The Future of AI
A Robotics Perspective

Wolfram Burgard

Autonomous Intelligent Systems
Department of Computer Science
University of Freiburg
Germany

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My Robotics Perspective

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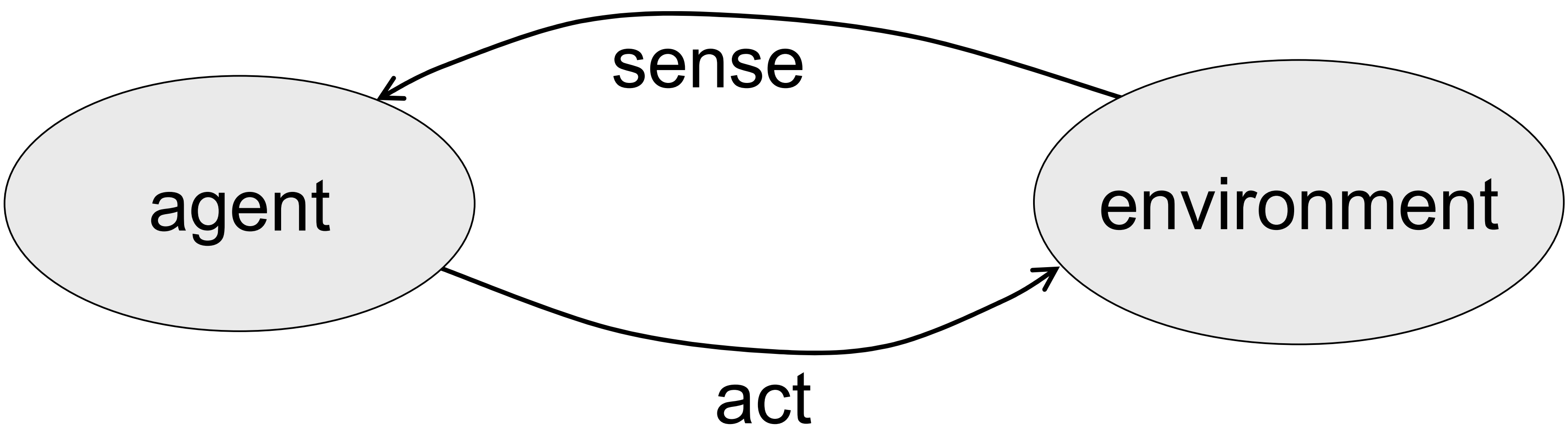
Autonomous Systems in AI

Agents that

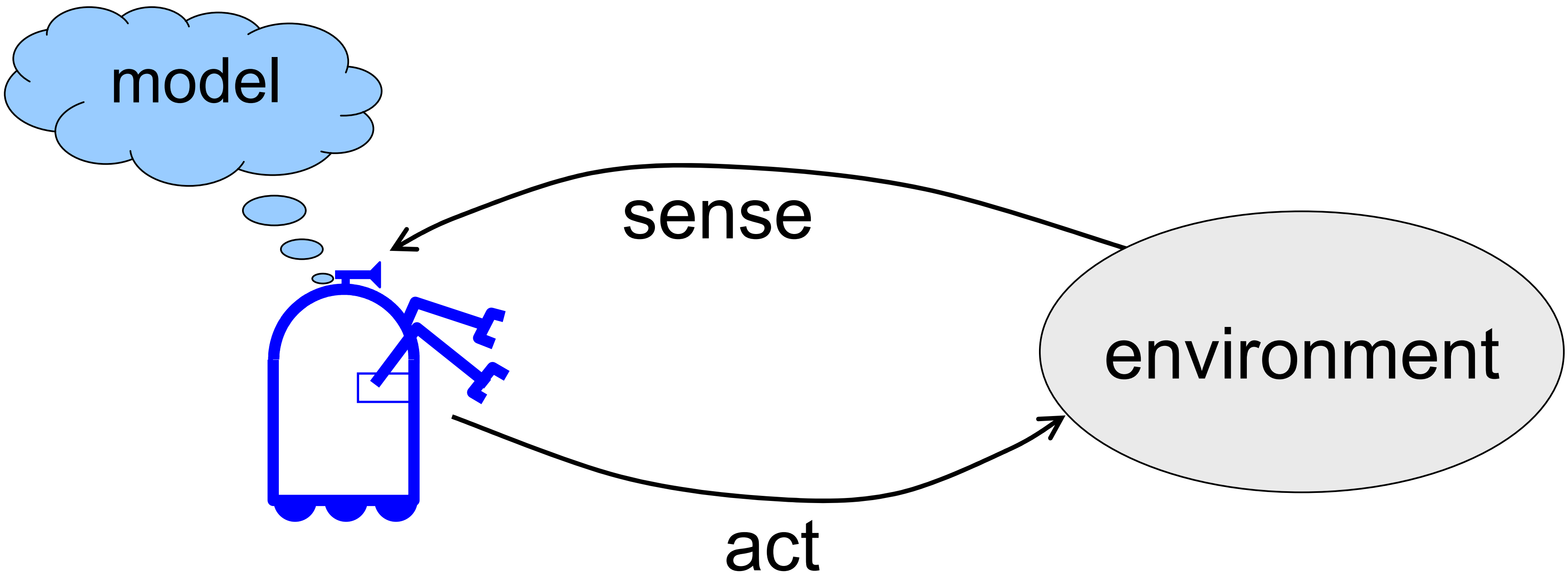
- perceive their environment and
- generate actions to achieve their goals



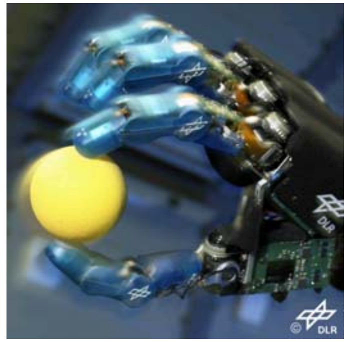
... in Robotics

Physical agents that

- perceive their environment and
- generate actions to achieve their goals

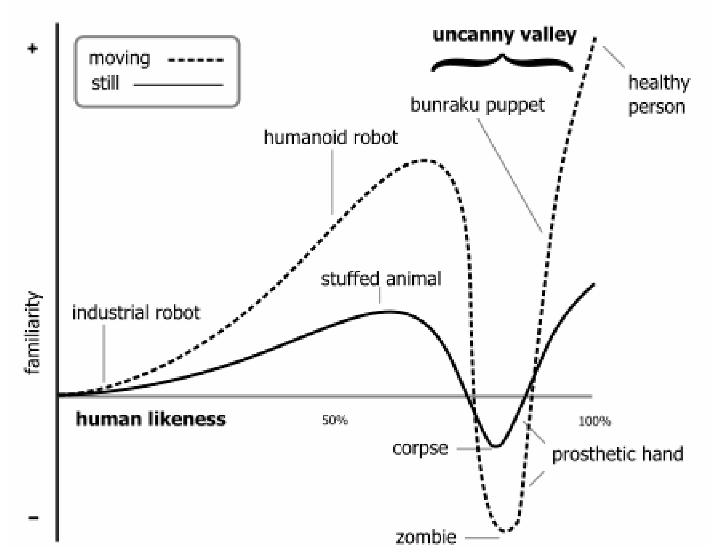


Where are We?



“Humanoids”

Overcoming the uncanny valley



[Courtesy by Hiroshi Ishiguro]

RoboCup

[Courtesy by Sven Behnke]

The DARPA Grand Challenge

[Courtesy by Sebastian Thrun]

Tasks to be Solved by Robots

- Collision Avoidance
- Mapping
- Localization
- Path planning
- Perception
- Acting (under uncertainty)
- Interaction
- Manipulation and grasping
- Planning
- Learning
- Cooperation
- ...

