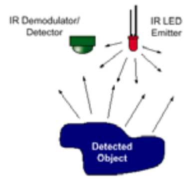
Overview of Challenges in the Development of Autonomous Mobile Robots

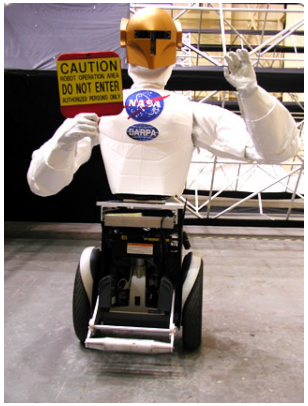
August 26, 2014

What is in a Robot?

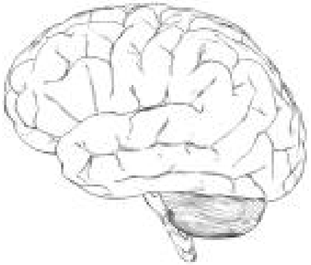
- Sensors



- Effectors and actuators (i.e., mechanical)
  - Used for locomotion and manipulation



- Controllers for the above systems
  - Coordinating information from sensors with commands for the robot's actuators

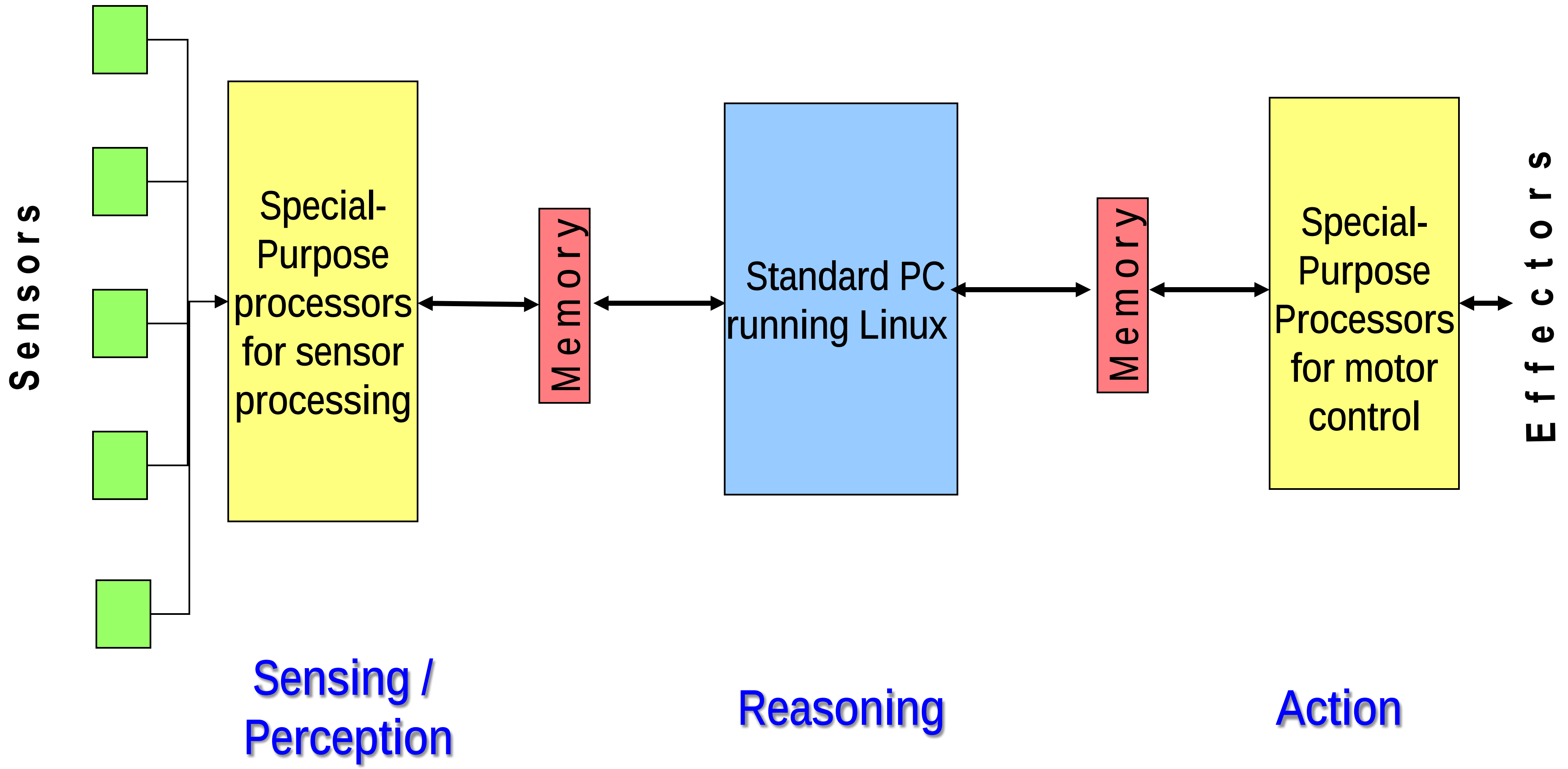


- Power

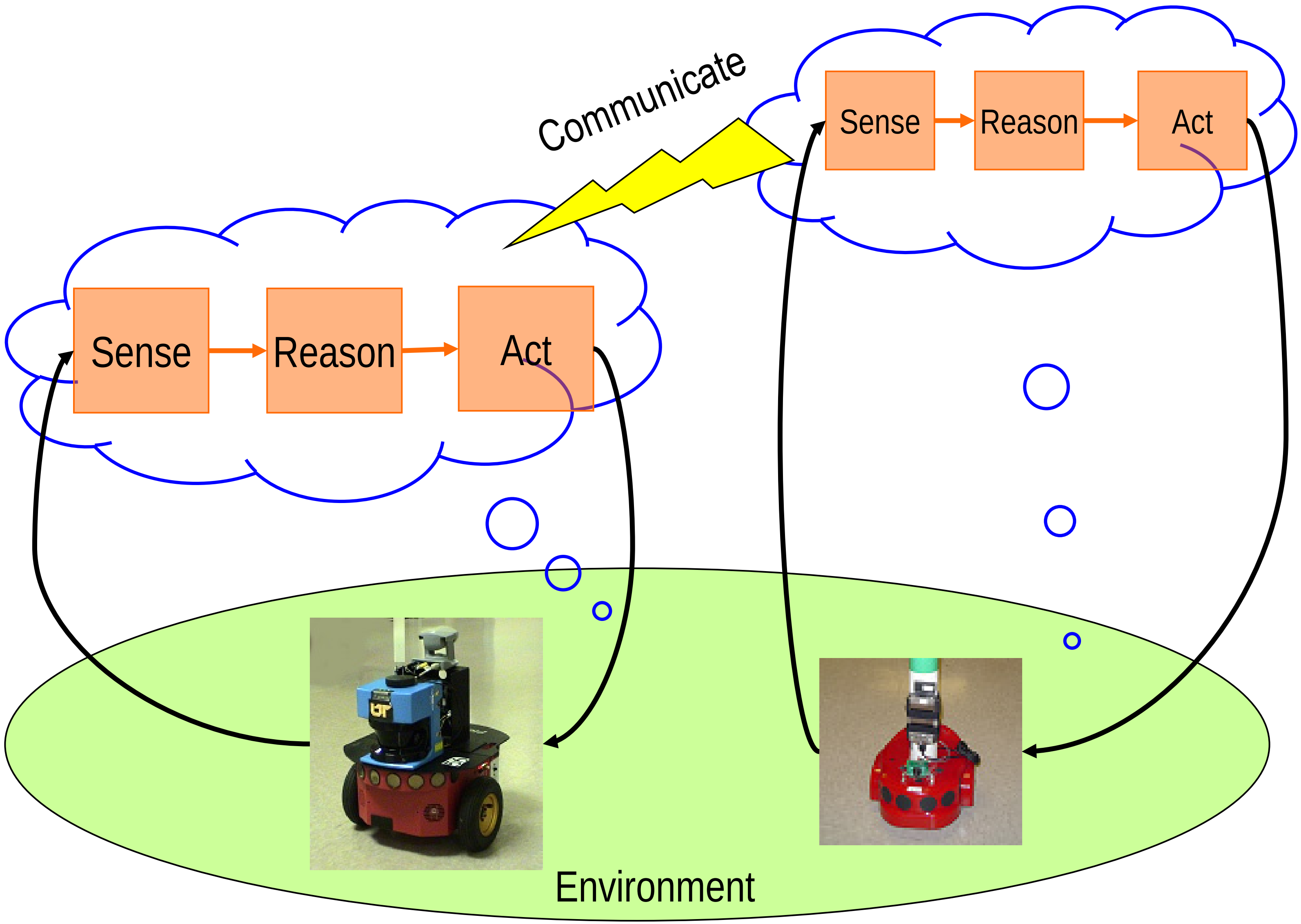
- Robot = an autonomous system which exists in the physical world, can sense its environment and can act on it to achieve some goals

FYI: Typical mobile robot implementation architecture

- Essentially: PC on wheels/legs/tracks/rotors...



