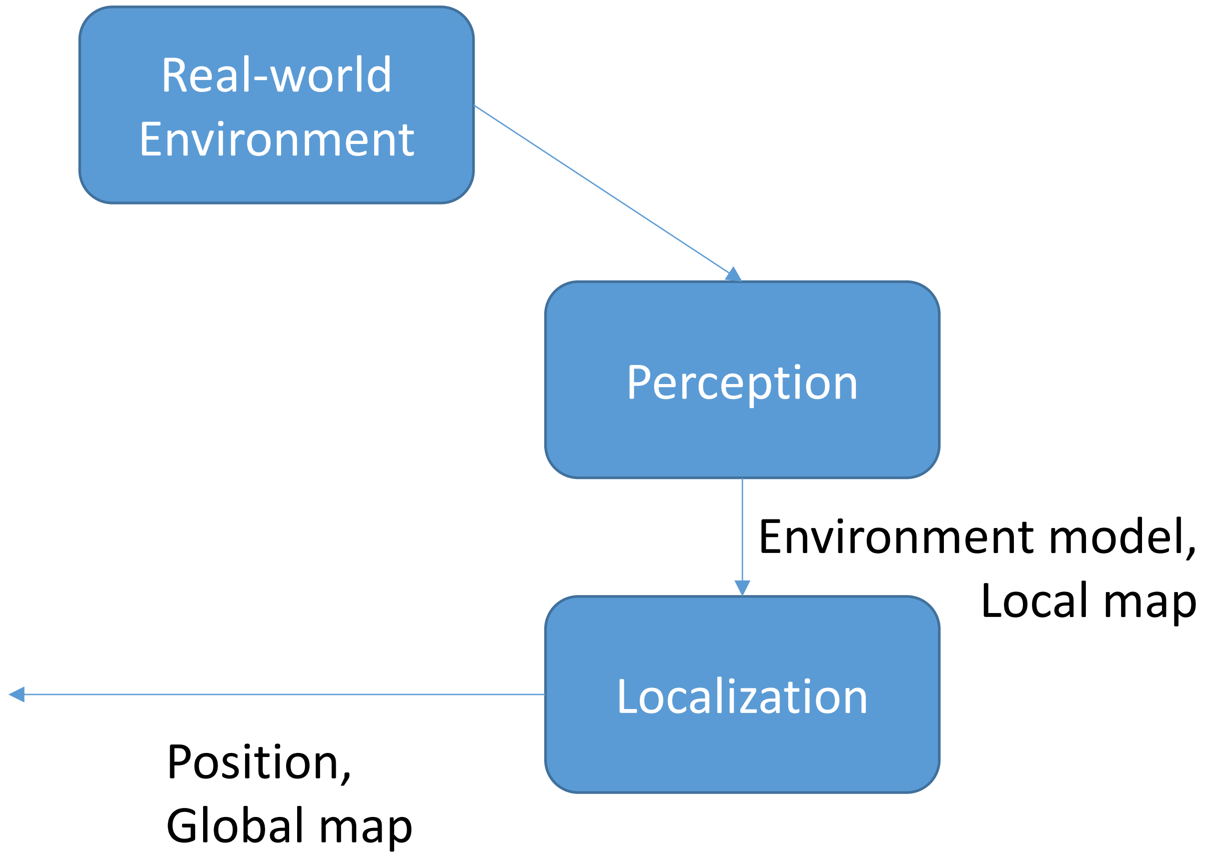
- introduce characteristic problems in robotics
- develop mathematical models for those problems
- describe typical algorithms to solve those problems
- implement and test our algorithms on a small mobile robot