} Navigation (Collision Avoidance, Mapping, Localization, Path planning)

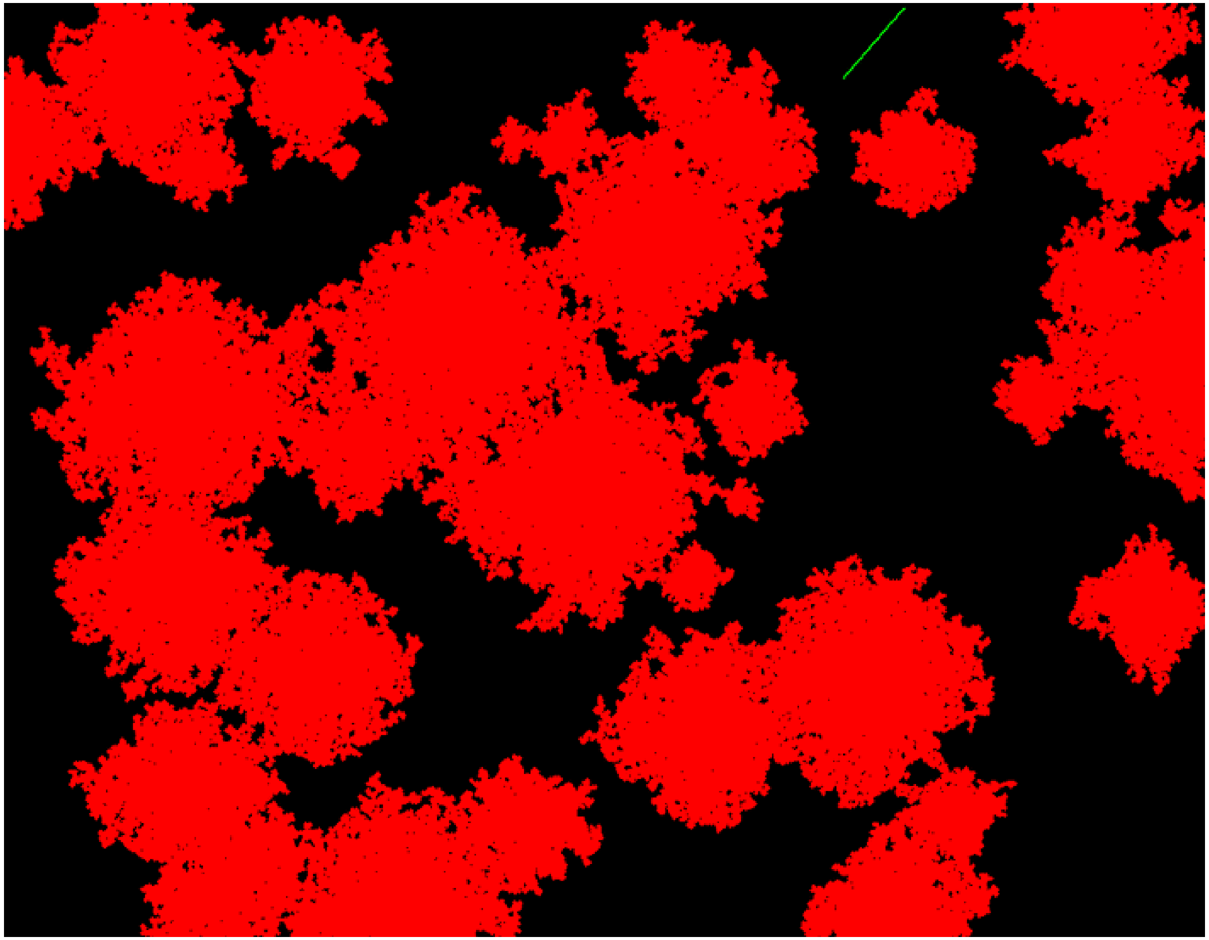
AI Disciplines Involved

- Machine learning
- Planning
- Distributed AI
- Probabilistic AI
- ...

Problems Argued to be Solved in Robotics

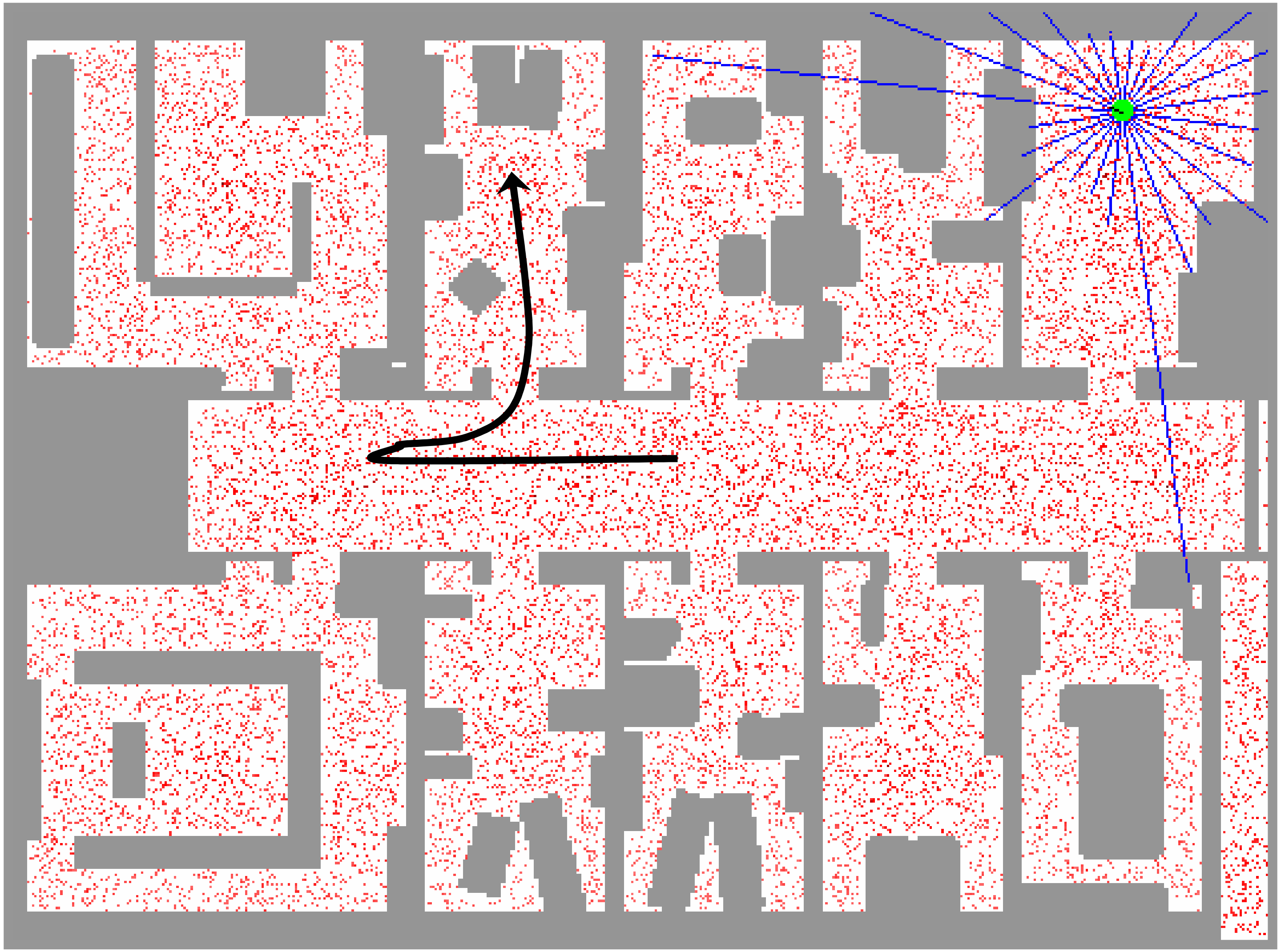
- Localization
- Path planning
- Mapping
- SLAM