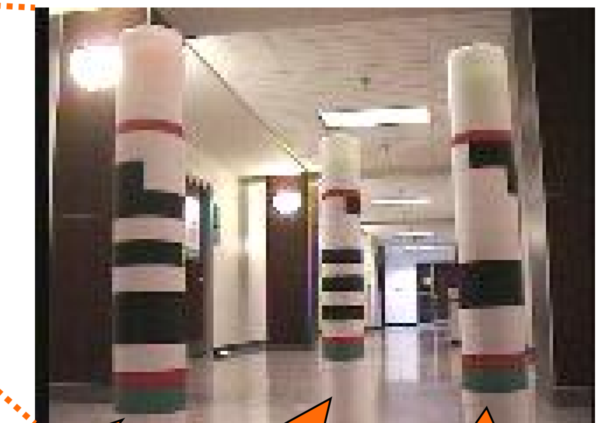
How do you design autonomous robots – or even teams of them?



How Does a Robot "Sense"? Can use vision...

Camera

Raw data



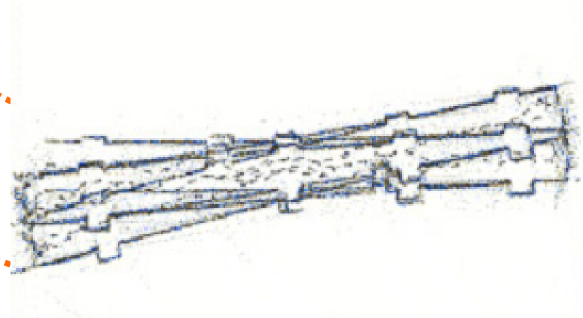
"Perceived" info. (using intelligent software algorithms on robot):

Marker 1:	Marker 2:	Marker 3:
ID = 1010110	ID = 0101010	ID = 0011000
d = 23"	d = 42"	d = 26"
$\theta = 117^{o}$	$\theta = 86^{o}$	$\theta = 61^{o}$
$\alpha = 76^{o}$	$\alpha = 0^{o}$	$\alpha = 32^{o}$

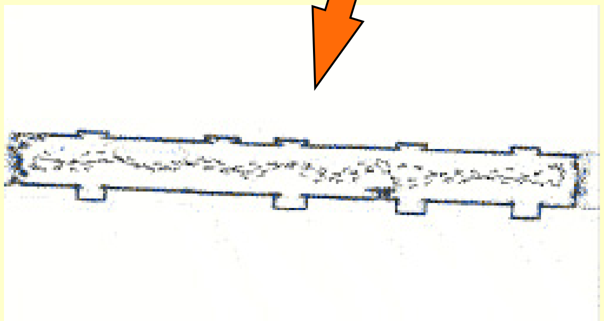
How Does a Robot "Sense"?
Can use laser range scanner…

Laser range scanner

Raw data (multiple scans)

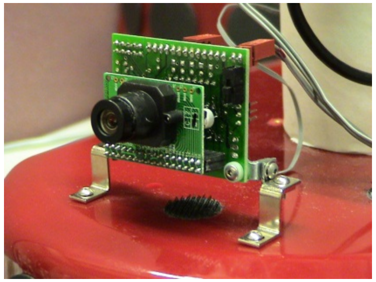


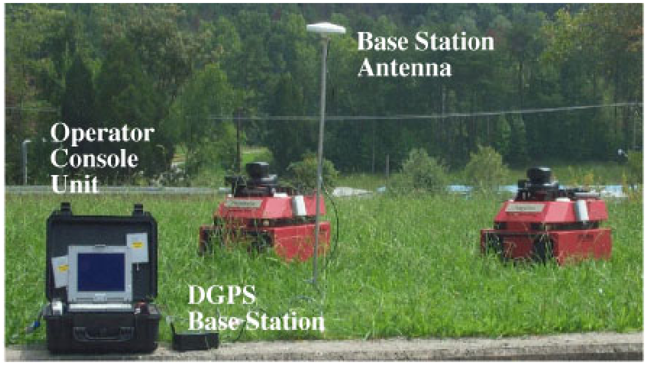
"Perceived" info. (using intelligent software algorithms on robot):



