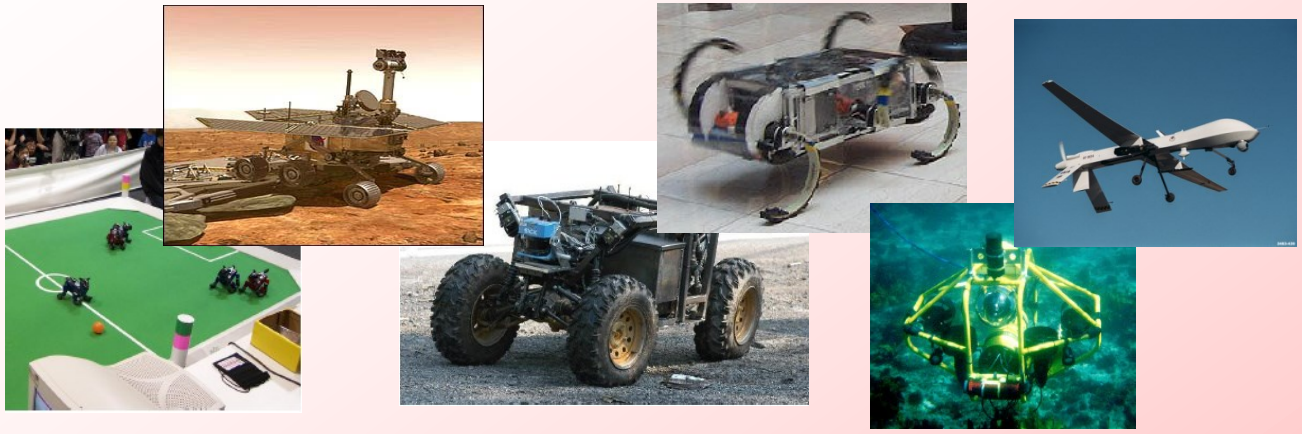
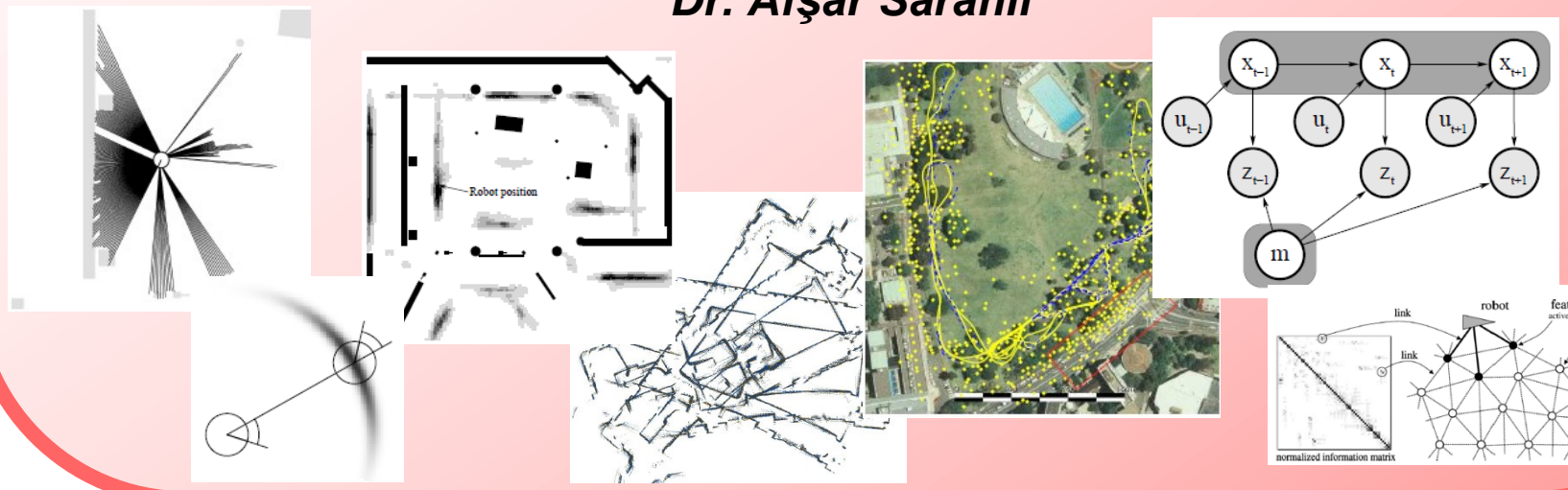
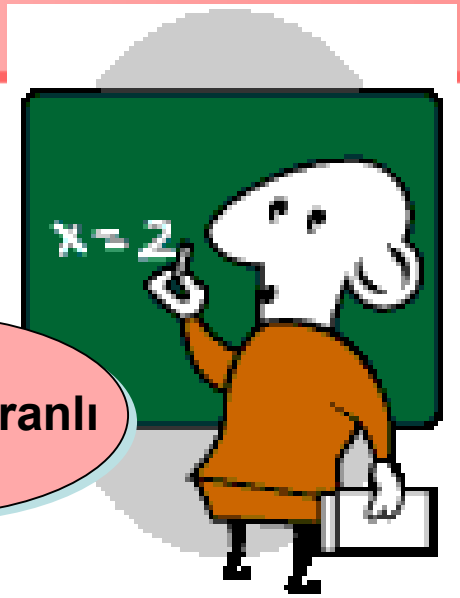


EE585 Probabilistic Robotics

Department of Electrical and Electronics Engineering
Dr. Afşar Saranlı



Your Instructor?



Dr. Afşar Saranlı

Telecom-Computer
BS in METU-EE
1993

MSc in Imperial College, London, UK
Telecom – DSP - 1994

PhD in METU-EE
Control – DSP – Pattern
2000

R&D in Industry, Toronto, Canada
Control – DSP – ImageProc
2000-2005

Then Here
Almost 21 years now!
Robotics - Control – DSP – ImageProcessing

The class?

Student introduction…

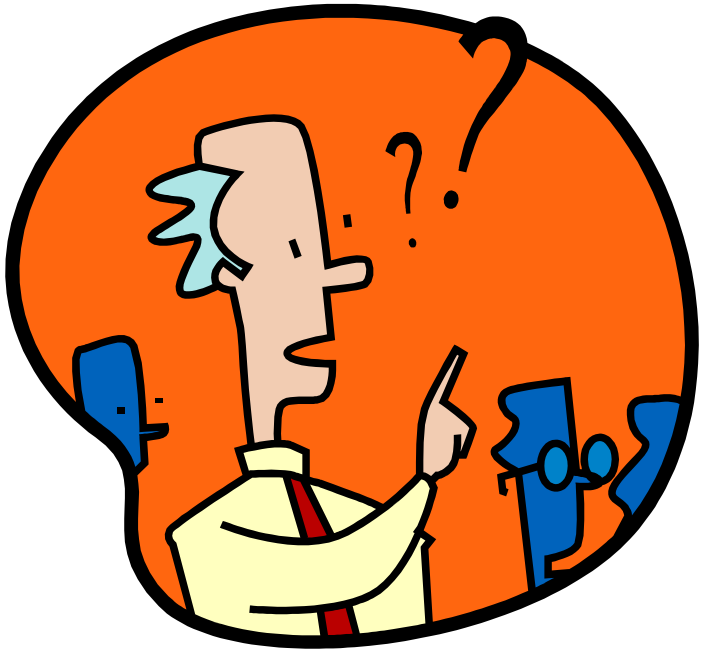
Then a short “quiz”…

The Quiz…

1. What do you expect from this course (why are you taking it?)
2. In METU, what do you aim to accomplish academically this term?
3. In general, what do aim to accomplish personally this term?