Path Planning

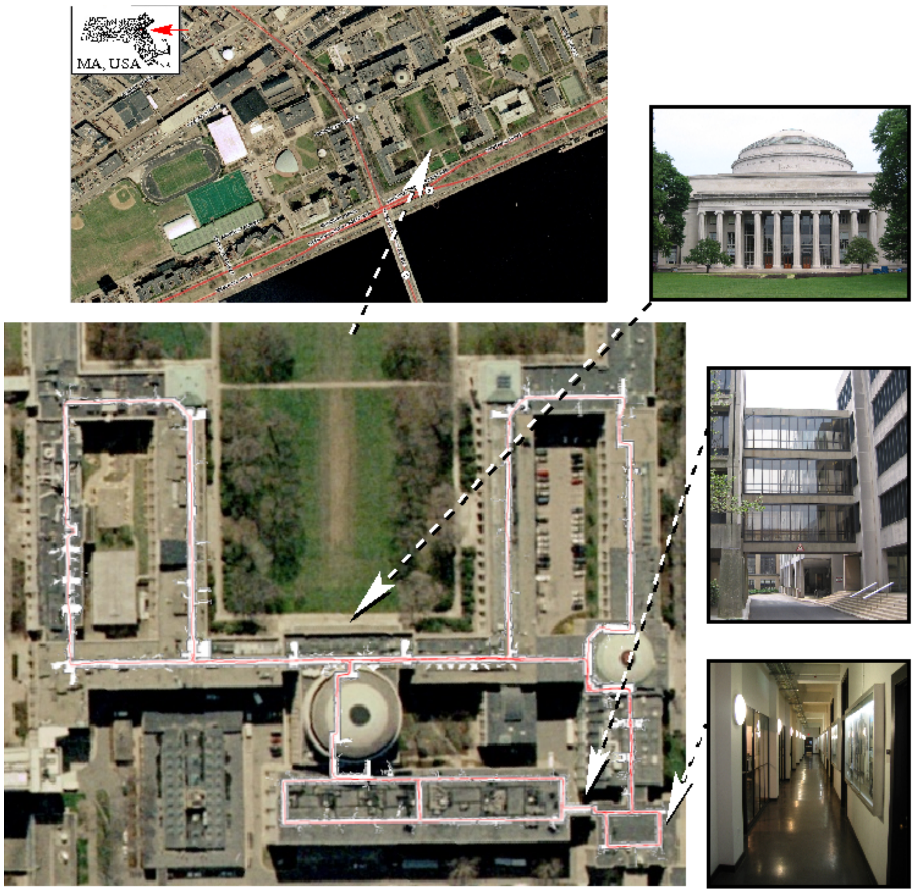


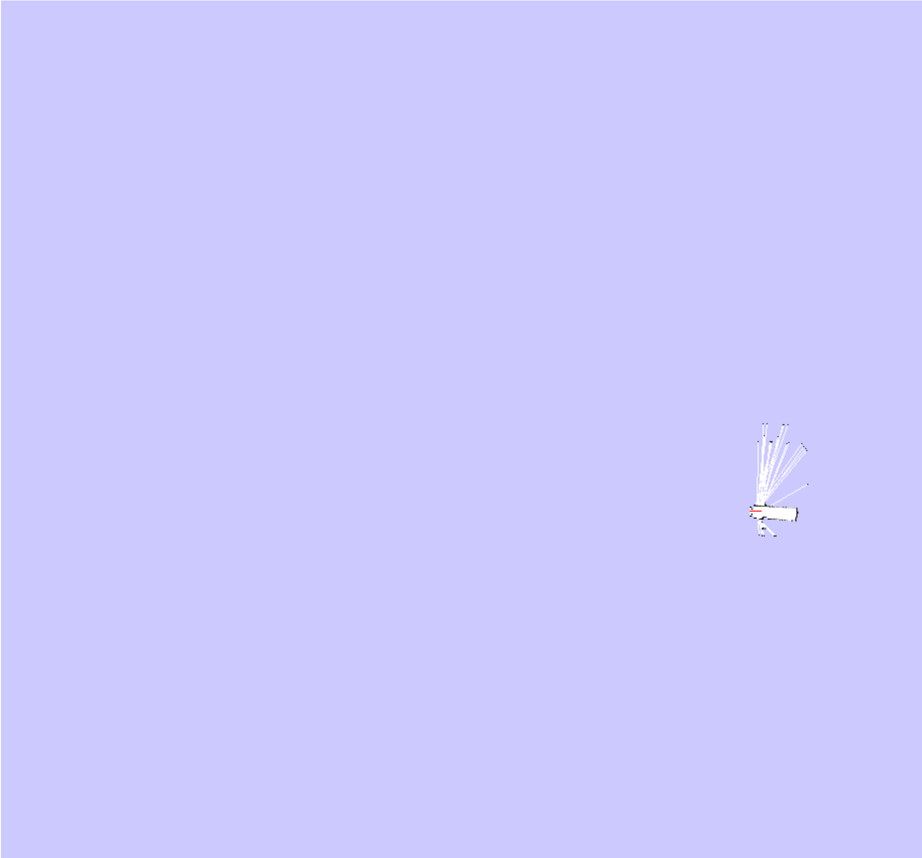
[Courtesy by Dave Ferguson]