And, there are lots of other sensors…

- "Low-end" camera
- Infrared
- Sonar
- Microphone
- DGPS
- Compass
- Odometry (wheel encoders)
- Inclinometer (tilt)
- Tactile
- Chemical, radiation, wind, …





But it's not so easy for a robot to sense…

What if camera breaks,

or the grass is too high,

or the lens gets dirty,

or the sensor gives bad data,

or 2 sensors tell you contradictory things,

or the lights get turned off,

or it starts raining,

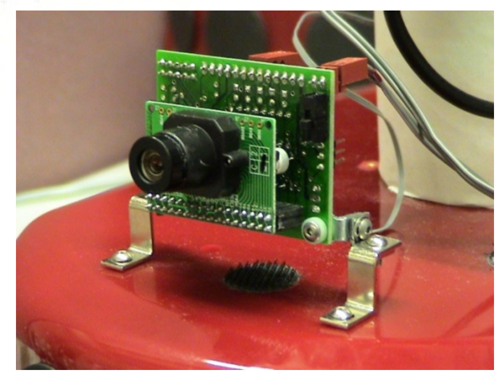
or, … ?

Sensing Uncertainties Abound!

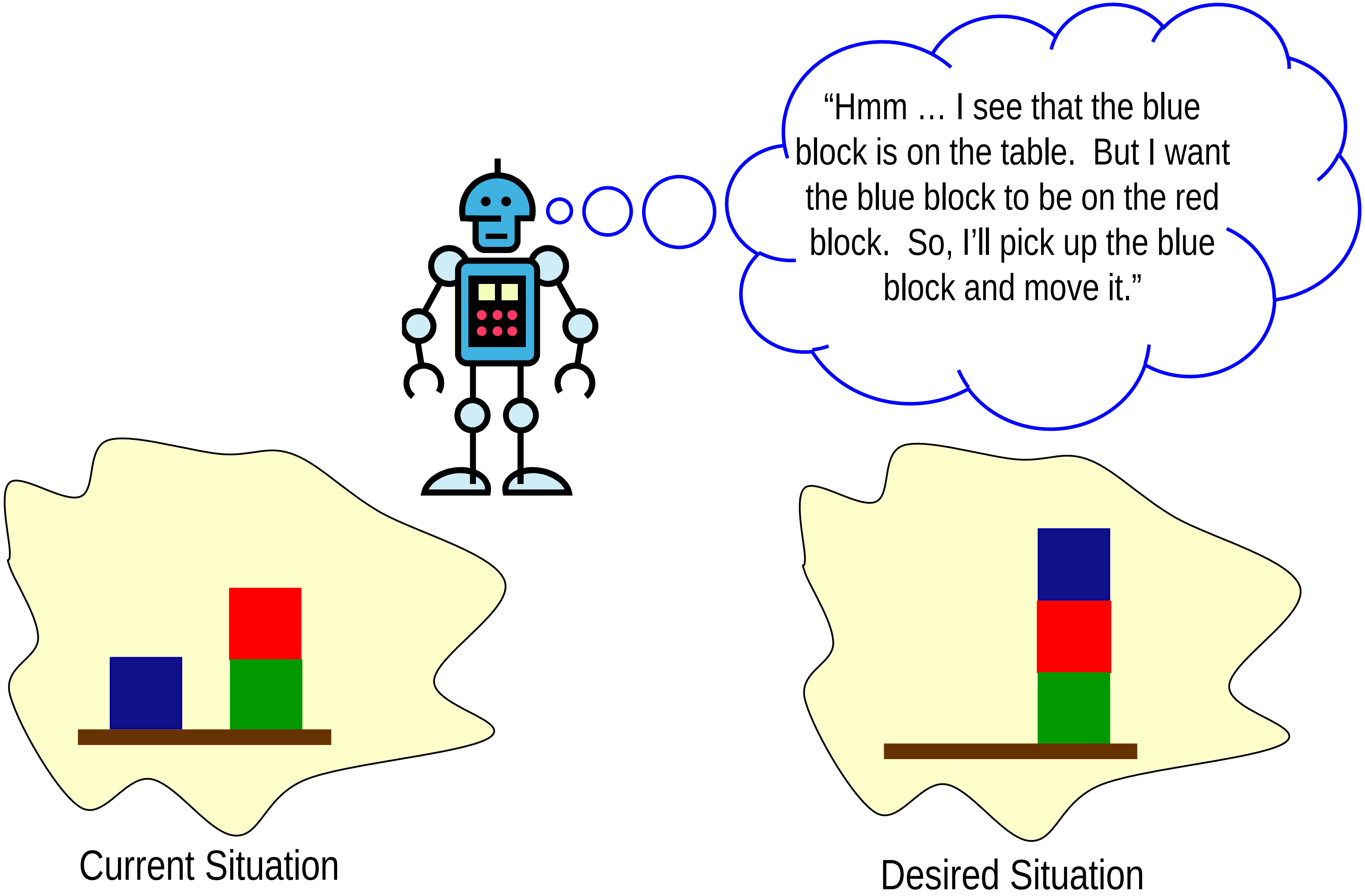
- Sensor failures
- Noisy data
- Conflicting data from multiple sensors
- Specular reflection
- Poor operating conditions
- Lack of calibration
- (etc.)