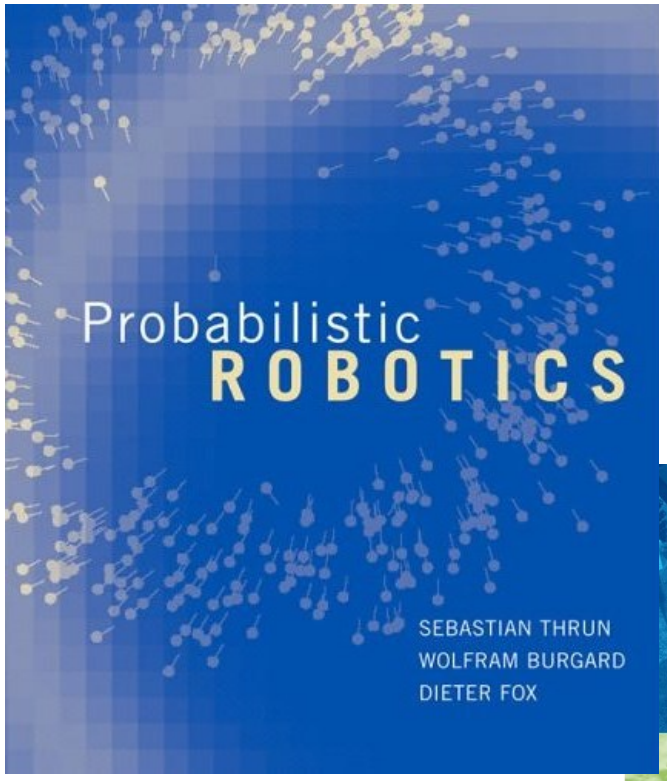
The Course?

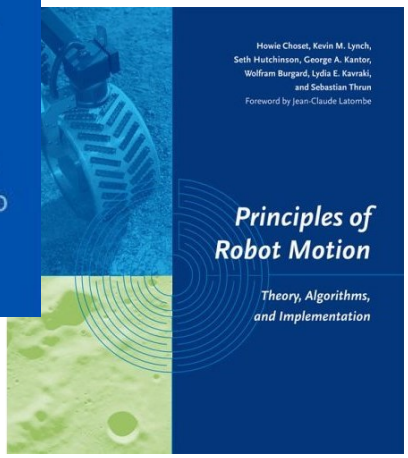
Hmmm… What should I say?

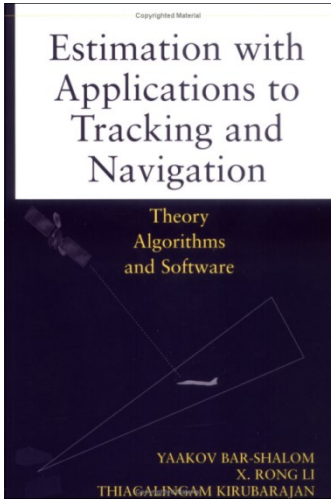


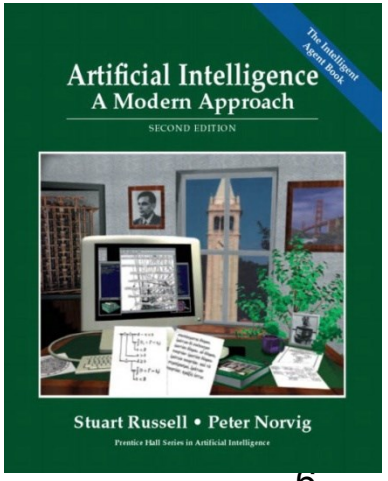
Seems today is all about that!!

Textbook and References

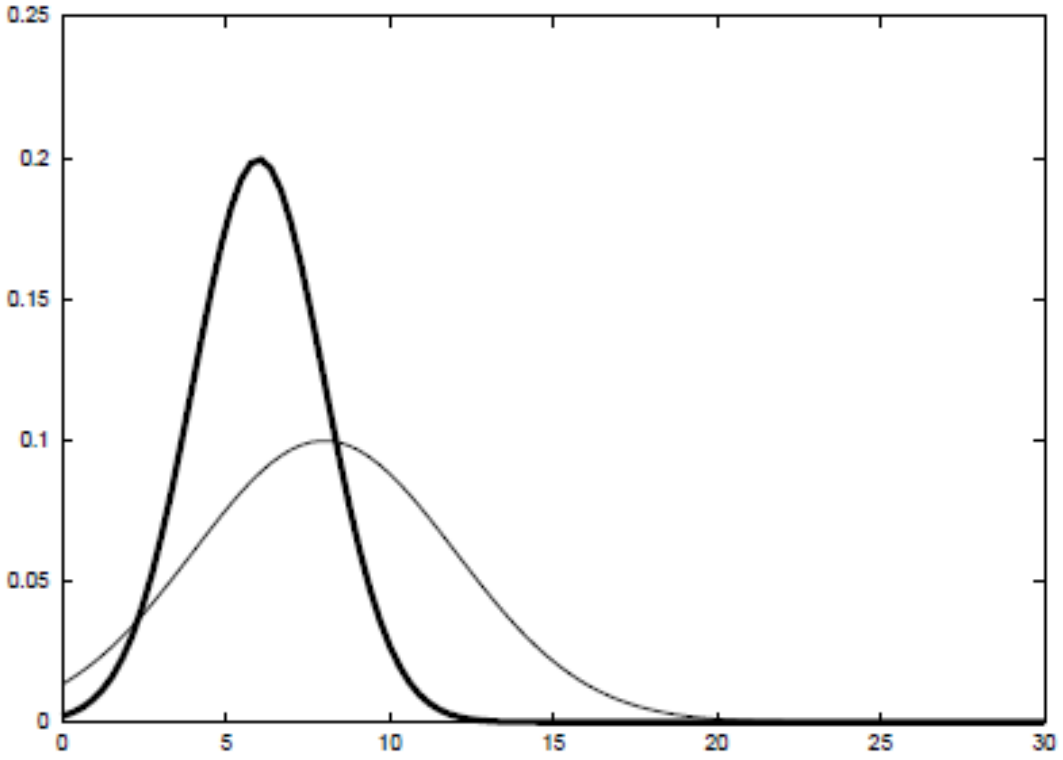








What are these?



"Probabilistic Robotics", S. Thrun, W.Burgard, D.Fox; MIT Press 2005

What are these?

$$P(x|y) = \frac{P(y|x)\ P(x)}{P(y)}$$

What are these?

$$x_t = A_t x_{t-1} + B_t u_t + \varepsilon_t$$

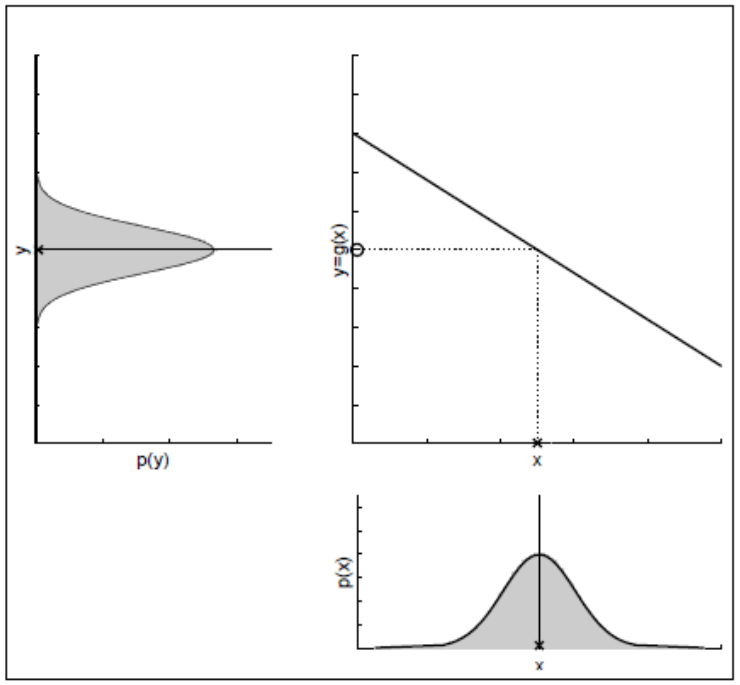
$$z_t = C_t x_t + \delta_t$$

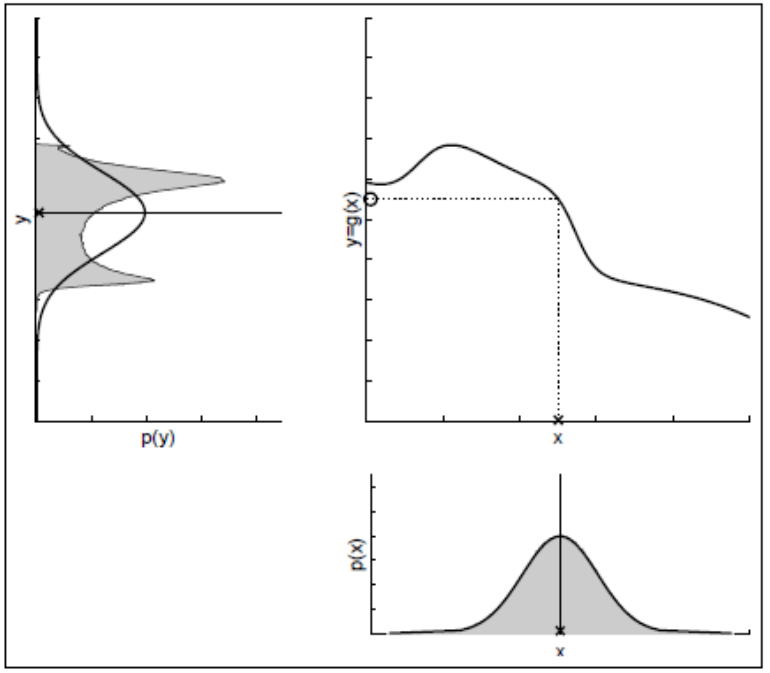
What are these?

$$x_t = g(u_t, x_{t-1}) + \varepsilon_t$$

$$z_t = h(x_t) + \delta_t$$

What is going on?