Localization

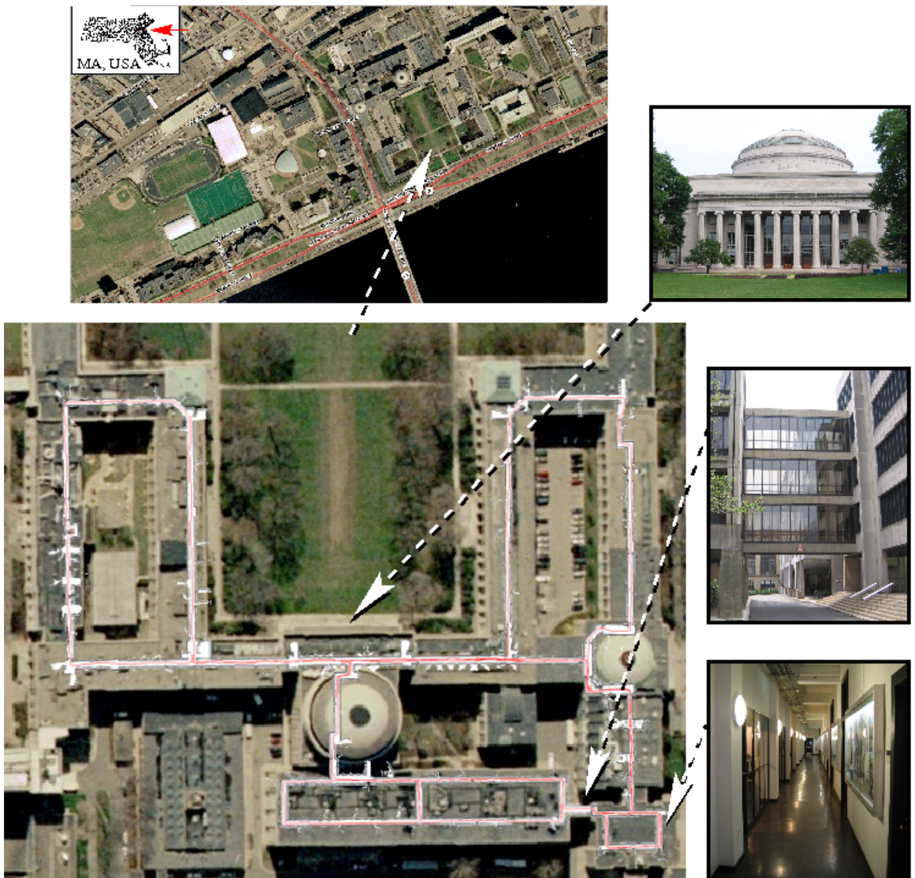


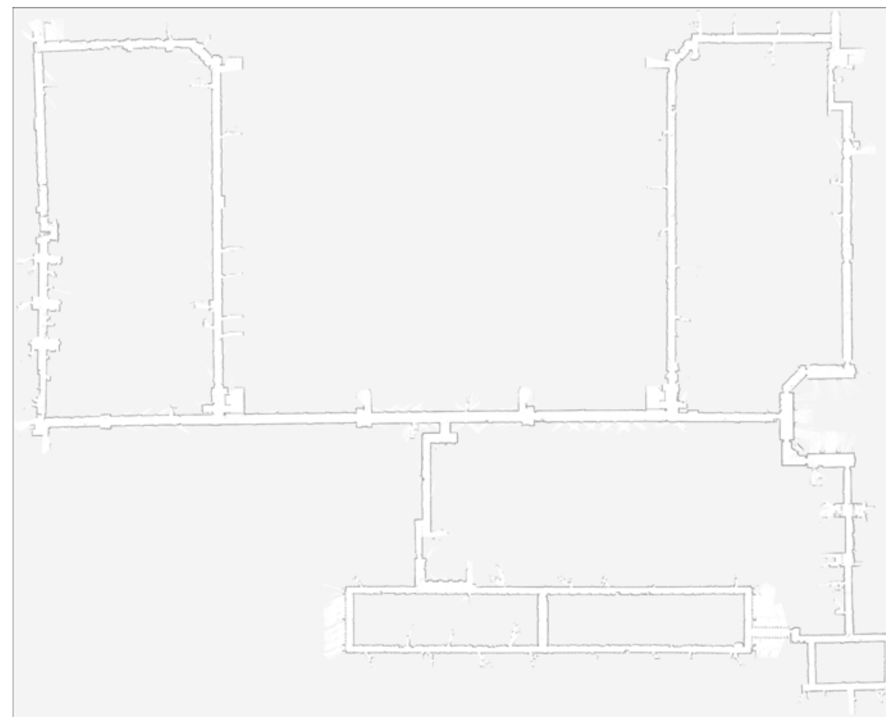
SLAM





SLAM





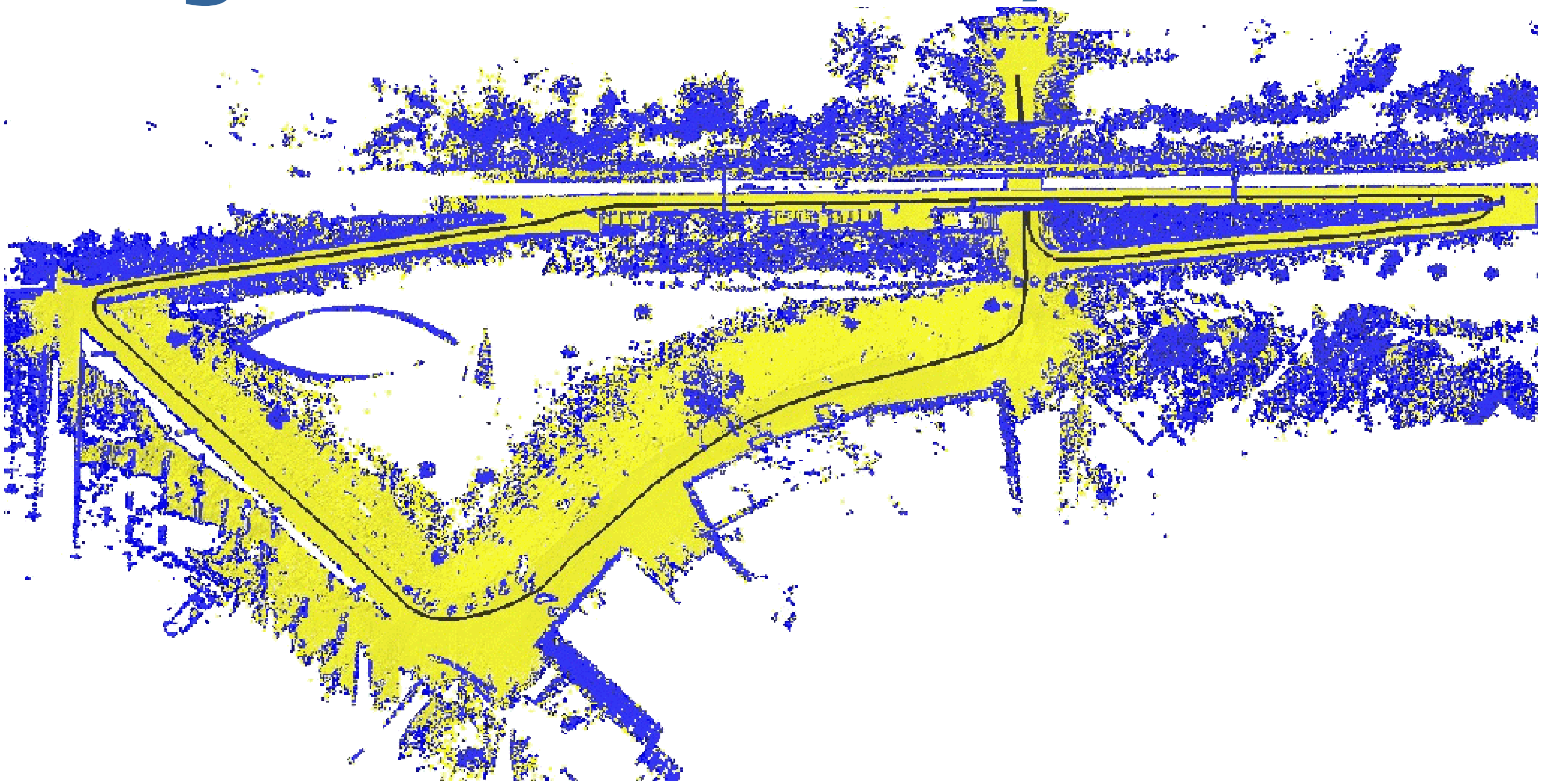
What are We Good At?

- Mechanical design
- Navigation
- Planning
- Multi-agent systems
- Learning

Limitations and Challenges

- Dynamic and changing environments
- Large-scale environments
- Object recognition
- Recognition of situations
- Representations
- Planning complex behaviors
- …

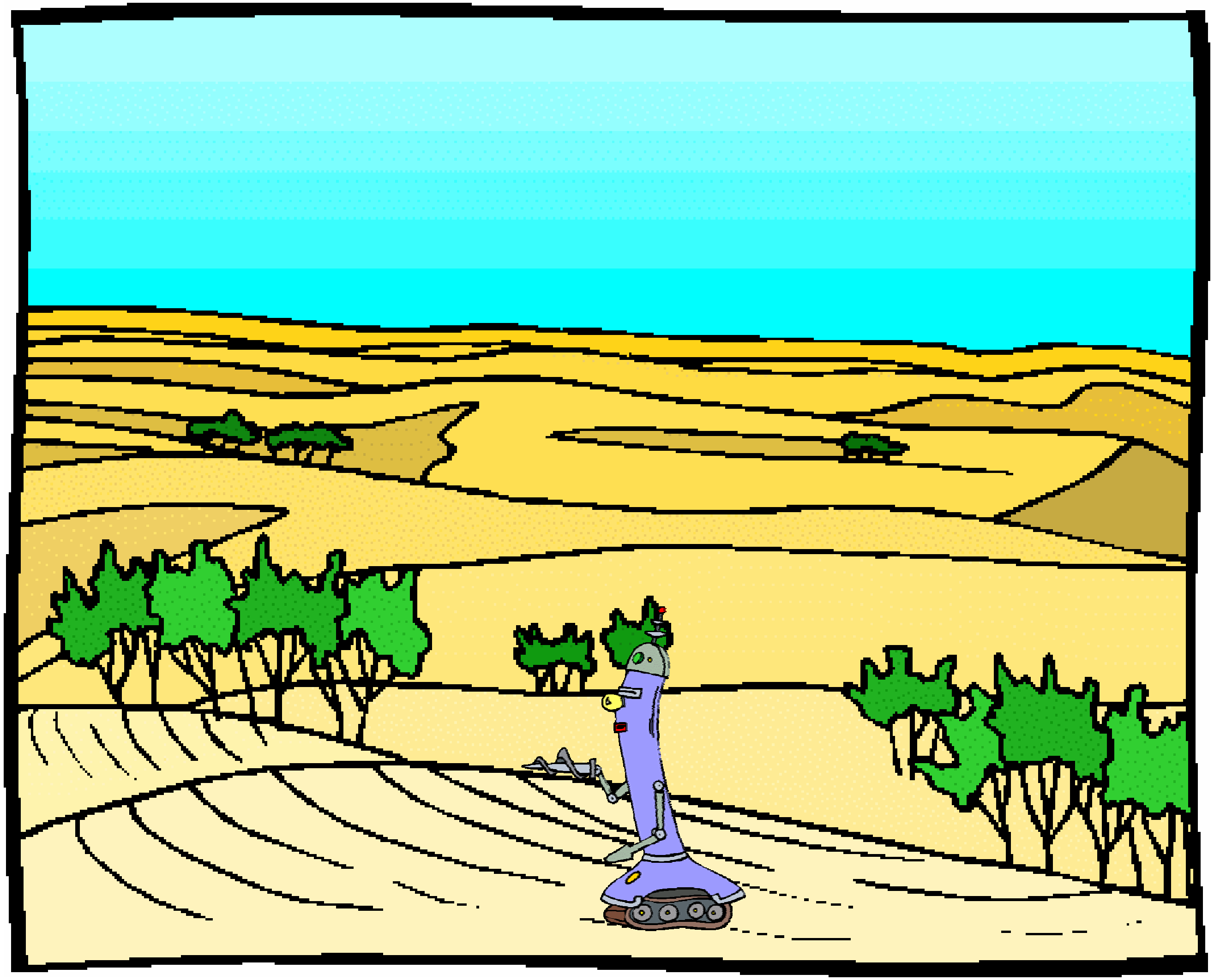
Large-Scale Indoor/Outdoor



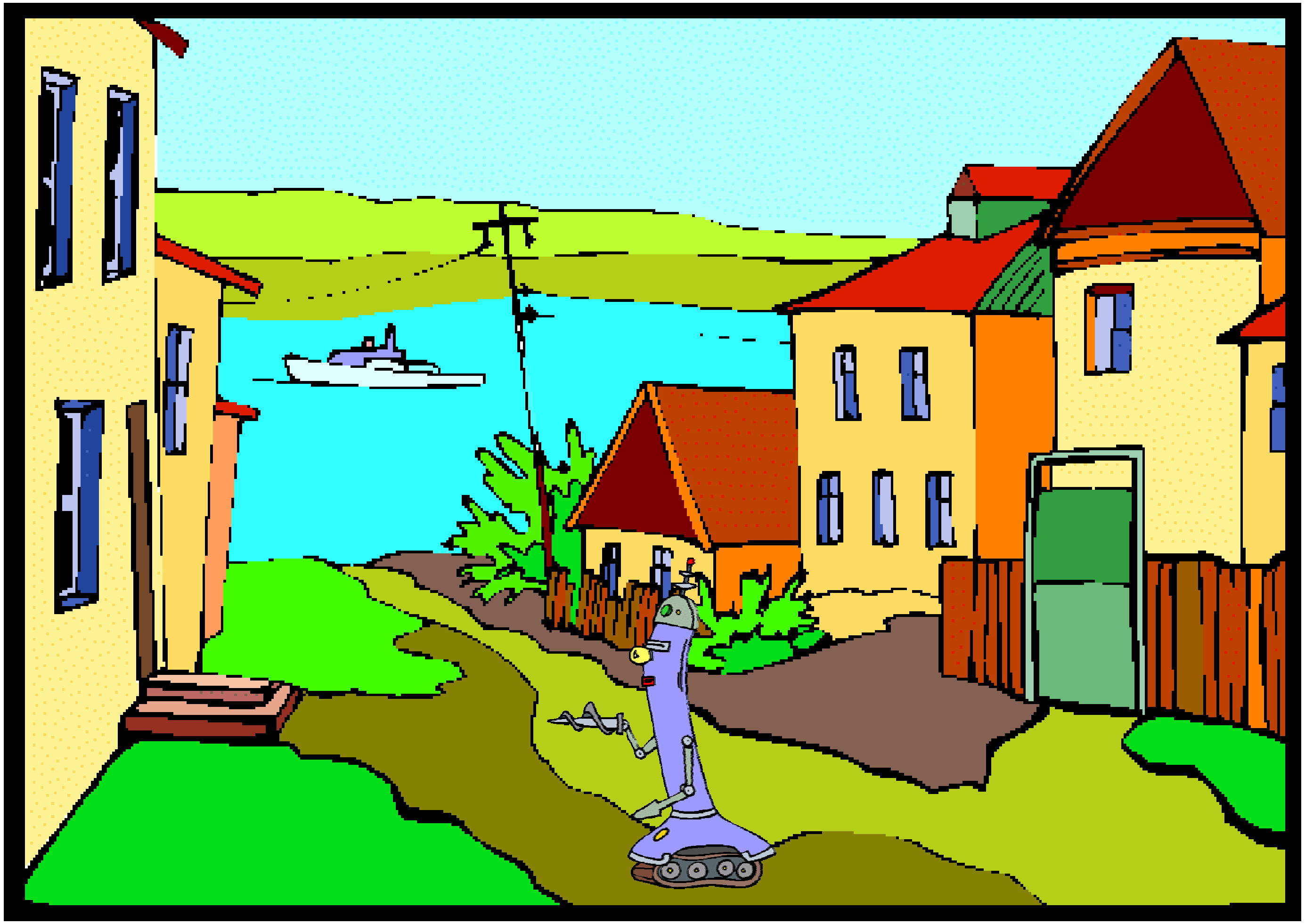
- Map size: 299 by 147*m*
- Cell resolution: 10*cm*
- Number of data points: 45,000,000