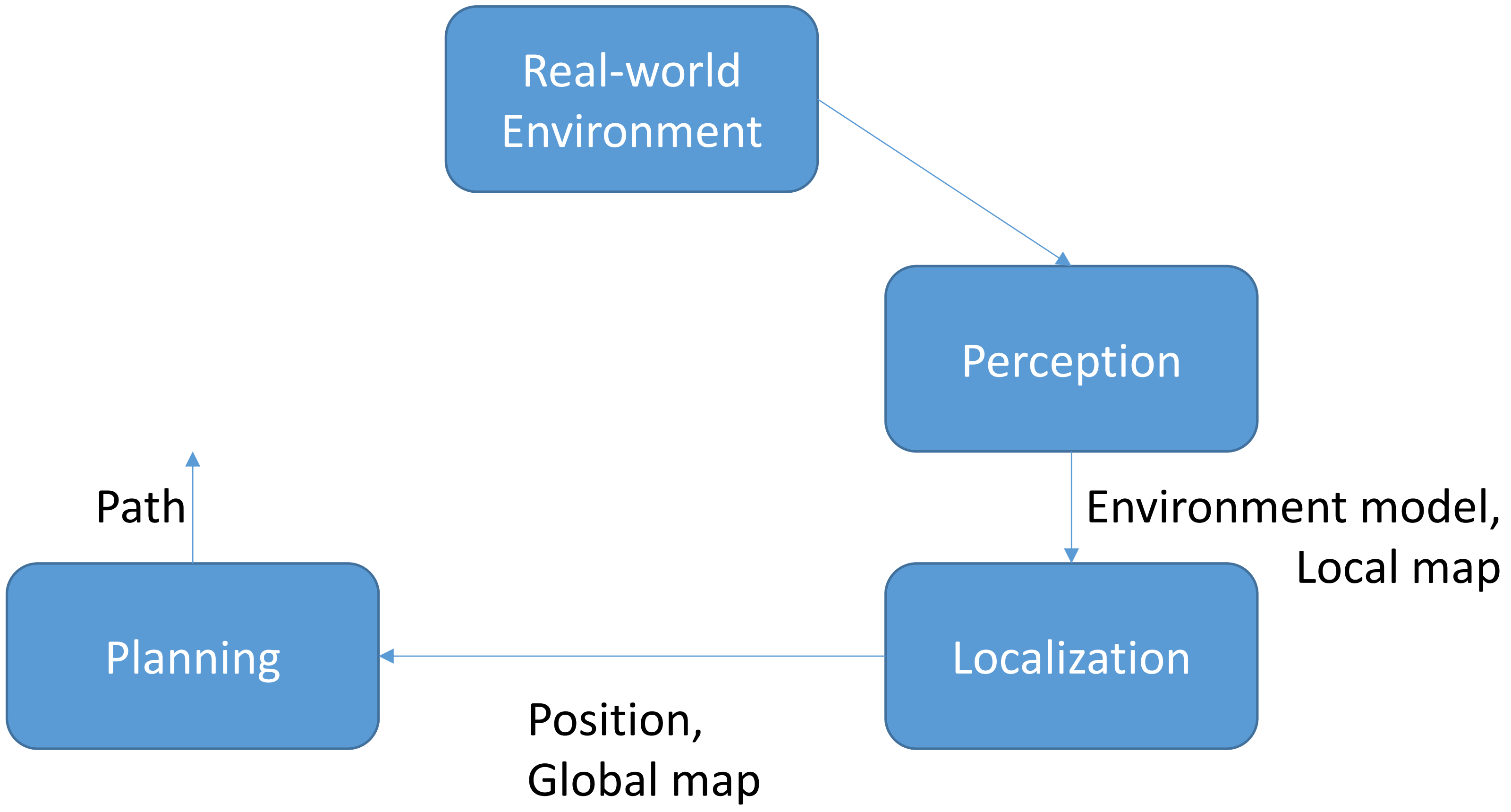
Topics covered in this class

- Perception (Sensing, Image processing)
- Kinematics and Odometry
- Localization
- Path planning
- Etc.