How Does a Robot "Reason"?

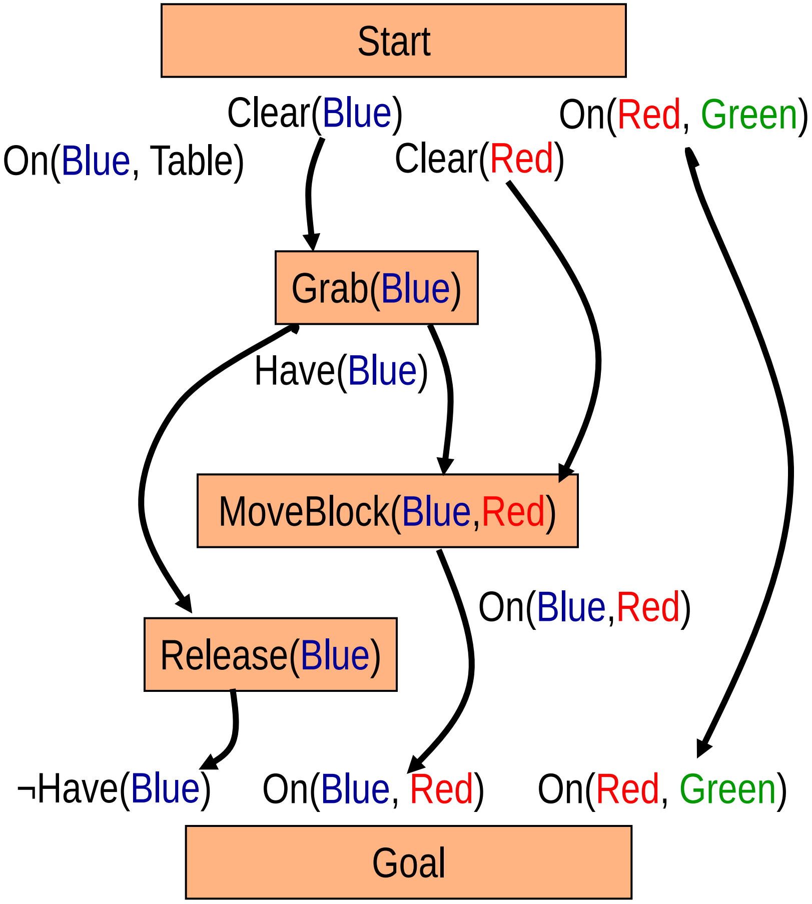


This Reasoning is called "Autonomous Planning"

Uses Logical Reasoning ("First Order Predicate Calculus")

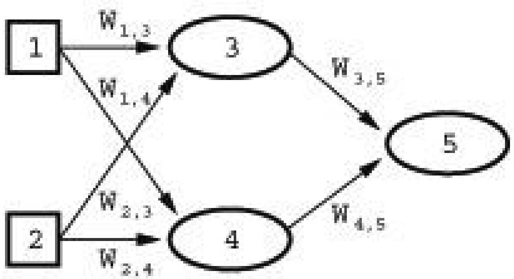
Rules expressed in Logic:

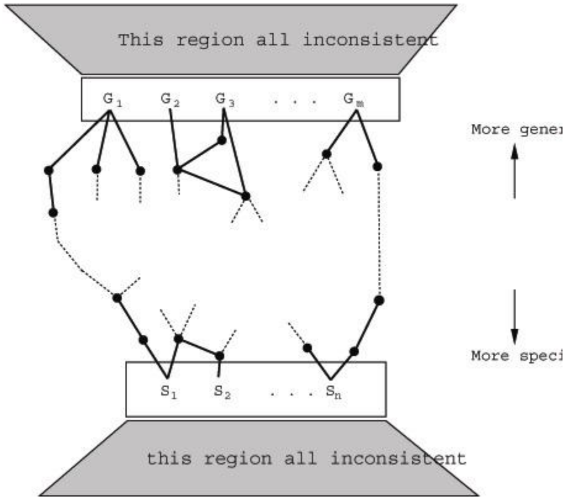
- `Action: MoveBlock(x,y)`
  - Preconditions: `Clear(y) ∧ Have(x)`
  - Effects: `On(x,y)`
- `Action: Grab(x)`
  - Preconditions: `Clear(x)`
  - Effects: `Have(x)`
- `Action: Release(x)`
  - Preconditions: `Have(x)`
  - Effects: `¬Have(x)`



And, there are lots of other ways to “reason”…

- Constraint propagation
- Production (“expert”) systems
- Decision networks
- Probabilistic reasoning
- Dynamic Bayesian networks
- Hidden Markov Models
- Genetic algorithms
- Neural networks
- …





But it's not so easy for a robot to reason…

What if blue block is glued to table,

or you accidentally drop your block,

or somebody keeps knocking down your blocks,

or the pathway is blocked,

or you don't know what to do,

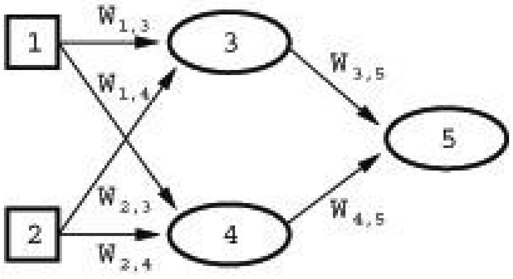
or by the time you've figured out what to do, the world has changed,

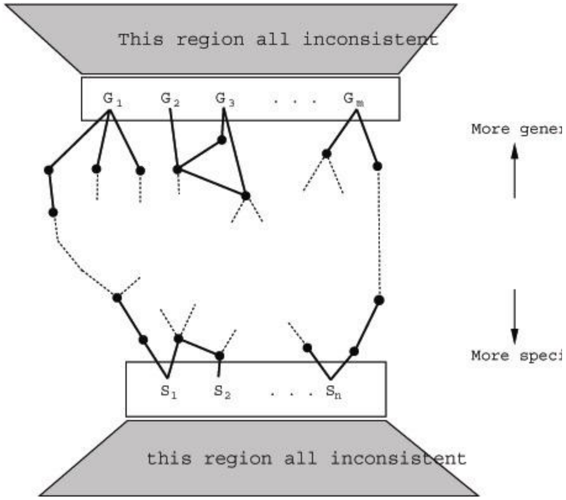
or the building catches on fire,

or, … ?

