Quick Robot Survey Cognition Architectures

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1

Robot Algorithms

Jean-Claude Latombe

Robotics: The combined application of mechanism, dynamics, control and programming.

2

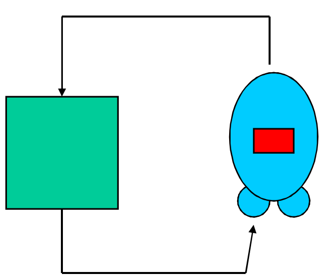
Robot Algorithms 2

Robot: a *medium* for controlling the physical environment.

Robot algorithm: the *relation* between the robot and the rest of the environment.

3

The Robot and Environment



Controllability

Observability

Planning

Tesselation

Abstraction

4

Mobile Robot Ingredients

- Mechanical
  - chassis, effectors
- Power
  - the greatest challenge of mobile robots
- Sensing
  - internal sensors, environmental sensors
- Control
  - multi-level control, P* -> A

Robotics' Major Issues

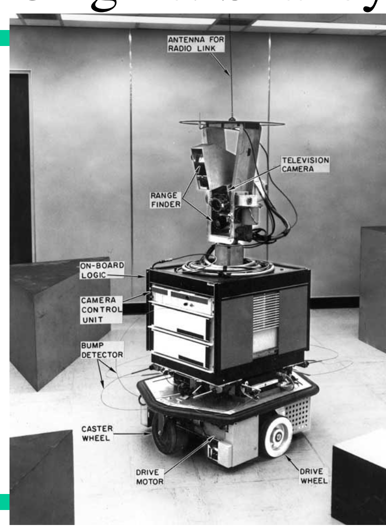
- Scaling up & scaling down
- Sensors: what are the right sensors?
- Formal completeness and optimality
- Deliberation vs. Reactivity

AI as research robotics' father

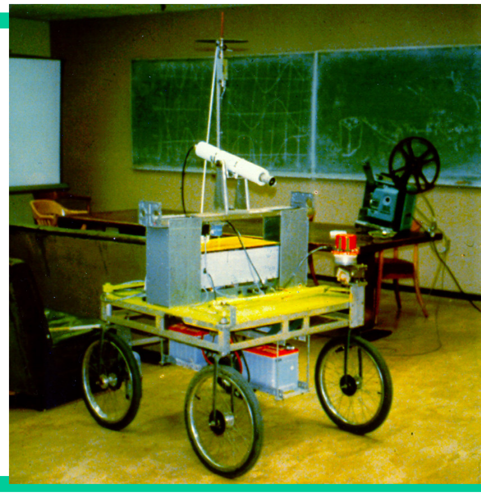
- Can an artificial intelligence reach maturity without being physically part of the real world?
  - 1969: SRI Shakey Project; Nils Nilsson
  - 1973: The Stanford Cart; Hans Moravec

7

Origins: Shakey



Origins: The Stanford Cart



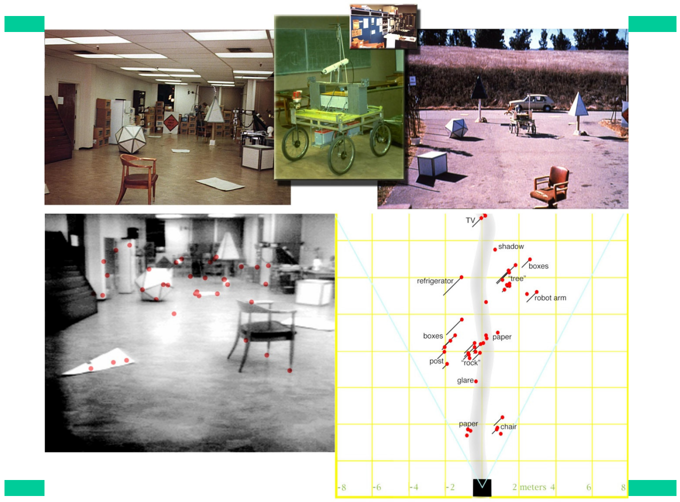
The Stanford CART

Hans Moravec

- Solving control & perception in harder worlds
- 1 TV camera, 52 cm track, 9 stops
- Pyramid-representation, Interest operator
- Move (3 minutes); Compute (15 minutes)

10

Origins: The Stanford Cart



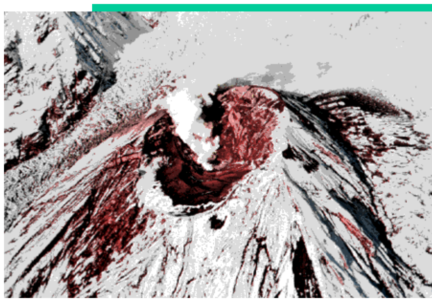
The Stanford CART

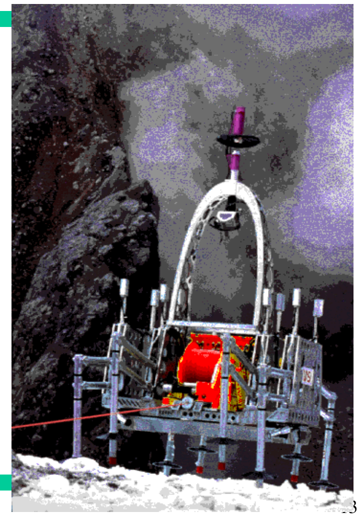
- Assumptions
  – static world
  – high-contrast world
  – no bounded rationality
  – observability (forgot obstacles that disappeared)

- Biggest problem: double noise of sensing and moving error.