3D Map Example

Increasing Size



Increasing Complexity



Consequences

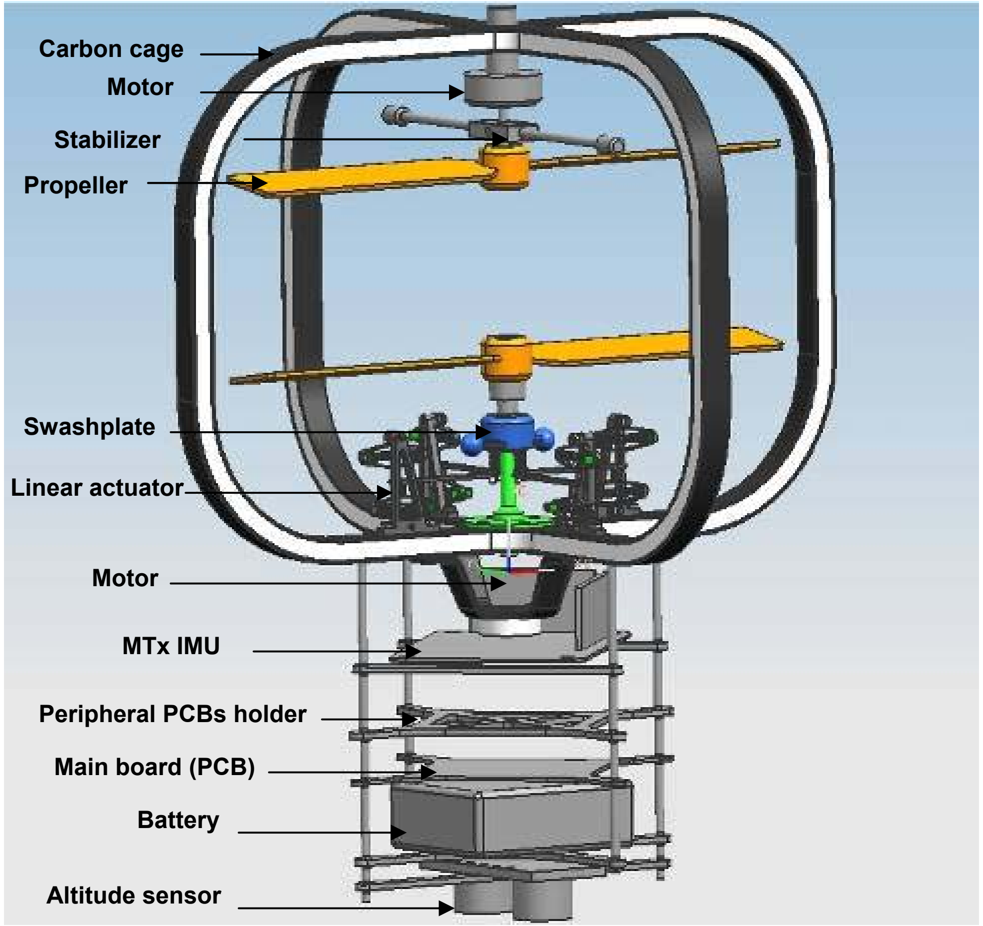
- Many existing algorithms are too complex to be applicable.
- Storage capacity eventually too small.
- We lack representations that
  - cover all relevant aspects and
  - can be efficiently updated upon sensory input

Reducing the Size of the Robot

- Minimization of energy consumption
- Low computational power
- Limited perception

Micro Arial Vehicles

- Characteristics
  - 80g
  - 120mm span width
  - 4mins flight time
  - BT communication
  - RC commands
  - Up to 2000 MMACs
- Features
  - Attitude control
  - Altitude control
  - Forward flight
  - Indoor operation
  - Manually launched



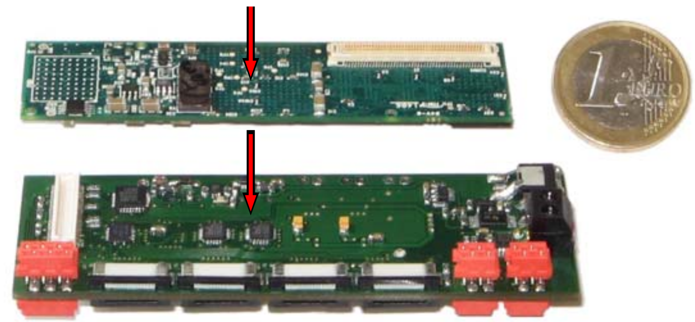
[Courtesy by muFly Project]

Prototype of the muFly Project

The Blimp System

Intel XScale PXA270 600MHz, 32MB flash memory with a full-fledged Linux system

Interface Card providing several communication interfaces like UART, SPI, I^2C, GPIO, and USB