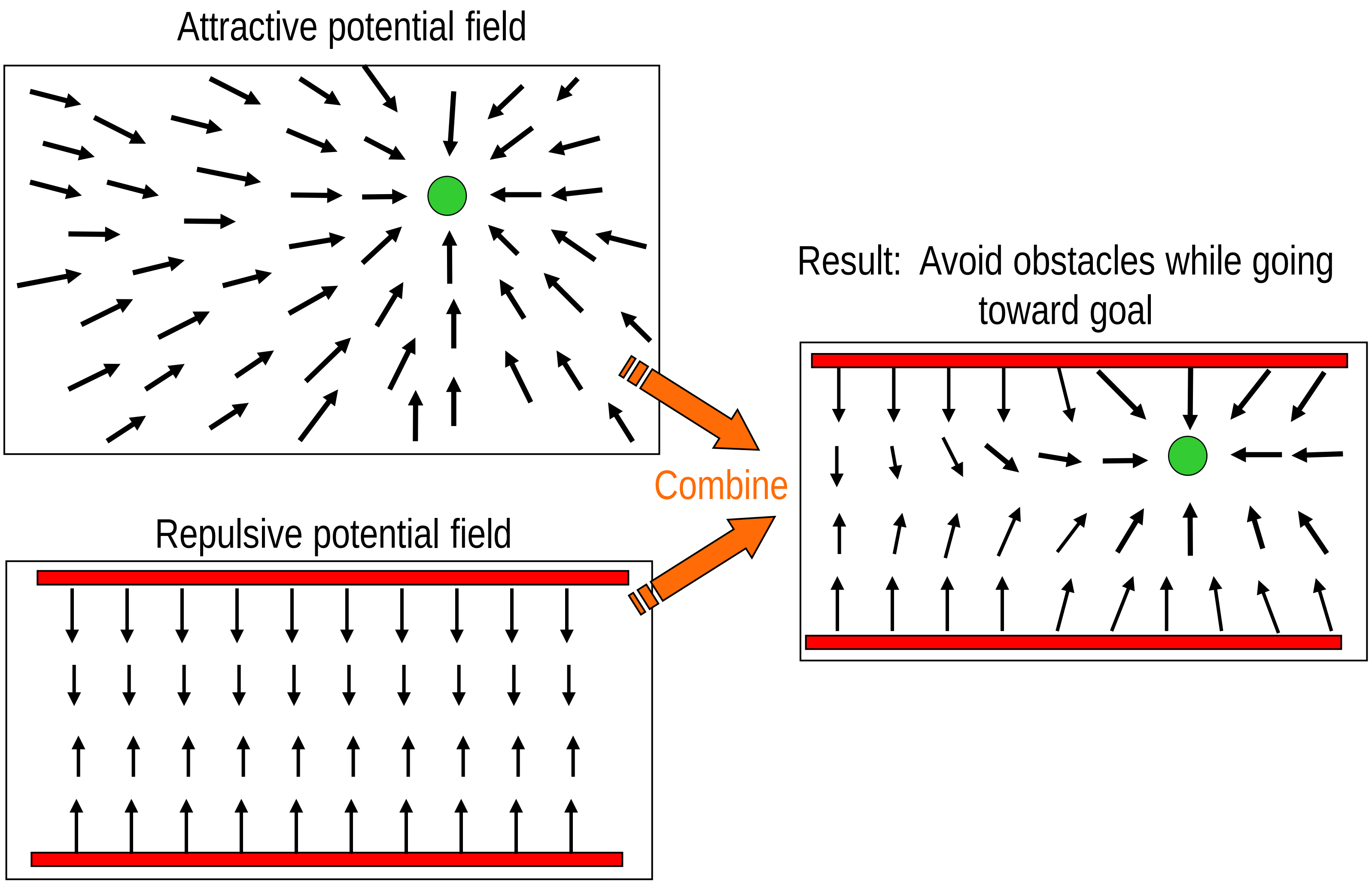
Reasoning Uncertainties Abound!

- Incomplete (often only local) information
- "Non-Markovian" environments
- Incomplete models of the world
- Dynamic environments
- Unexpected events
- NP-hard problems require approximate solutions
- Lack of common sense reasoning
- (etc.)

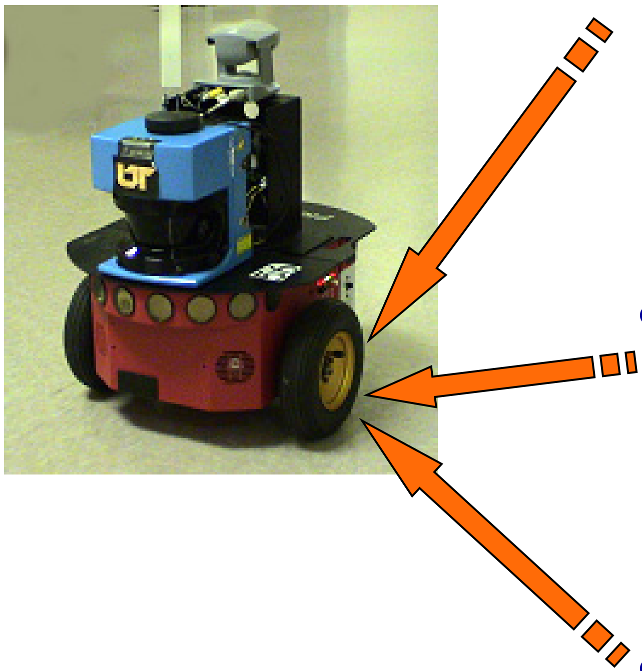




How does a robot “act”? Can use potential fields…



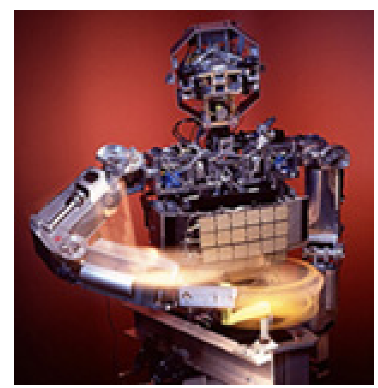
How Does a Robot Convert "Potential Fields" to Motion? Can use wheels...