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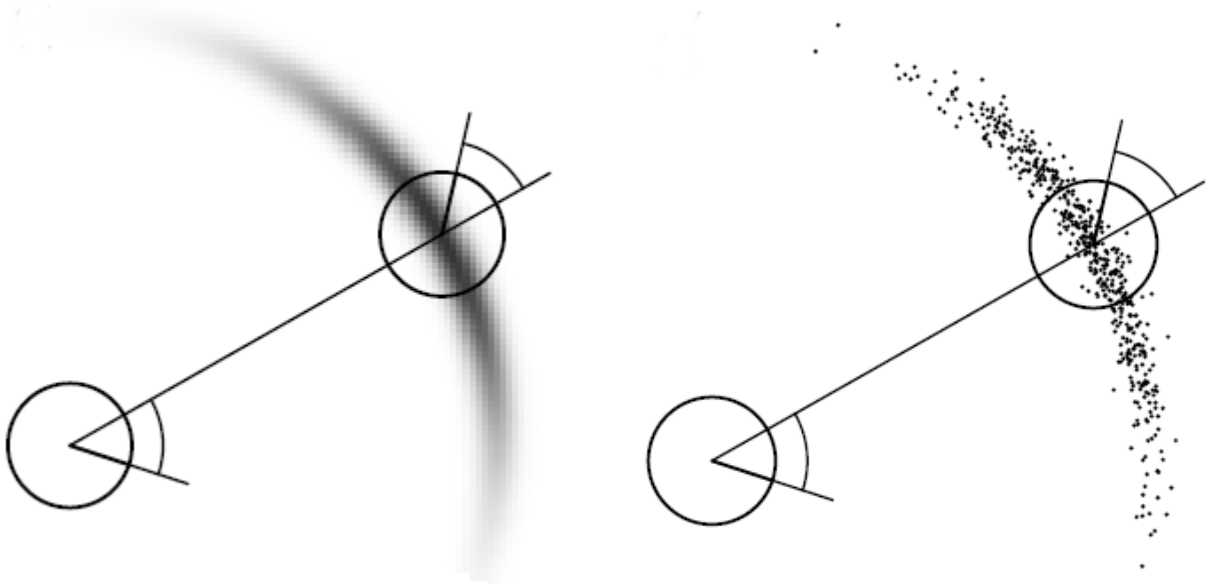

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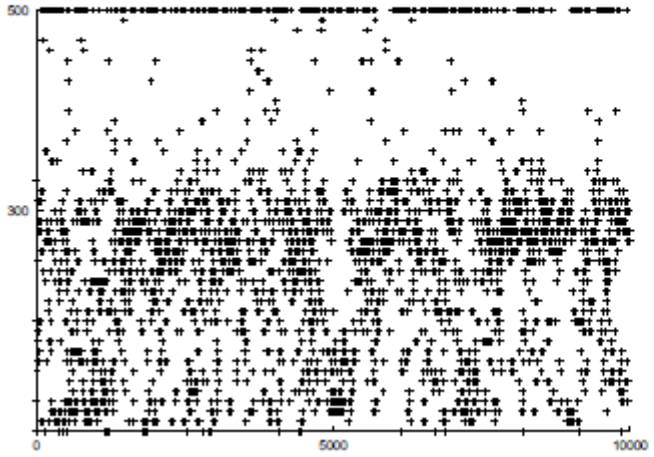

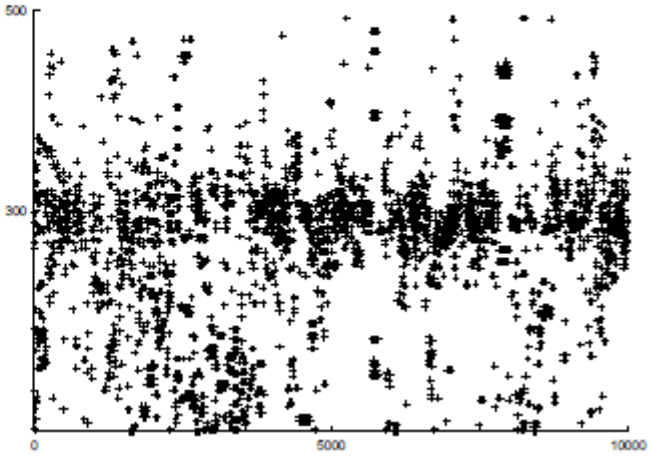

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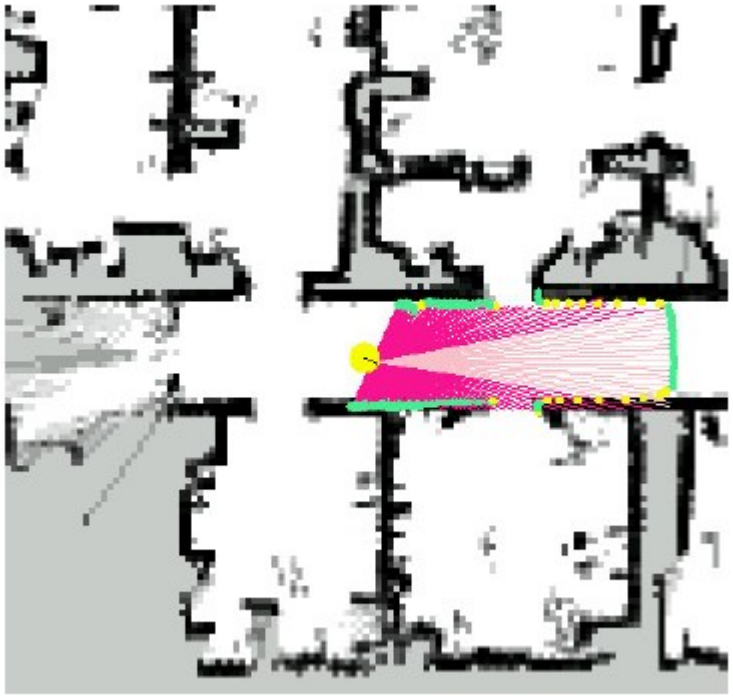