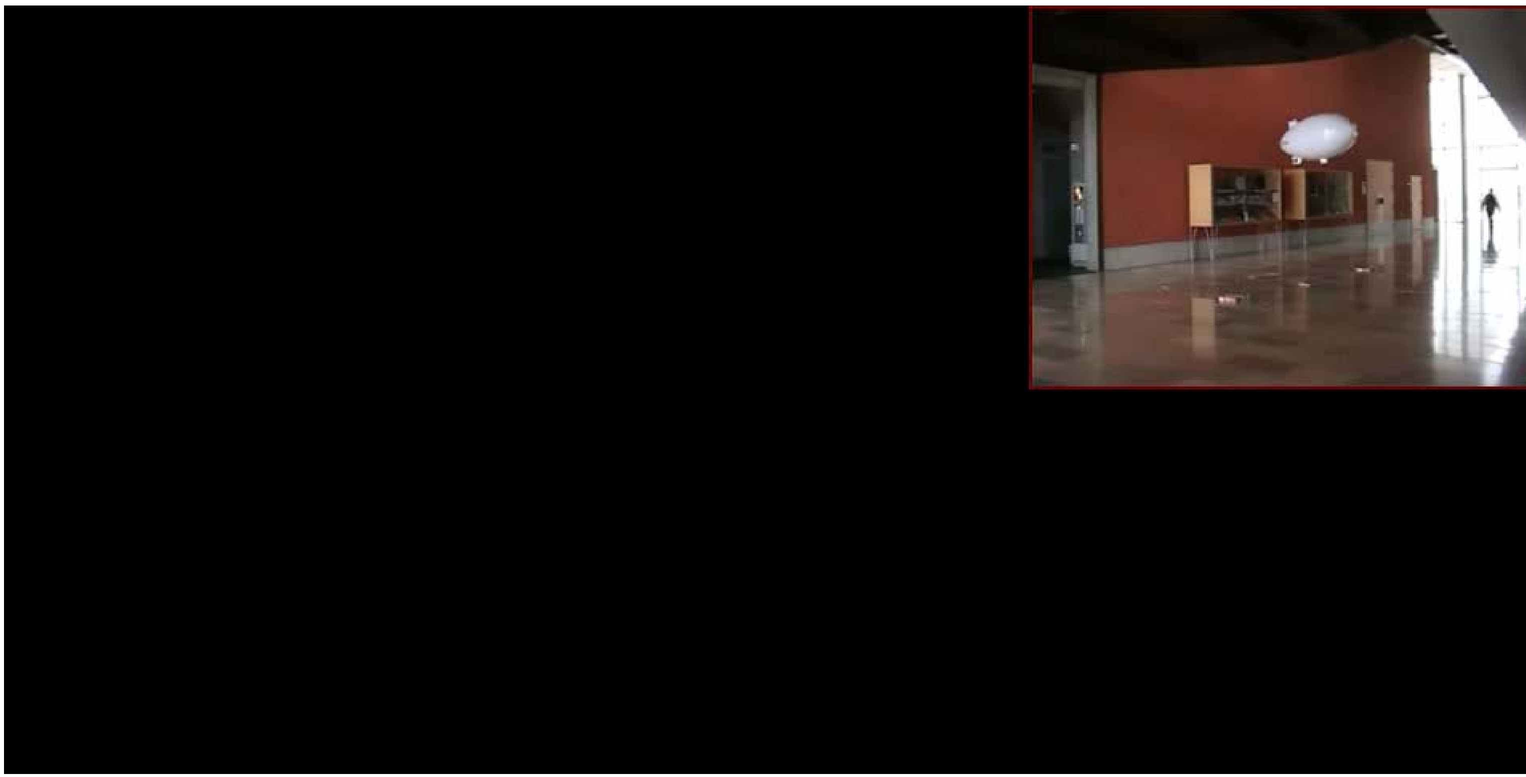
USB camera

Ultrasonic senor

Battery, 3.7V, 1500mAh

Total weight 180 grams

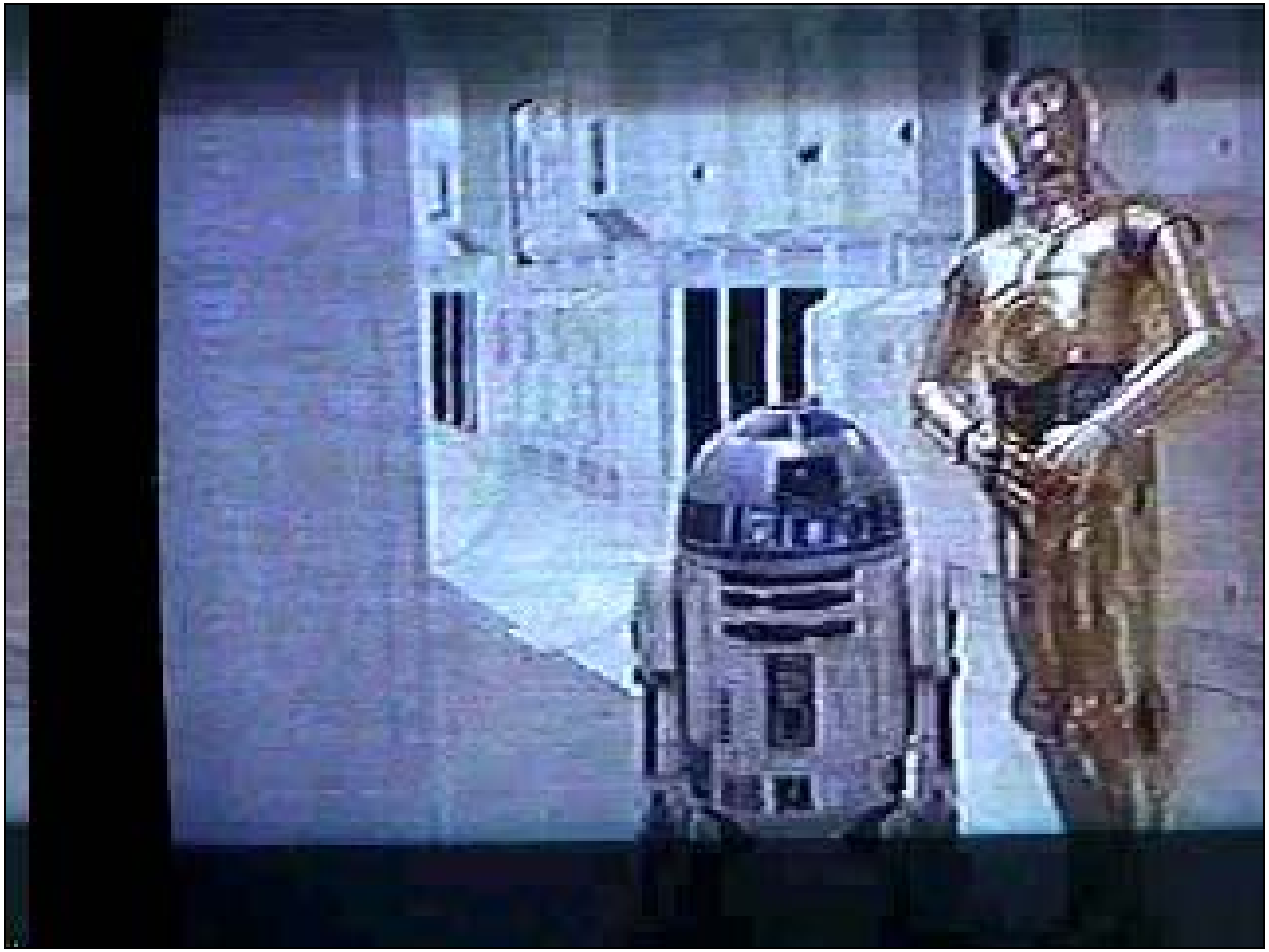
How to Scale Computing Intensive Algorithms?



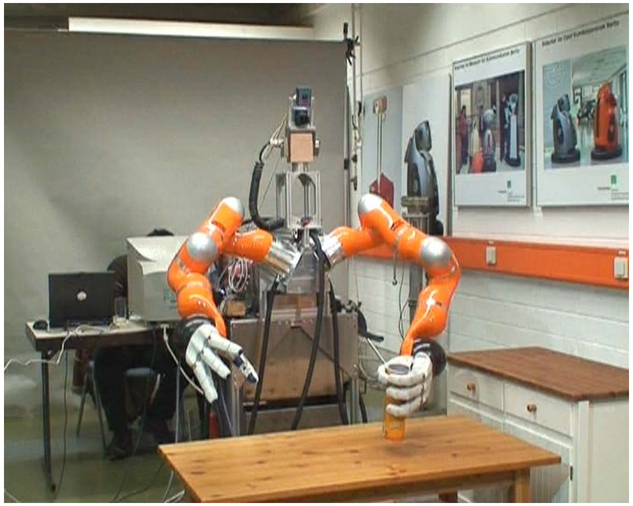
Challenges

- Large-scale environments are too demanding with respect to storage and computational requirements
- Small-scale or low-cost robots require to down-scale computing-intensive algorithms
- Representations
  - that cover all relevant aspects
  - and can efficiently be updated

Robotics Tomorrow?



Service Robot Projects

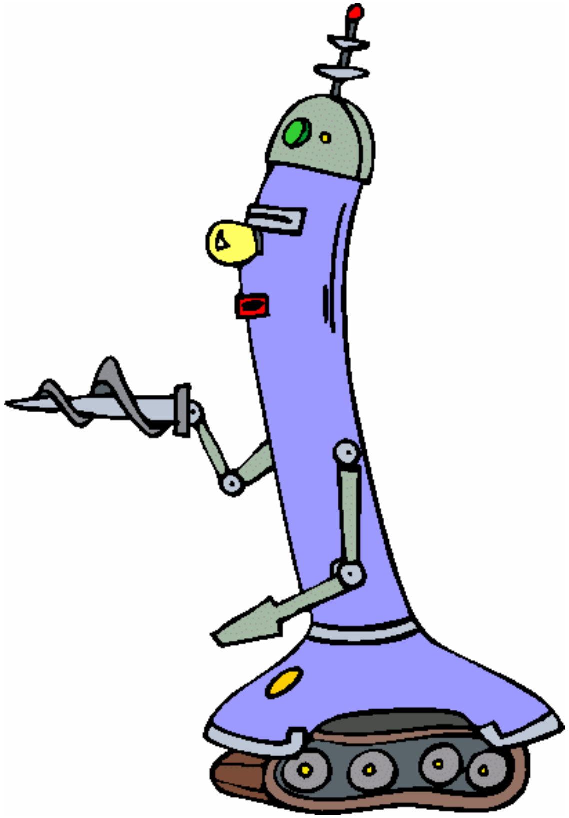


Why do We Have this Gap?

- Why is there currently no real service robot that assists us in our everyday life?

- Let us assume we get a huge grant for building one, what are the technical challenges that we will be faced with?

What Would we Need to Build a Service Robot?