- "Go forward at 1 meter per second"
  - SetMotorState(1)
  - SetSpeed(1000,0)
- "Steer hard to the right"
  - SetMotorState(1)
  - SetSpeed(50,90)
- "Stop!"
  - SetSpeed(0,0)
  - SetMotorState(0)

And, there are lots of other ways to move…

- Legs
- Tracks
- Arms
- Wings…

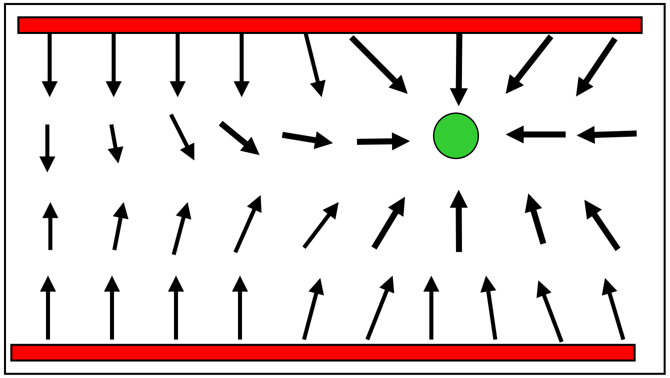


But it's not so easy for a robot to act…

What if your wheels get stuck,
or your gripper breaks,
or you collide with something,
or your battery gets too low,
or you try to grip something, but it doesn't work,
or you fall into a hole,
or a car is coming,
or, …?

Acting Uncertainties Abound!

- Wheels/legs/etc. do not execute perfectly
- Slipping, sliding, friction
- Collisions
- Battery levels
- Mechanisms degrade or fail
- Robot localization difficult
- Poor repeatability
- (etc.)



How do Robots Cooperate?
Can communicate local info to each other…

- Share and compare local sensor data:
  - Acoustics
  - Chemical concentrations
  - Visual tracks, …

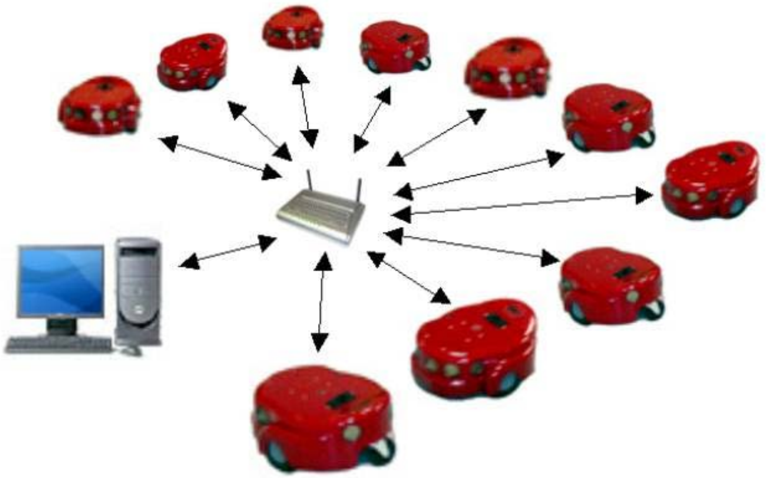
Acoustic sensor network:

Parker's DI Lab, UTK, 2004

But, it's not so easy for robots to cooperate…

What if some of the robots fail,
or the wireless communication goes down,
or robots can't find each other,
or one robot un-does what another robot just did,
or one robots thinks push while the other thinks pull,
or one robot refuses to help another,
or, … ?

Communication/Cooperation Uncertainties Abound!



- Noisy wireless communications
  - Lost messages
  - Delayed messages
  - Signal interference
- Unknown state of other robots
- Robots may not recognize each other
- Inter-robot interference/collisions
- Competing priorities
- Heterogeneous robots
- (etc.)