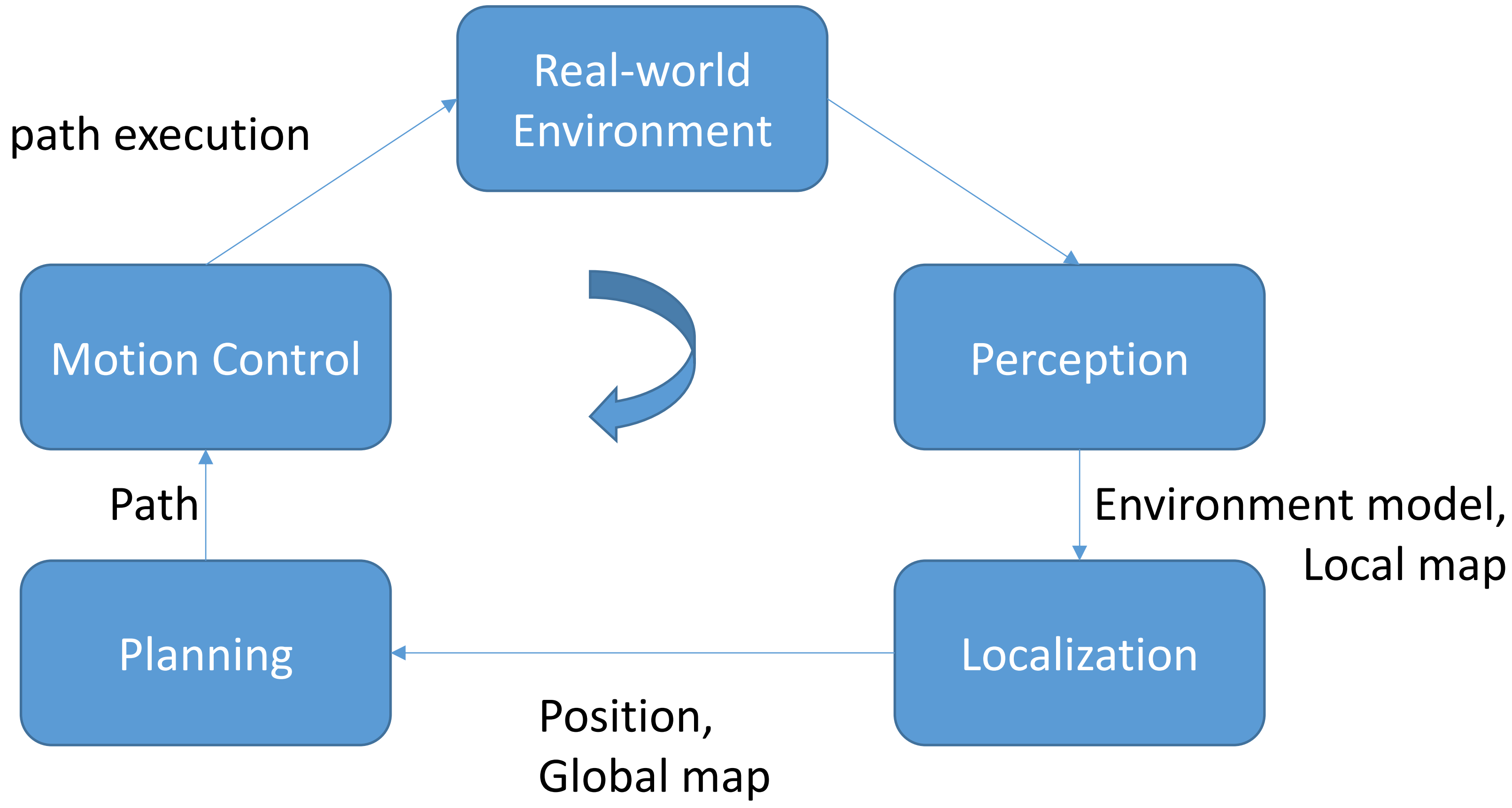
Real-world
Environment


Real-world Environment
Perception
Environment model,
Local map


Real-world Environment
Perception
Environment model,
Local map
Localization
Position,
Global map



Real-world Environment
Perception
Environment model,
Local map
Localization
Position,
Global map
Planning
Path


Real-world Environment
path execution
Motion Control
Perception
Path
Environment model,
Local map
Planning
Localization
Position,
Global map