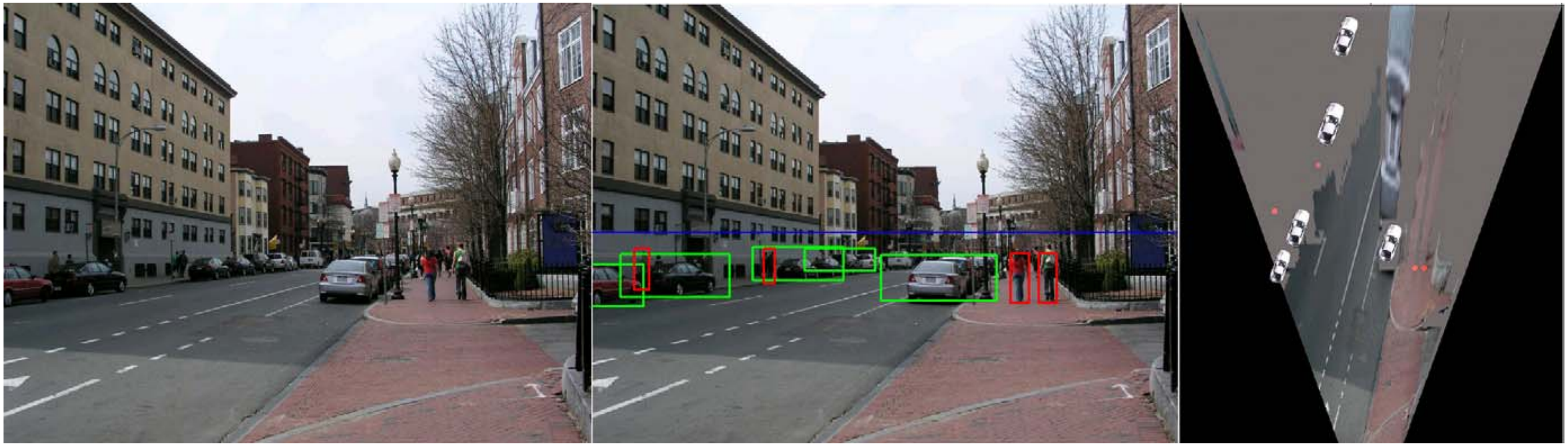
Requirements

- Complex representations and planning
- Object recognition
- Vision
- …

Object Recognition

- Object recognition is a fundamental requirement for service robots.
- Current technology is not robust enough to flexibly handle sufficiently many objects.
  - Object identification
  - Learning the geometry and object properties
  - Learning how to handle the objects

Object and Scene Recognition



[Courtesy by D. Hoiem, A.A. Efros, and M. Hebert]

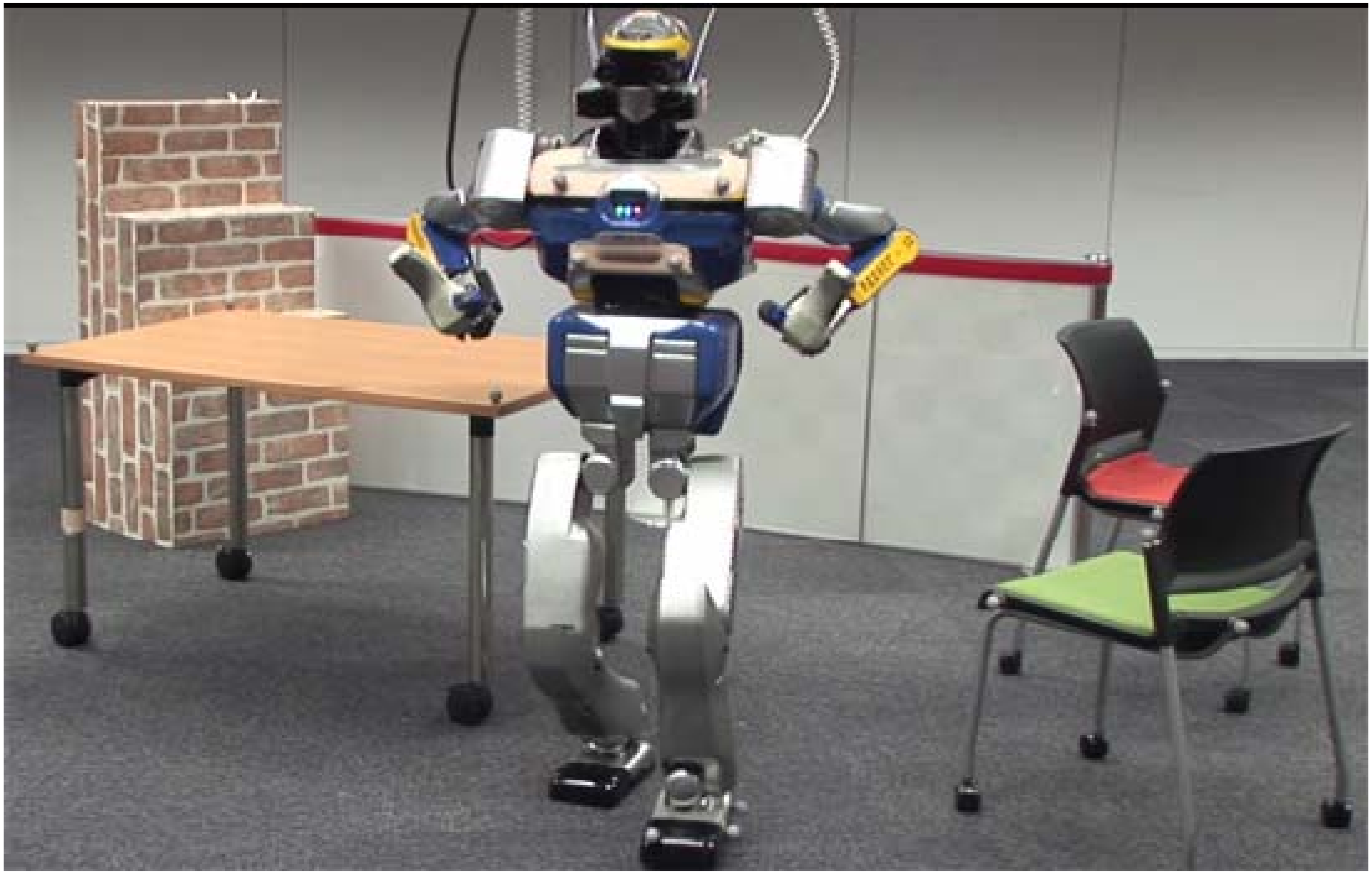
Moving Objects Around

[Courtesy by Stilman et al.]

Moving Objects Around

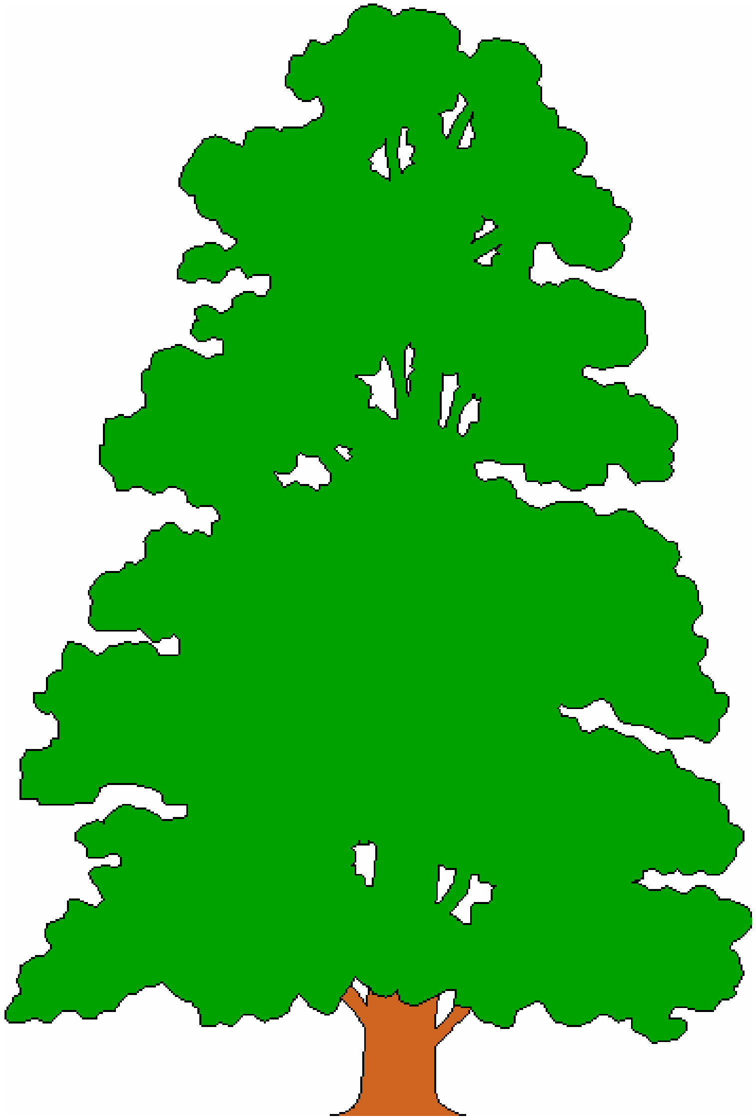
[Courtesy by Stilman et al.]