12

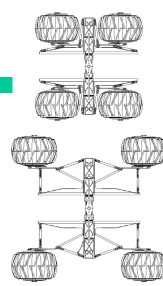
Mt. Spur Volcano Exploration 1993



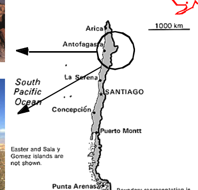


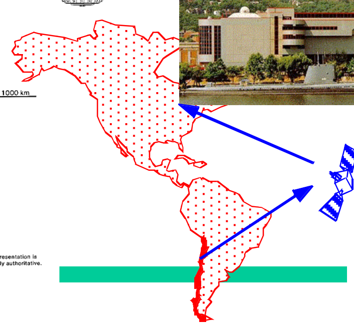
Dr. William Whittaker, John Bares

Nomad Atacama Desert Trek: June/July 1997



- Deployable, terrain-adaptable, locomotive mechanism
- Stereo
- Panospheric imaging
- Tele-auto operation
- Satellite communication link
- 223.56 km traverse (21 km autonomous; 24 km/day max)
- Meteorites detection experiments





14

Navlab Progress (1)

Navlab 1: 1986-89
Park pathway
~20 km/hr, 10km
Cameras, Laser range finder
Sun 3s and 4s

Navlab II: 1990-92
Natural Terrain, 20km/hr
Freeway, 70km/hr, 150km
Cameras, Laser range finder, Sparc 20s

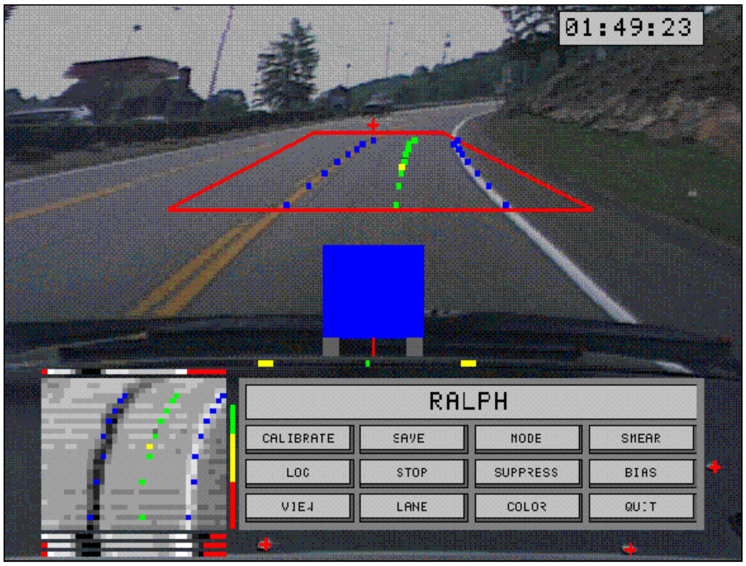
Terregator: ~1985
Campus pathway
<100m/hr, 100m total
Camera, Off-board computing

15

Navlab on streets

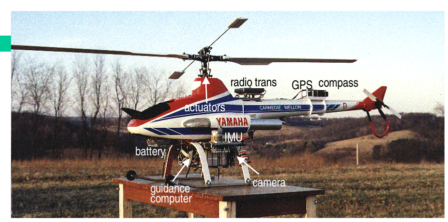
16

RALPH Autonomous Driving



17

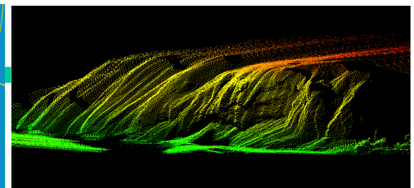
CMU Autonomous Helicopter Project



- Integrated vision-guided sensing and guidance
- Auto takeoff, landing, and trajectory following
- On-board vision for stability and high-level tasks
- Coupling of inertial and visual sensing for robustness
- On-board range sensing and 3D mapping
- Winner 1997 Unmanned Aerial Robotics Competition
- Deployed in the Canadian arctic for 3D site mapping
- Development through incremental testbeds since 1991

18

Haughton Crater Mapping Mission: July 12-22 ‘98



Aerial mapping of Mars-analog environments by CMU autonomous helicopter

- •Relative accuracy of < 20 cm in 3D
- •Full range and image data for textured map building
- •Four sites modeled for a total of 50K square meters
- •10 day field deployment

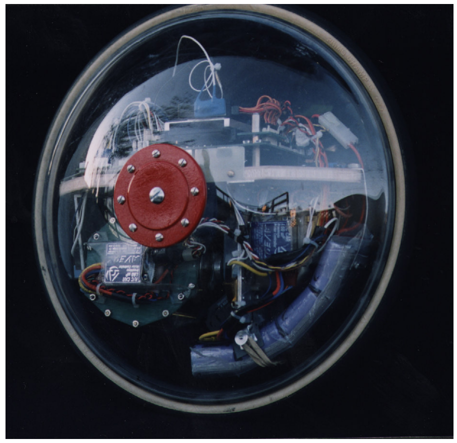
Automated Harvesting System

Increase productivity of harvesting ops.