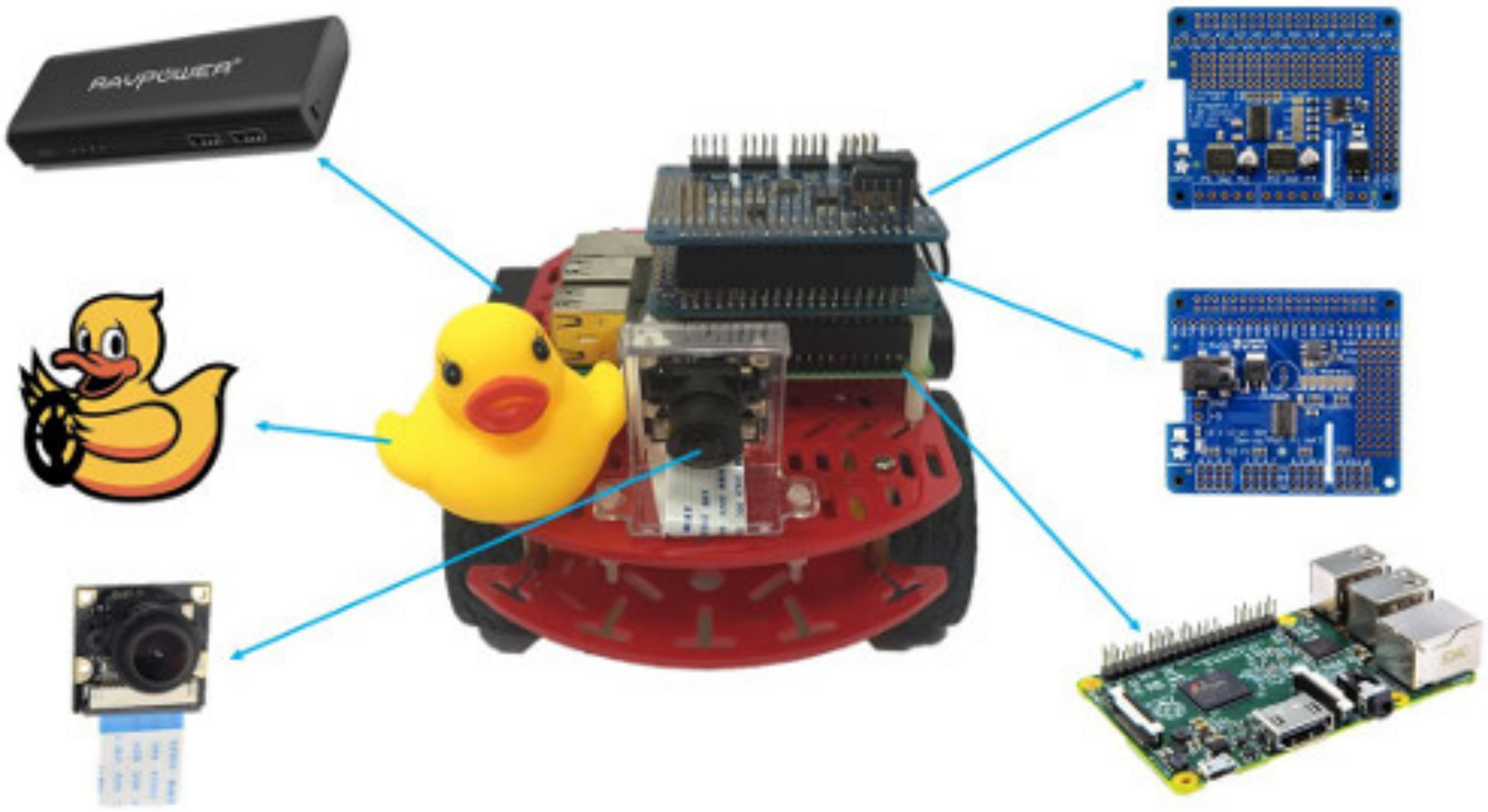
Class Logistics

A New Version of CS3630

- We'll use ***Duckiebots*** this year. Linux-based, Raspberry Pi for computation, better motor control, better WiFi connectivity.
  - Duckiebots are being used in many courses across the world, so there's a growing support infrastructure for this platform.
  - In past years, we used the Cozmo robots for the experimental portion of the class. Sadly, the company that makes the Cozmos (Anki) has gone out of business, so we've changed robot platforms.
  - Happily, the capabilities of this robot are better than the Cozmo.

- Since we'll be using more capable robots, this seems like a good time to upgrade the content of the class.
  - New, modernized list of topics.
  - New lab assignments.
  - We'll occasionally need to adjust as we go, deal with problems as they arise.
  - It will be an adventure for us all!

The Duckiebot:



Why this Duckie business??

- *The Duckie was introduced into the robotics community to be included in robot videos for a past ICRA, to show scale.*