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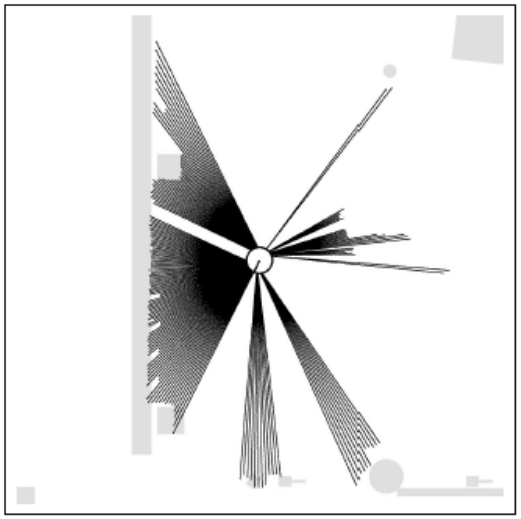
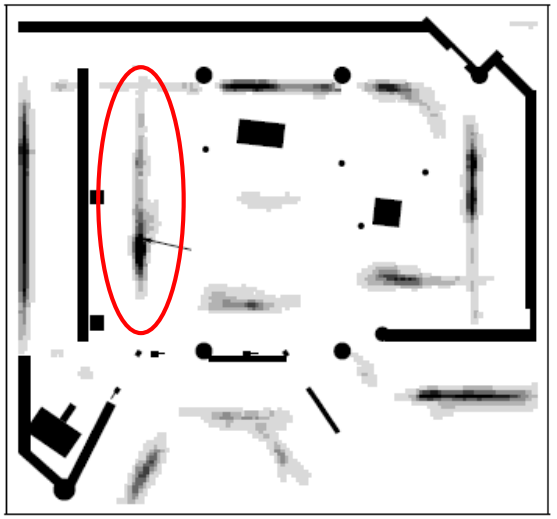
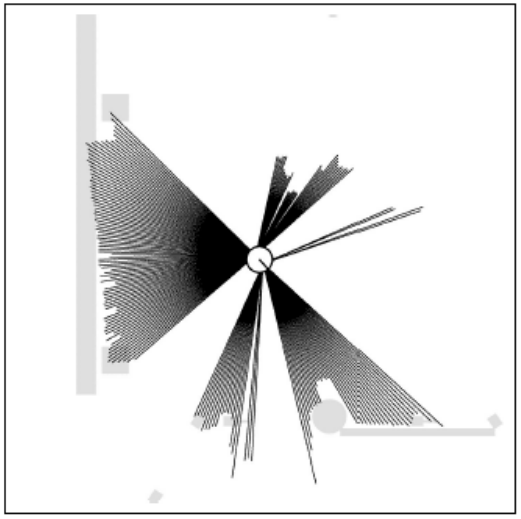
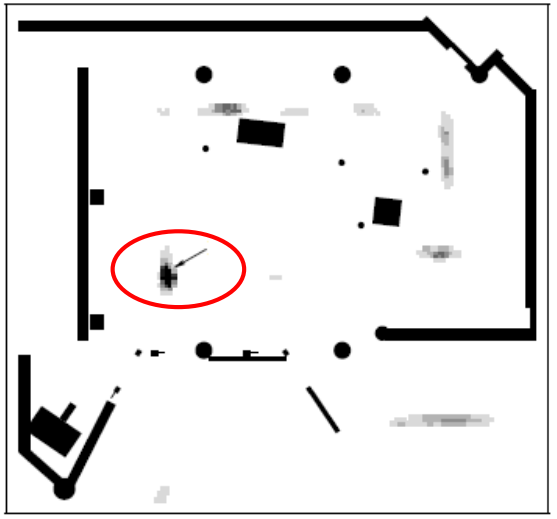


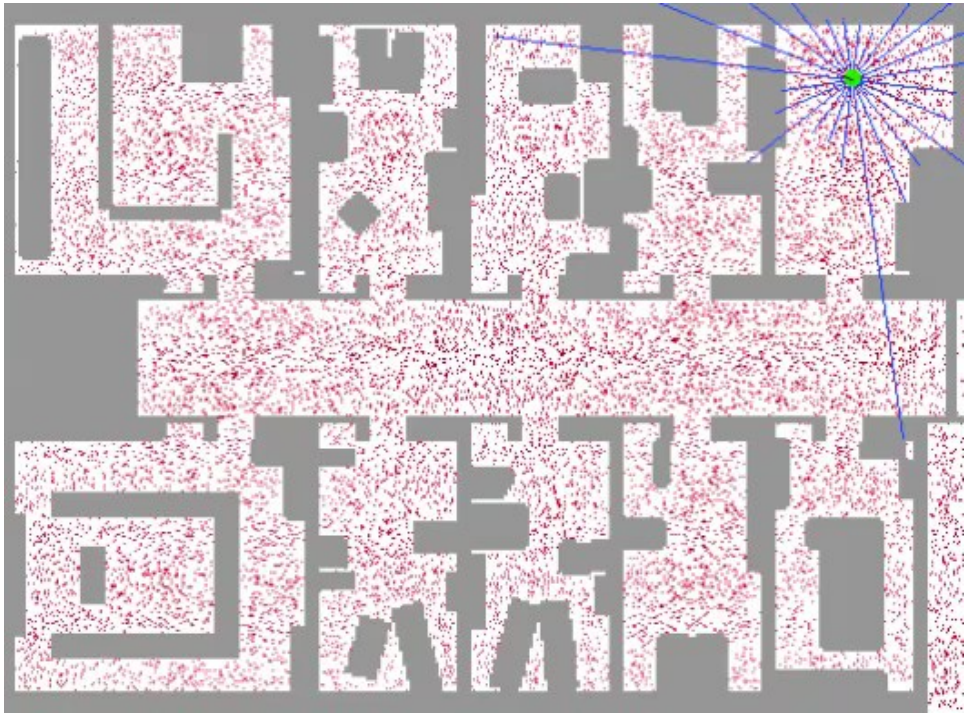






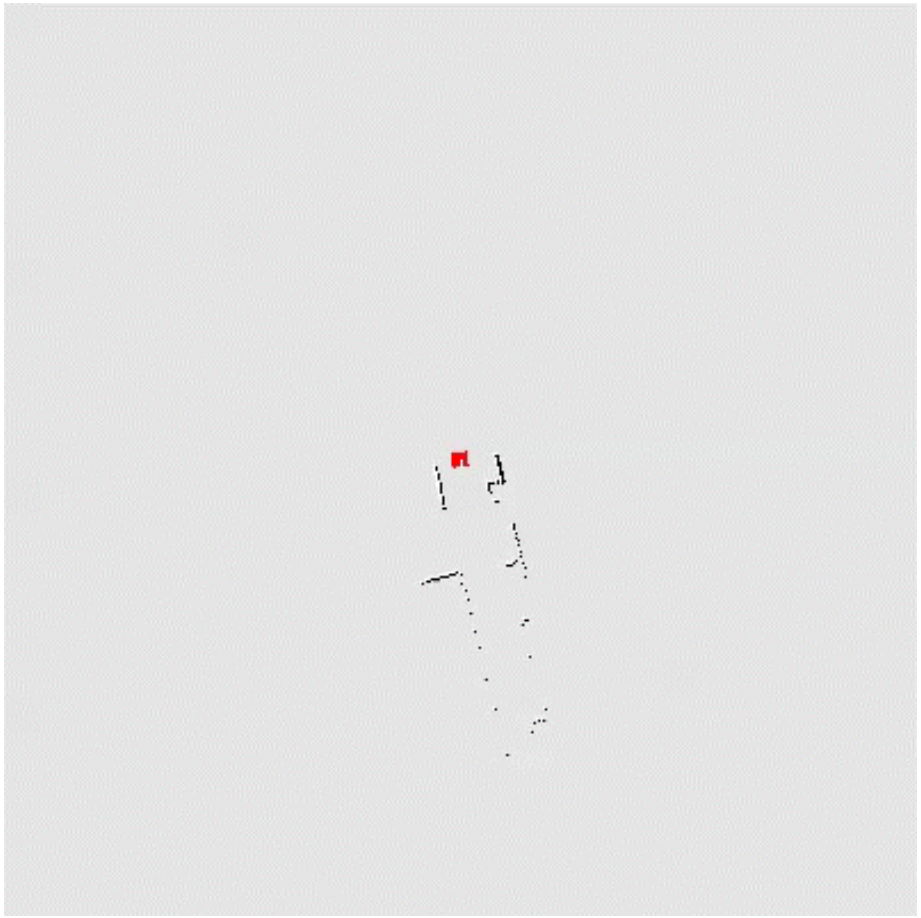
"Probabilistic Robotics", S. Thrun, W.Burgard, D.Fox; MIT Press 2005

Now what is happening?