200 acres harvested; 600 mi. driven.

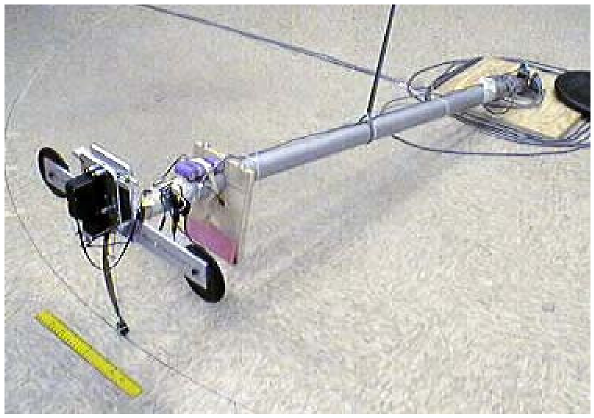
CMU NREC: New Holland Inc. and NASA)

Gyrover



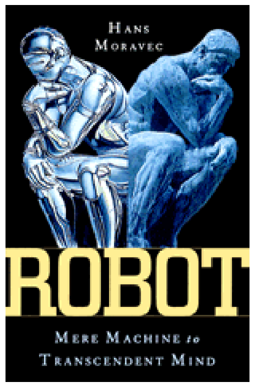
BroomBot

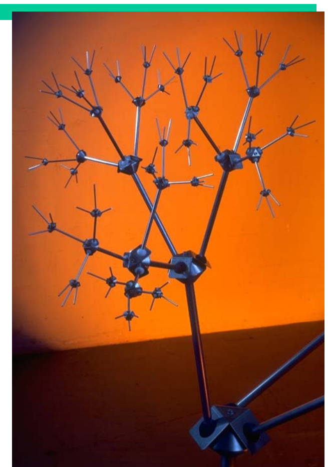
2D Bow Leg Hopper



BowGo I

Maybe Later





Robot as Situated Automata

Rosenschein, Genesereth, Nourbakhsh

- Environment and Robot form a closed system
- We abstract to a discrete representation
- The underlying world is deterministic

30

Robot as Situated Automata

Rosenschein, Genesereth, Nourbakhsh

Robot: <X,Y,Z,f,g,y>

f: X x Y -> Y   g: X x Y -> Z

Environment: <Z,E,X,h,i,e>

h: Z x E -> Z   I: Z x E -> X

The Goal

Given initial conditions and goal constraints, design a robot automata such that the robot-environment system satisfies the goal constraints.

What is Intelligence?

Levels of Deception (Mitchell 1988)

- Camouflage
- Programmed but active
- Tailored responses
- Awareness of other mental processes

33

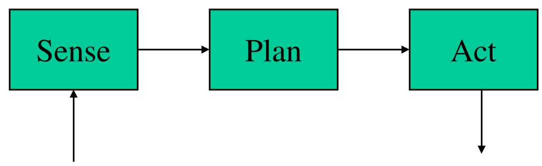
The Planning Problem

Given initial conditions I and goal conditions G, create a plan P such that if the robot executes P from any initial state consistent with I it reaches a goal state consistent with G.

34

Sense-Plan-Act

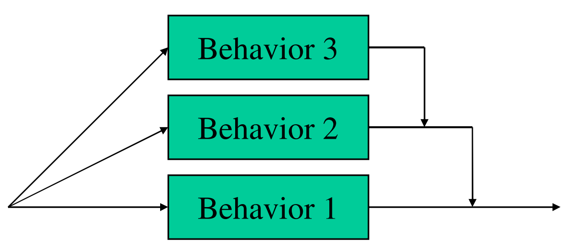
Nilsson



35

Layered Subsumption

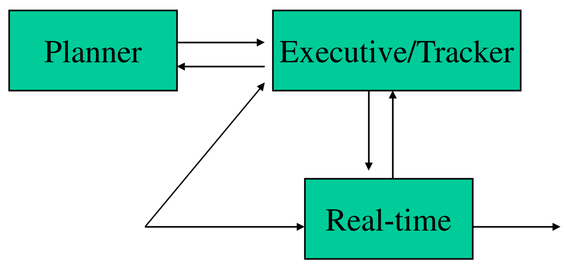
Brooks



36

Tiered Architecture

everyone else!



37

Plan Reuse and Plan Abstraction

- The real world has an impossibly large search space
- Humans plan very little
- Humans repeat the same nonoptimalities
- How can we create robots that satisfy but do not necessarily optimize?

38

Interleaved Planning & Execution

Assumptive Planning Architecture

39