Basic chasis

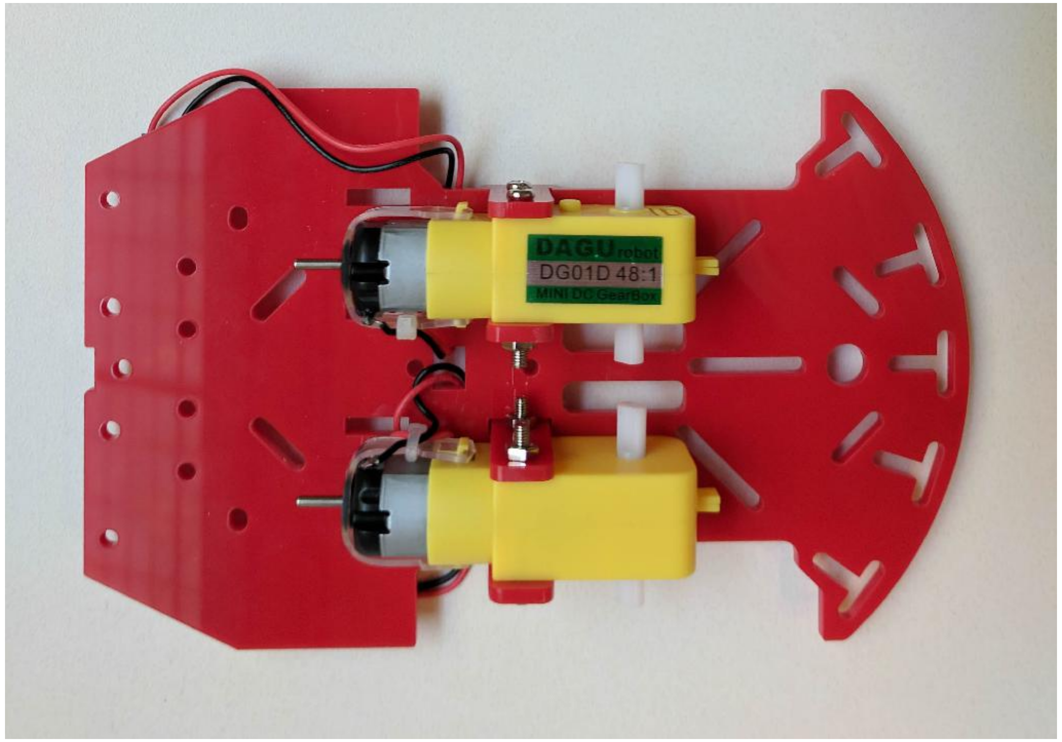
The chassis pack includes 2 DC motors and wheels as well as the structural part.

This robot is a *differential drive* robot:

- The two wheels are controlled independently.
- If the wheels spin in the same direction at the same speed, the robot moves forward.
- If the wheels spin in opposite directions at the same speed, the robot turns in place.

We'll learn all about the kinematics of differential drive robots soon.

Wheel Motors



The motors are attached to the bottom plate of the chassis.

- Our Duckiebots have wheel encoders, which allows us to do some simple odometry in addition to using computer vision for localization.

On-board processing

The Raspberry Pi is the central computer of the Duckiebot.

Duckiebots use Model B

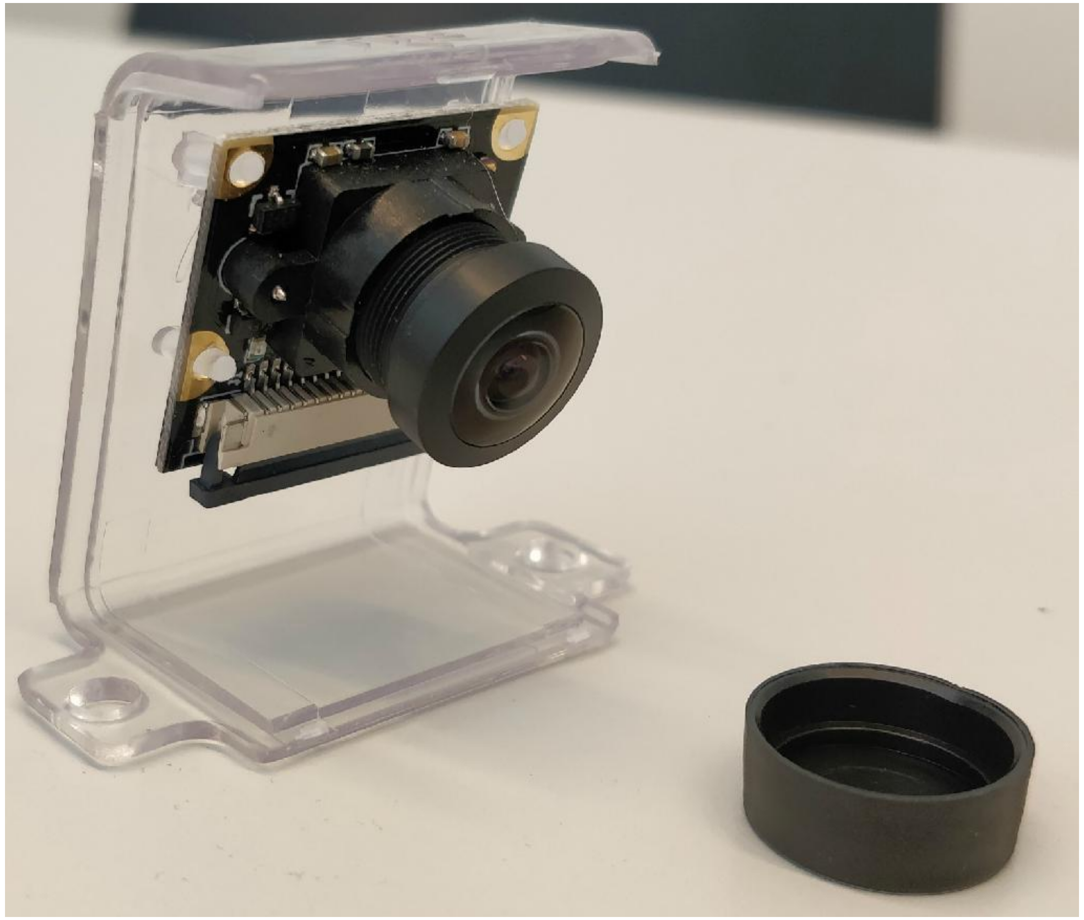
- 1.2GHz 64-bit quad-core ARMv8 CPU
- 1GB RAM