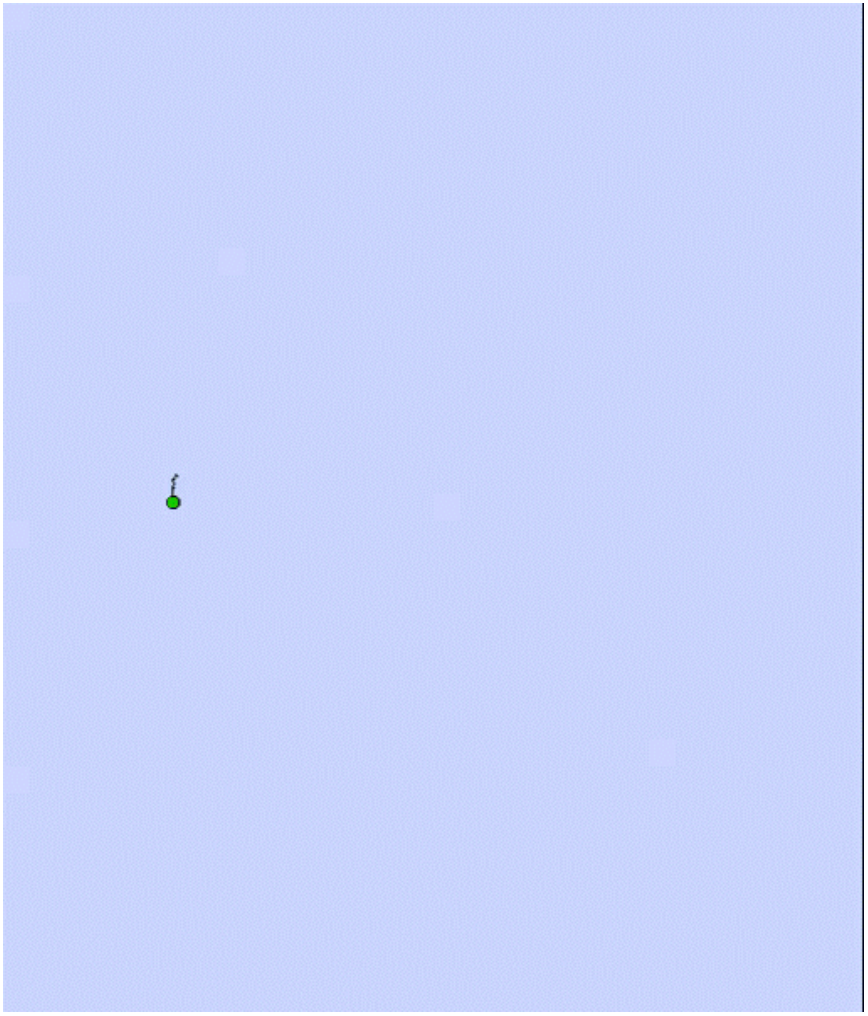
Courtesy of S. Thrun. http://robots.stanford.edu/videos.html

And now?



Courtesy of S. Thrun. http://robots.stanford.edu/videos.html

Another example

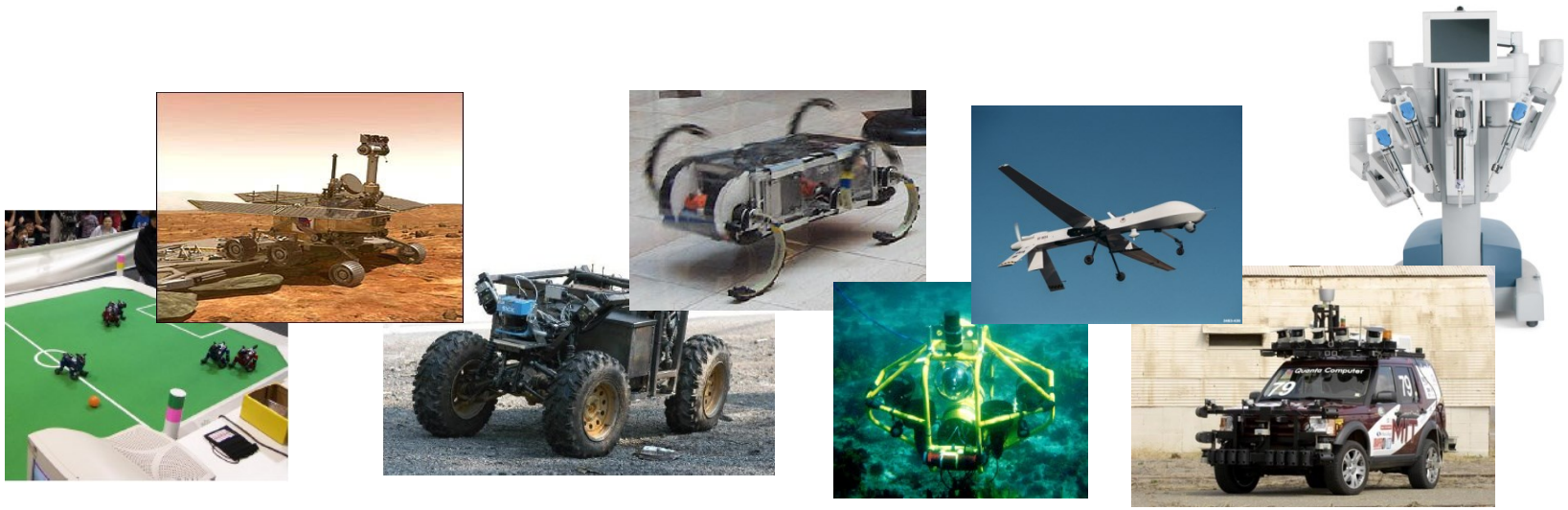


Courtesy of S. Thrun. http://robots.stanford.edu/videos.html

Next Generation Robotics

Robotics:

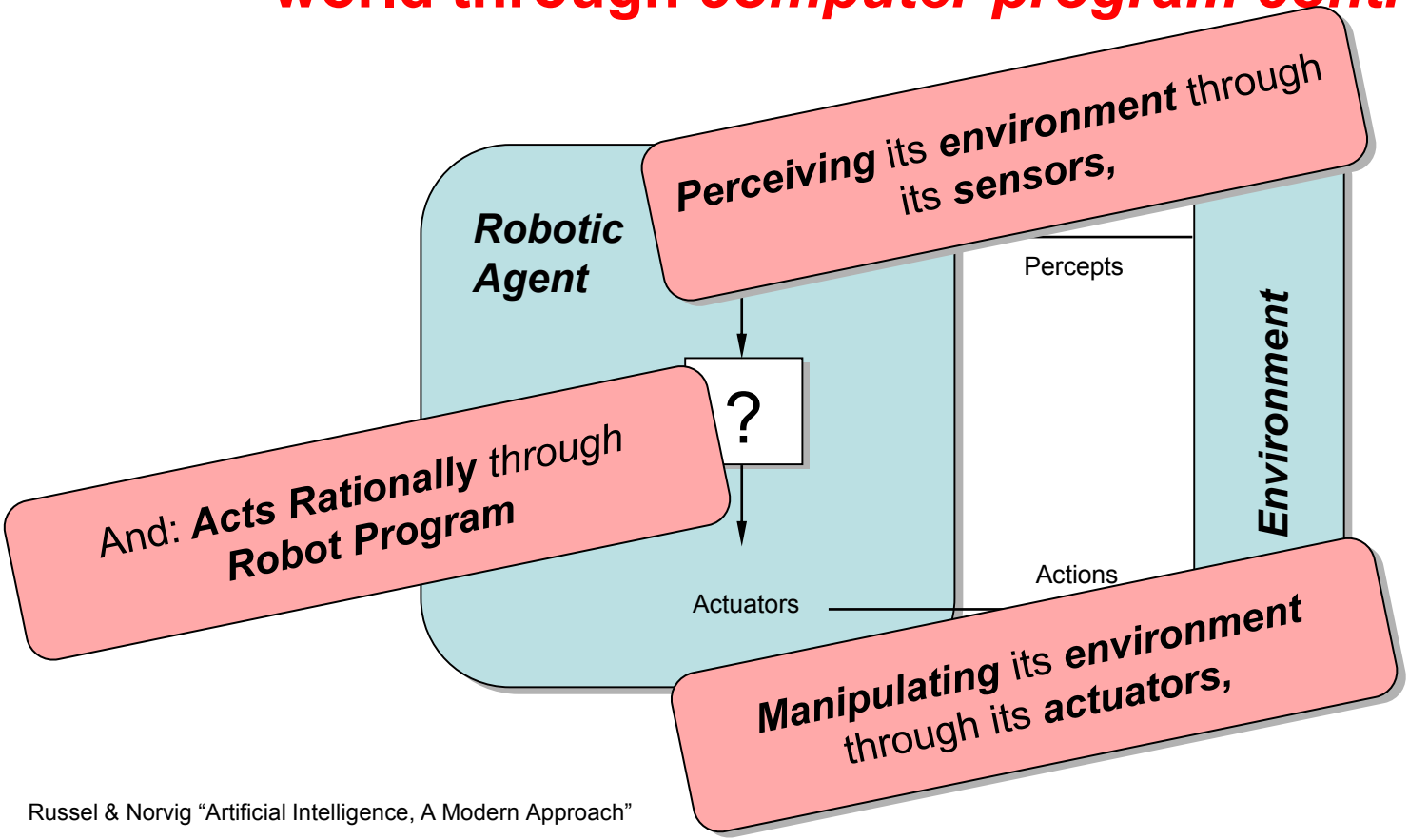
"Science of *perceiving* and *manipulating* the physical world through *computer controlled devices*"