Moving Objects Around

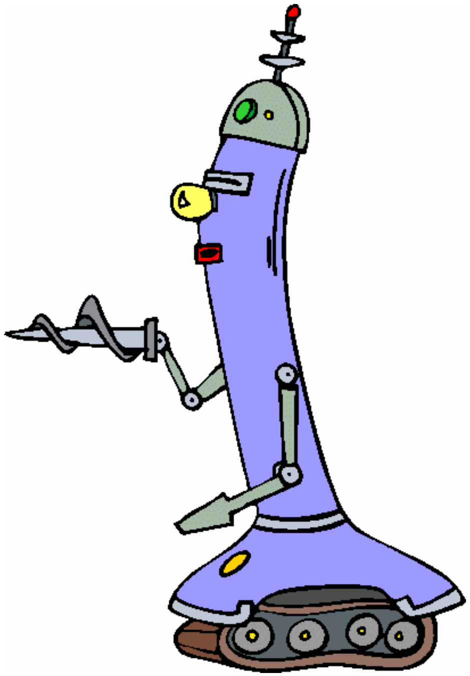


[Courtesy by Stilman et al.]

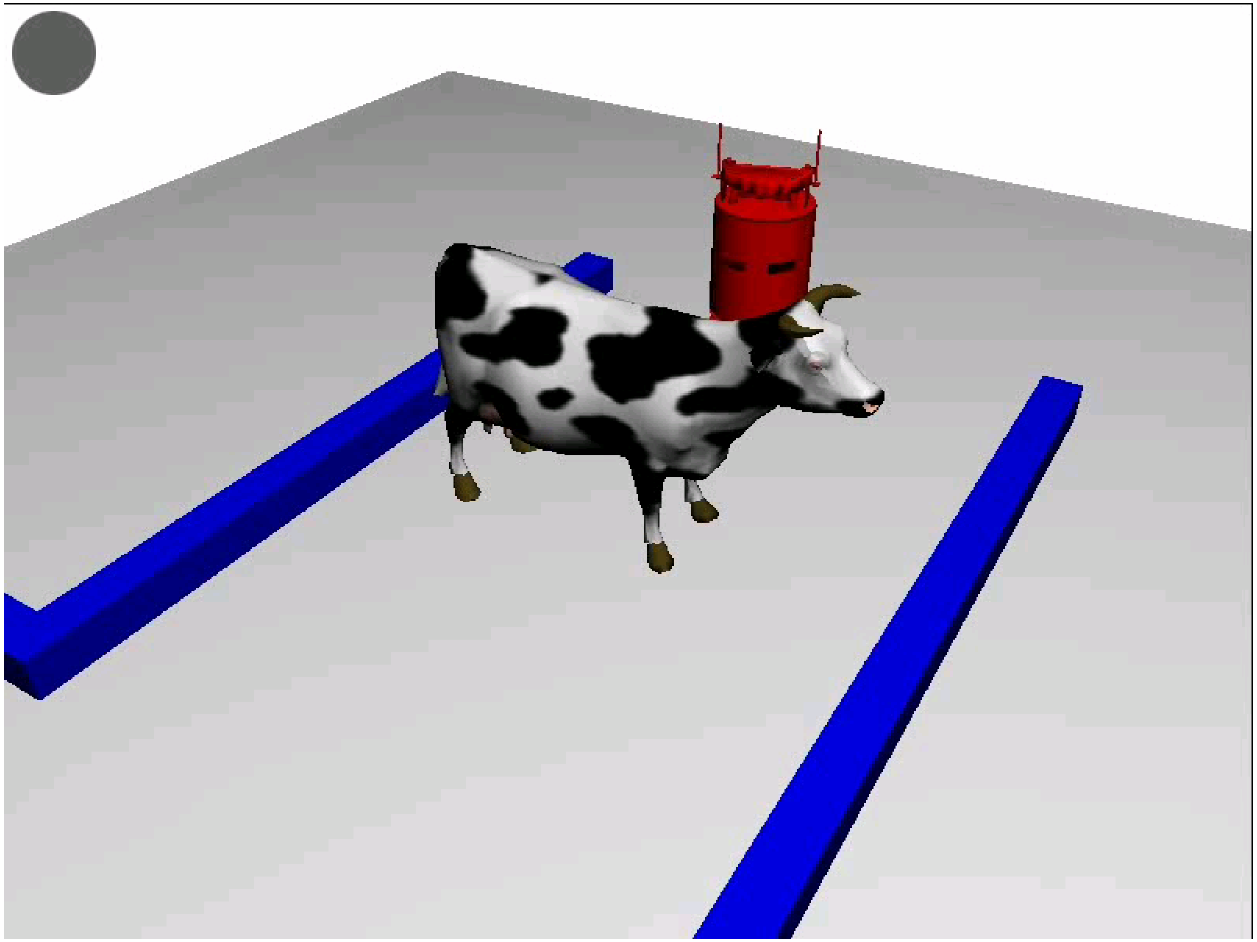
To Go or Not To Go



To Go or Not To Go



Navigation in Environments with Deformable Objects



Knowledge Representation and Planning

$$
\begin{aligned}
&Broken(x, do(a, s)) \equiv \\
&\qquad a = drop(x) \wedge Fragile(x, s) \vee \\
&\qquad \exists b.(a = explode(b) \wedge NextTo(b, x, s)) \vee \\
&\qquad Broken(x, s) \wedge a \neq repair(x).
\end{aligned}
$$

$$
Poss(pickup(x), s) \equiv \forall x. \neg Holding(x, s) \wedge NextTo(x, s) \wedge \neg Heavy(x)
$$

- Uncertainty?
- Time?
- Optimality?
- Ambiguities?

[Giacomo et al.]

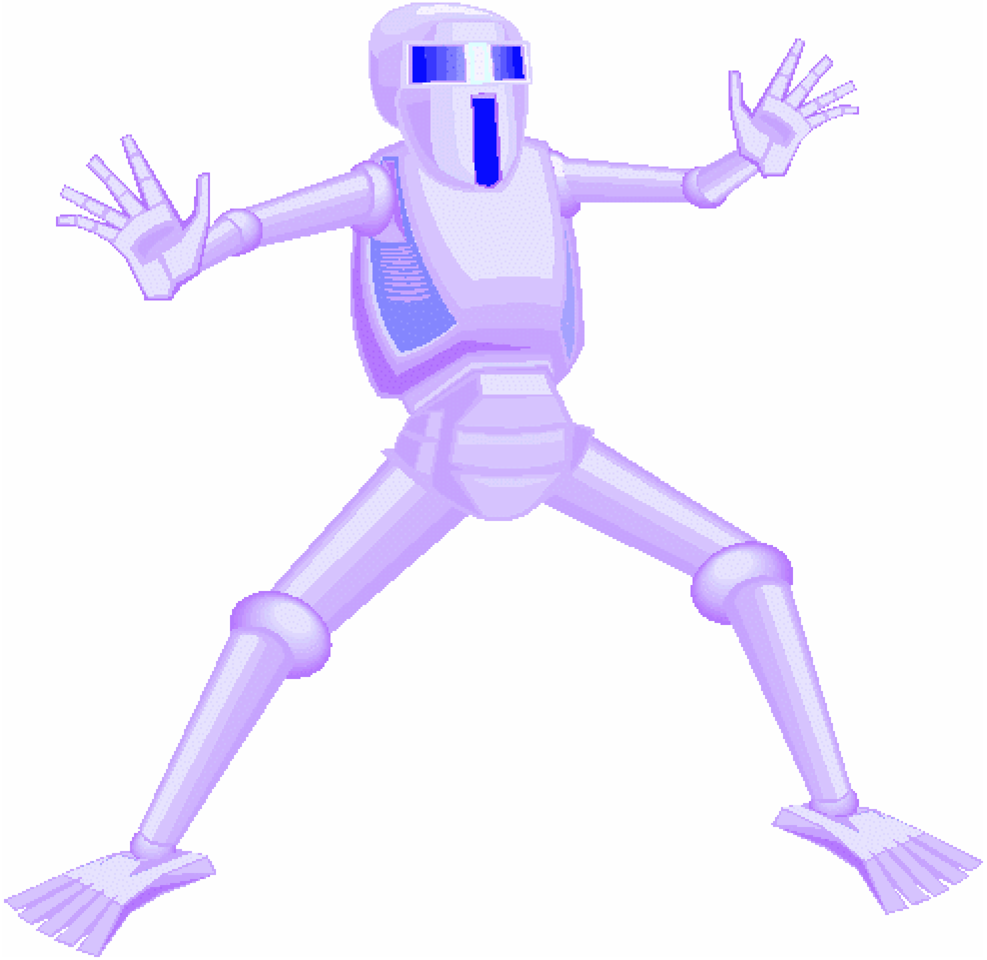
Spatial Reasoning

- Take the second door on the left.
- Take the orange juice out of the fridge and put it on the kitchen table.
- Lay a dinner table for four people.
- Go straight for .1 miles, then take a right.

Conclusions

- Robotics is faced with many (AI) problems that are individually hard.
  - Vision
  - Object recognition
  - Representation
  - Planning and reasoning
  - Scaling problems
  - Perception and state estimation
- One key challenge for the future lies in the **development of new robust solutions to these problems and their successful integration**

Don’t Panic!



AI will provide key technologies!

The Future

- Advances will be due to
  - advances in the individual sub-disciplines or areas
  - increase of computing power
  - integration
  - …
- The improvements in the performance of the robots will directly illustrate the advance.
- Robotics is an ideal benchmark for AI

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