A small but powerful computer.

The MicroSD card is the hard disk of the Raspberry Pi.

- ➢ 16 GB of capacity are sufficient for the system image.

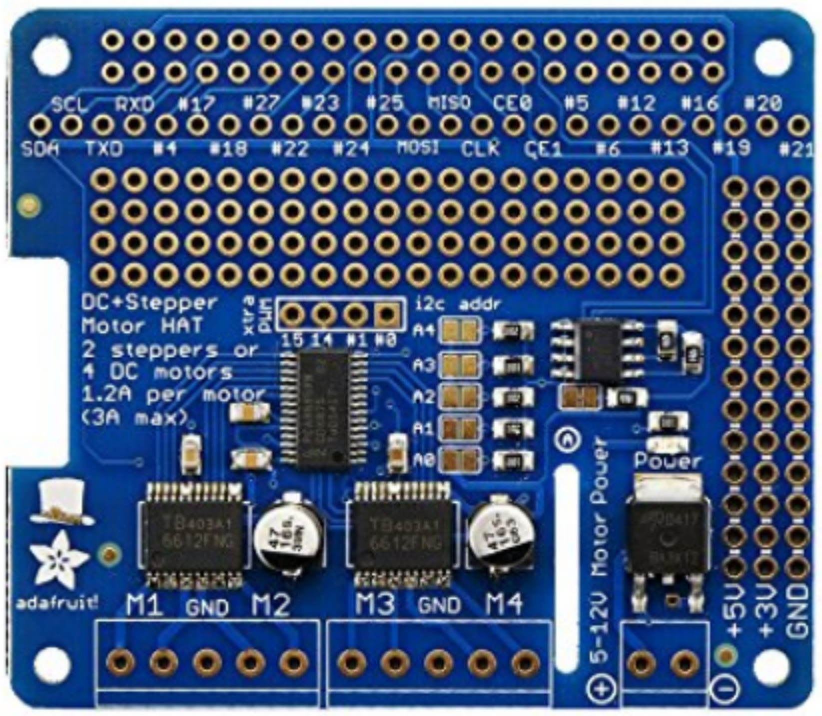
Sensing: On-board camera



The Camera is the main sensor of the Duckiebot.