Robotic Agents

Intelligent Robotic Agent:

"A Device *perceiving* and *manipulating* the physical world through *computer program control*"



Russel & Norvig "Artificial Intelligence, A Modern Approach"

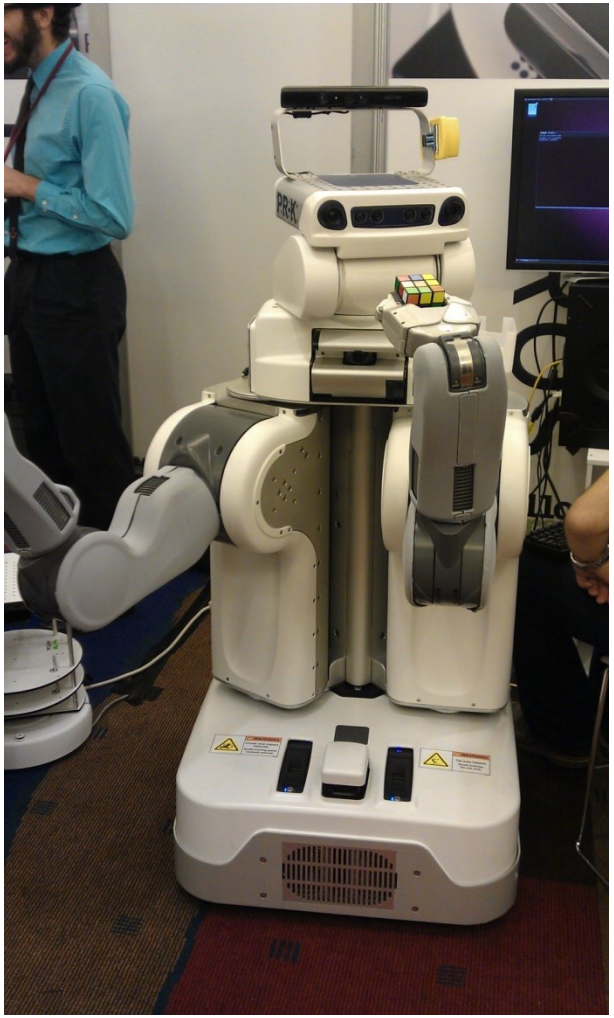
Robotic Agents

Think About the near future (or today even?):

- Cars safely steering themselves on highways,
- Devices that clean up nuclear disaster sites like Chernobyl or Fukushima,
- Robots that find human survivors in wreckages like that of 1999 Earthquake,
- Home robots that take care of daily tasks like vacuum, laundry, dishes, setting up/cleaning the table,
- Robots that explore inaccessible places like other planets, mines, underwater fields,
- Robotic sentries that patrol our dangerous borders.

Some Examples (IROS Conference)

The iCub humanoid child

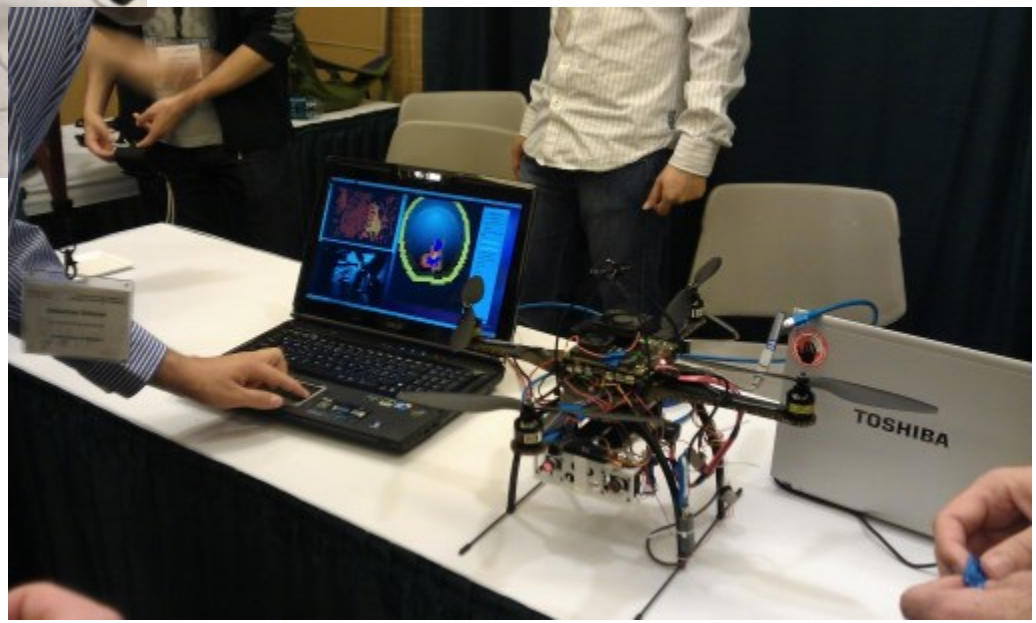


Willow Garage healthcare robot

Some Examples (IROS Conference)

Multi-Rotor flyer with stabilized camera

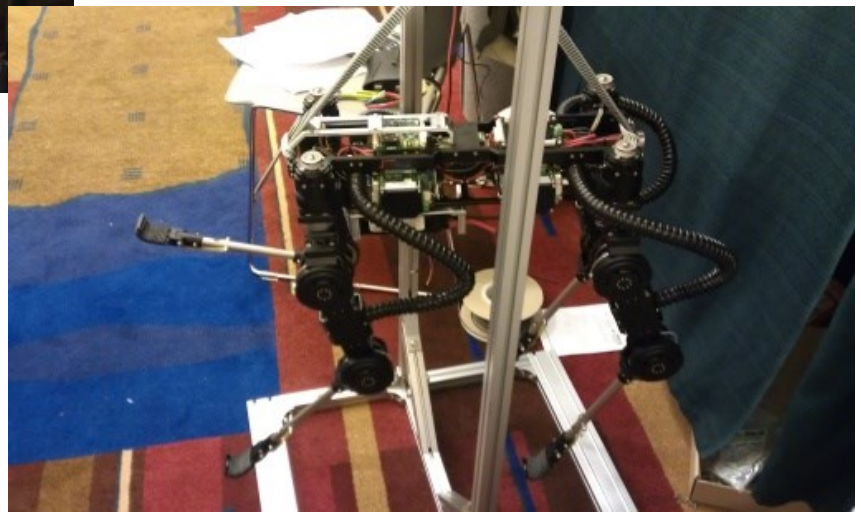
Quad-rotor with camera based mapping



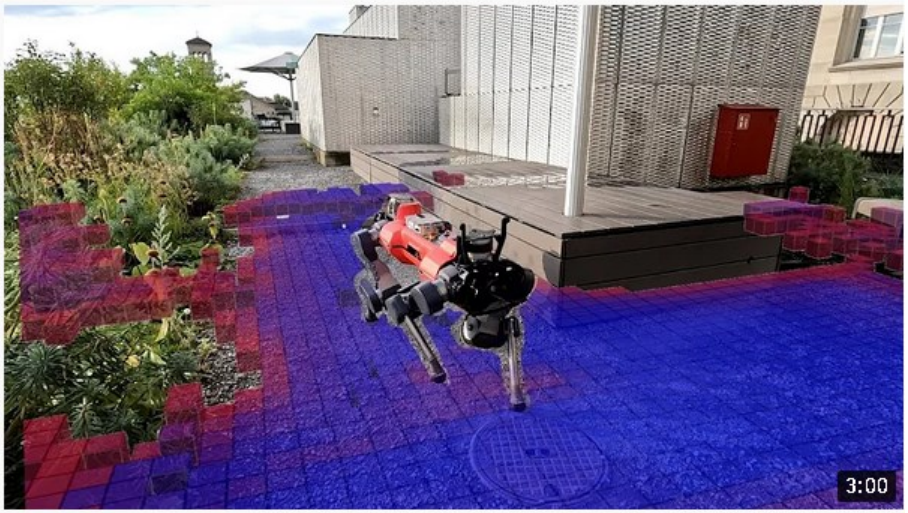
Some Examples (IROS Conference)

Multi-Rotor flyer with Laser Scanner

Kinematic Quadruped



Many Recent Planary Talks



Locomotion Policy Guided Traversability Learning [IROS 2022]

Keeping an Eye on Things, Keynote Talk [IROS 2021]

[IROS 2020] Yukie Nagai : Cognitive Development in Humans and Robots

Andrea Thomaz: Human + Robot Teams - From Theory to Practice [IROS2020]

Uncertainty in Robotics

To do all this:

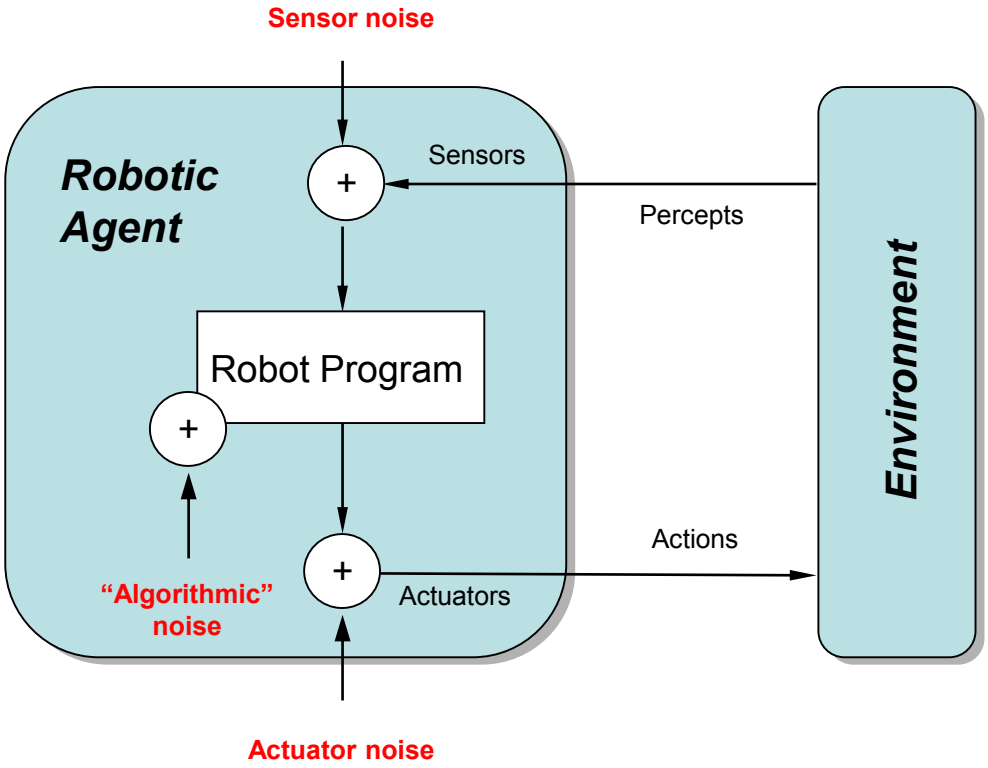
Robots need to accommodate the enormous uncertainty that exist in the real world!!

“But… robotics is around since the early 80s! We did not care about uncertainty before!”

Question: *Why now and not before?*

Why did we manage to ignore uncertainty in robotics before? When can we still *sometimes* ignore it today? What are the drawbacks such ignorance?

Sources of Uncertainty



Sensors:
Limitation of sensors,
Range and Resolution
Environment interaction
Unpredictable Humans!
Failure

Actuators:
Control noise,
Wear and Tear,
Environment interaction
Failure

Programs/Algorithms:
Modeling errors,
Approximations,
missed bugs,
compromises for real-time operation

We now have to deal with it!

Robotics is moving to the open world…

and hence:

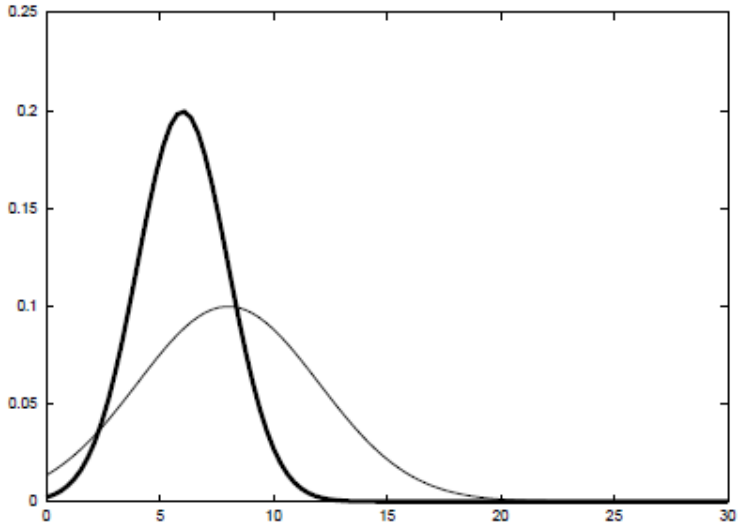
We need to deal with the uncertainty that can no longer be ignored.

Formally represent and deal with uncertainty through the
Calculus of Probability Theory

Calculus of Probability Theory

"Represent the "*belief*" as a likelyhood distribution over the space of possibilities"

"Use calculus of Probability Theory to propagate "belief""



"Act to *reduce uncertainty*. *Degrade gracefully* in the presence of uncertainty."

An example: Localization

"Localization" is the problem of estimating robot pose (position and orientation with respect to an external reference frame)

- **Robot has the map of the environment,**
- **But has to rely on its internal models and local, noisy sensor data to find its location on the map.**

An example: “1D - Localization”

Robot in the environment **does not know its location**!

*Robot **observes a door** (knows there are 3 doors in the map)*

Sensor Model

*Robot knows how its “door sensor” works. **Updates its “possible locations”** in the map.*

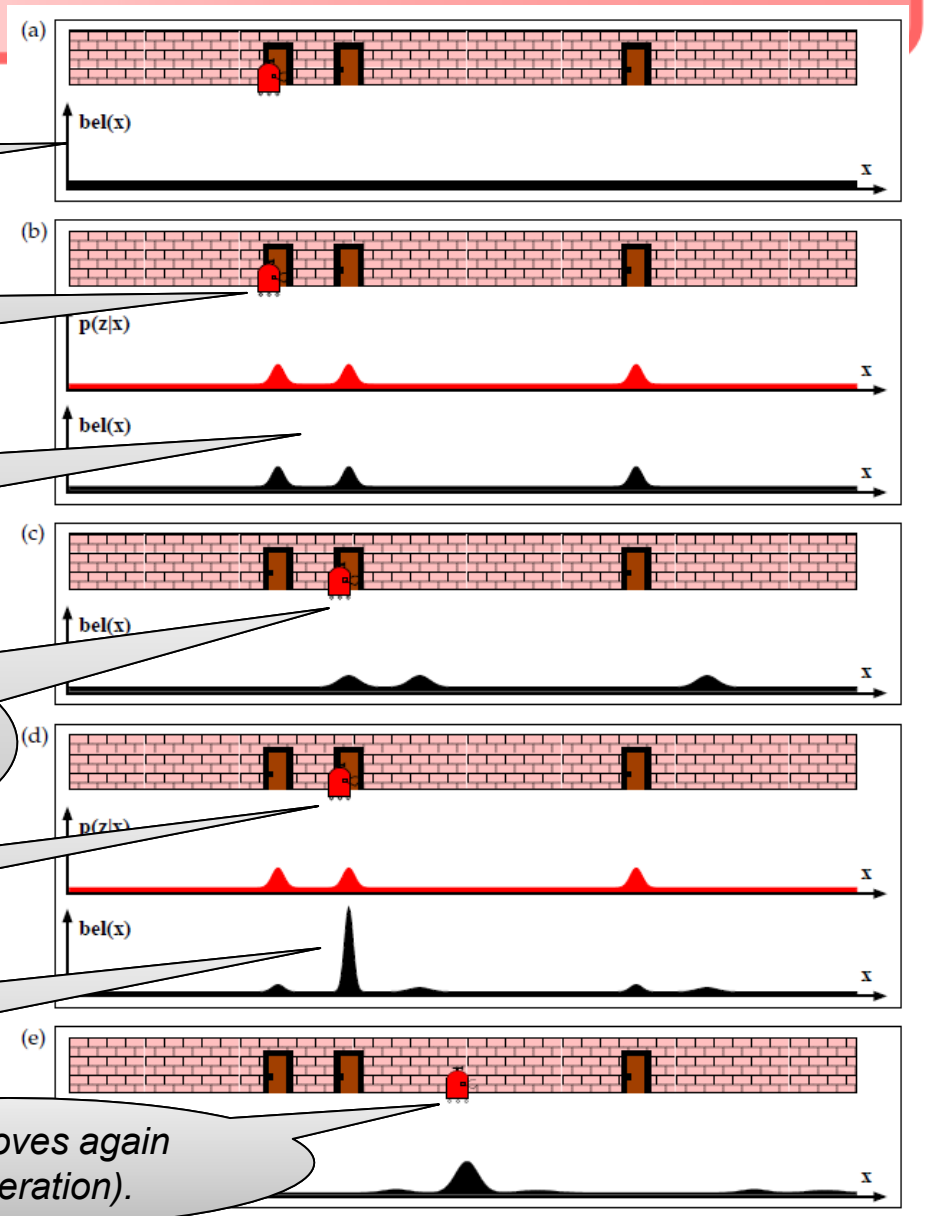
Motion Model

***Robot moves.** Possible locations move with it. But this **degrades** its certainty about location possibilities.*

*Robot **observes a door** again.*

*Observation **combines with the location possibilities** to **improve** location estimate.*

Robot moves again (next iteration).