All versions equip a 5 Mega Pixels 1080p camera with wide field of view (160∘160∘) fisheye lens

Motor Control



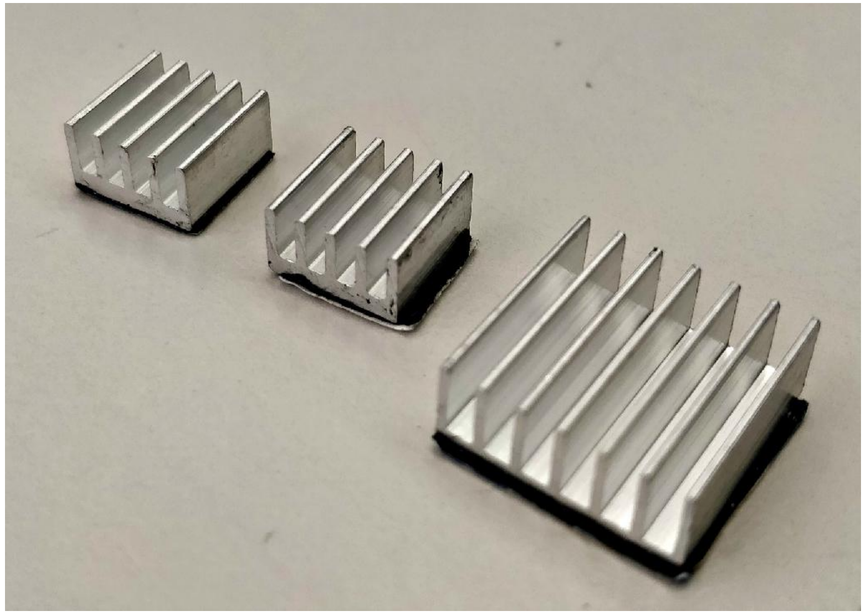
We use the DC Stepper motor HAT to control the DC motors that drive the wheels.

This HAT has dedicated PWM and H-bridge for driving the motors.

***HAT**: Hardware Attached on Top.*

A HAT is an add-on board for B+ that conforms to a specific set of rules that will make life easier for users.
A significant feature of HATs is the inclusion of a system that allows the B+ to identify a connected HAT and automatically configure the GPIOs and drivers for the board, making life for the end user much easier.

Hardware concerns



The Raspberry Pi will heat up significantly during use. It is warmly recommended to add heat sinks.

Since we will be stacking HATs on top of the Raspberry Pi with 15 mm standoffs, the maximum height of the heat sinks should be well below 15 mm.

The chip dimensions are 15x15mm and 10x10mm.

You will need a **laptop** to participate in this class.

If you don’t have one, come talk to me.

All programming will be in **Python**.

Can you take this class if you don’t know python?

- Yes, if you’re willing to put in the time to learn.

Textbook

This year, we will be creating a course textbook in real time, during the semester. The evolving draft will be available on the course web site.

In addition, we'll frequently provide alternative source material for topics that are covered in class. In general, this material will be available online (i.e., no need to buy a textbook for this class). A few references include:

- *Introduction to Autonomous Mobile Robots*, by R. Siegwart, I. R. Nourbakhsh, MIT Press, 2011.
- *Springer Handbook of Robotics*, Bruno Siciliano and Oussama Khatib (Eds.), Springer, 2008.
- *Robotics, Vision and Control*, by Peter Corke, Springer, 2011.

Resources will be made available as needed.

Grading

- 7 projects, each worth 10% of the total grade
  - Hardware projects will be done in teams of size two
- 7 quizzes
  - Drop the two lowest grades
  - Remaining 5 quizzes each worth 6% of the total grade

Since we are dropping the two lowest quiz grades, quizzes will not be rescheduled for absences due to minor illness, interviews, trips, etc.

Please contact me directly if you have extenuating circumstances (prolonged illness, hospitalization, death in the family) and we will make special arrangements.

Cheating

We take cheating seriously, there were multiple instances last semester.
Sharing code and creating public repositories constitutes as cheating.

Discussing ideas is fine.

Please reference any external sources you used in your submission.

Partners

You will need a partner for hardware labs.

You are free to select your own partner, though we can help connect people if needed.

You can change partners at any time.

We encourage you not to continue working with a partner who is not pulling their weight. Switch to someone else, or come talk to me about making other arrangements.

Course websites

Canvas: grades (also contains links to syllabus and assignments)

Course web site (available soon)

Please communicate to us through online discussion forum instead of email for all general questions.

Outcomes of this course

You will learn the joys and frustrations of programming a physical robot

You will gain an understanding of the challenges involved in perception and navigation, as well as some of the top solutions for addressing these problems

You will implement techniques for image processing, path planning and localization, and develop a behavior architecture that enables the robot to integrate all of these components

Course Instructors

Frank Dellaert, Professor

School of Interactive Computing

Seth Hutchinson, Professor

School of Interactive Computing