An example: “1D - Localization”

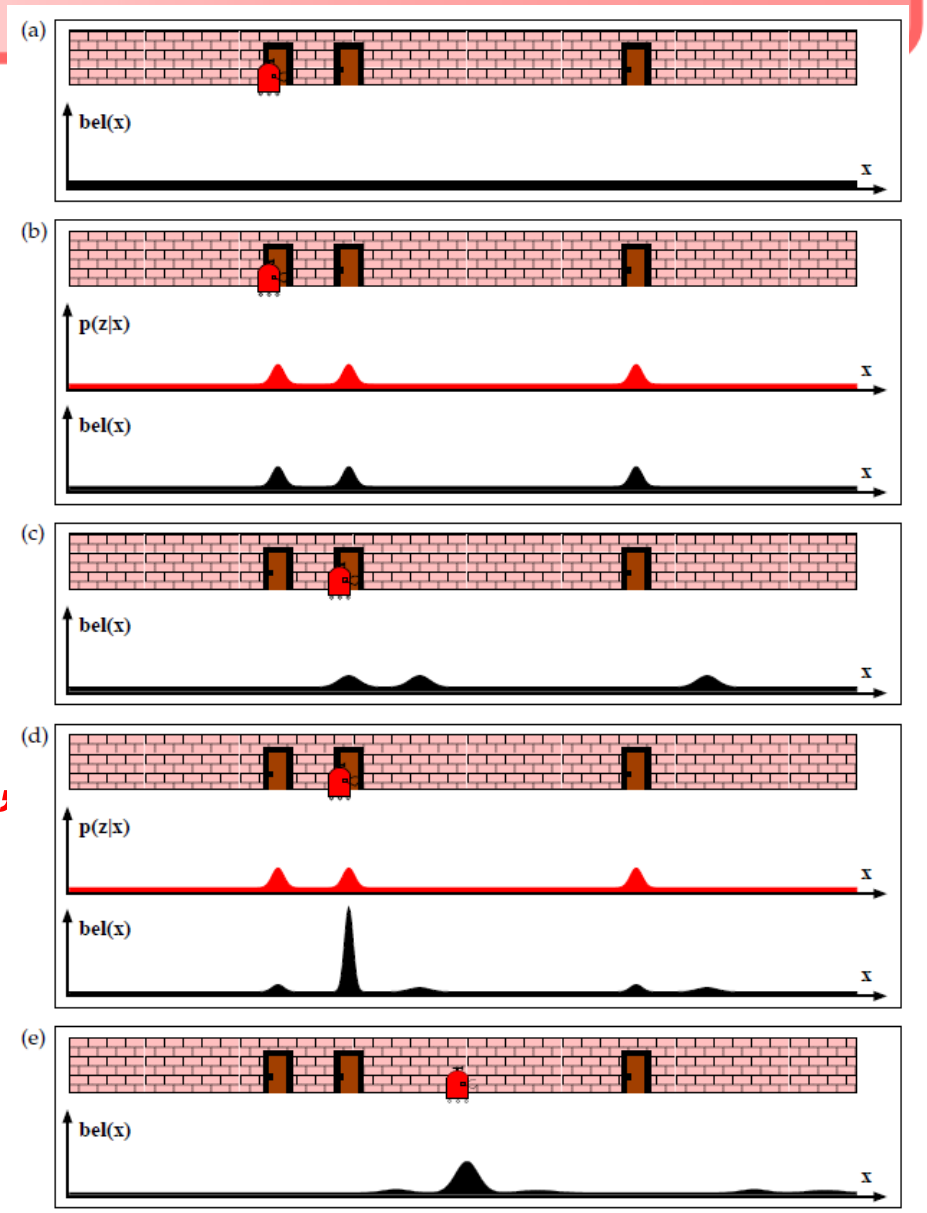
“Global Localization”

through:

“Bayes Filter”

More specifically:

“A Multi-Hypothesis Extended Kalman Filter”



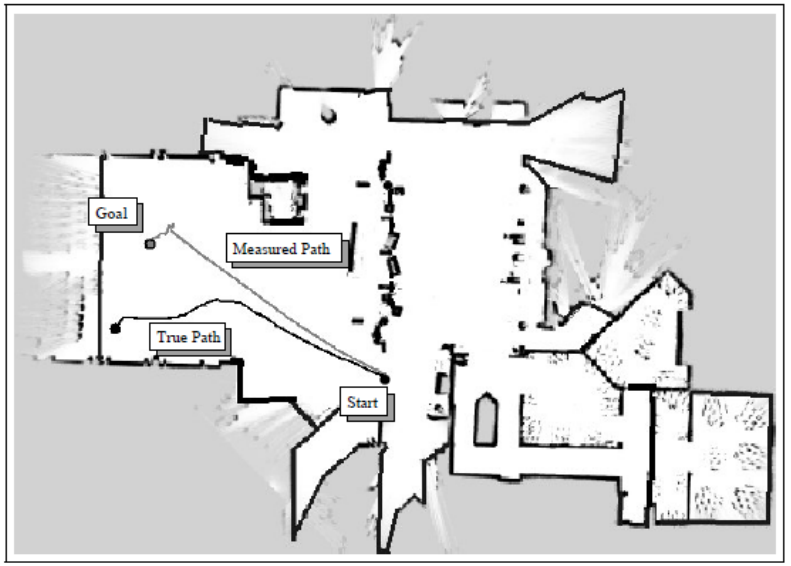
Another example: Coastal Navigation

"Coastal Navigation"

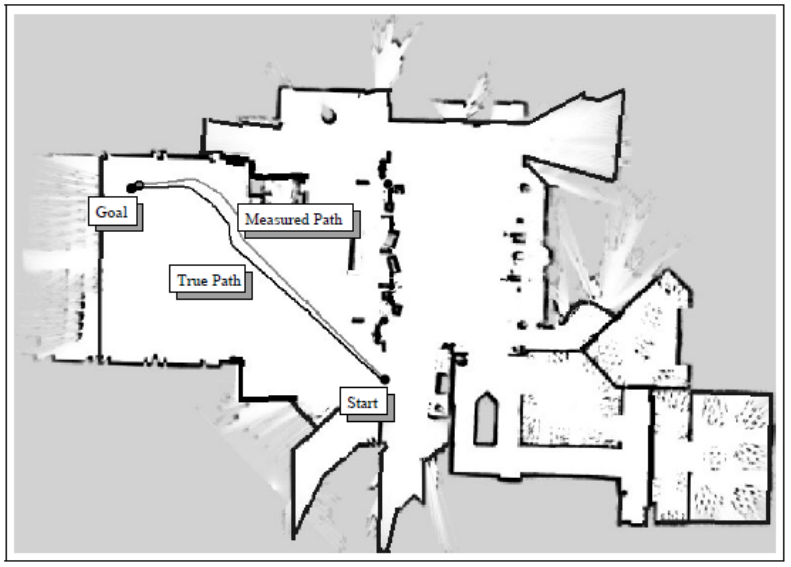
an example of:

"Active control (exploration – exploitation) to reduce uncertainty about localization"

(a)



(b)



The Syllabus

Course Syllabus is already in odtuclass…

Let me know about any questions the next time…

An example of concepts together

The "Minerva" Tourguide Robot (1999)