

Exploring Robotics

Unit E Control Architecture and USAR



Robot Control Architectures

- Provides strategy for the control system to tackle problems
- Refers to the way in which the sensing and action of a robot are coordinated
- Refers to software control level, not hardware
- Implemented in a programming language
- Don't confuse "programming language" with "control architecture"
- Control architecture guides how programs are structured

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Four Basic Approaches

1. Deliberative Control: Think hard, then act
 2. Reactive Control: Don't think, (re)act
 3. Hybrid Control: Think and act independently, in parallel
 4. Behavior-Based Control: Distribute thinking over acting
- No single approach is "the best" for all robots; each has its strengths and weaknesses

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Deliberative Control

- Similar to human planning
- Classical control architecture (first to be tried)
- First used in AI to reason about actions in non-physical domains (like playing chess)
- Example: Shakey (1960's, SRI)
 - First mobile robot to reason about its own actions
 - State-of-the-art machine vision used to process visual information
 - Used classical planner (STRIPS) for planning

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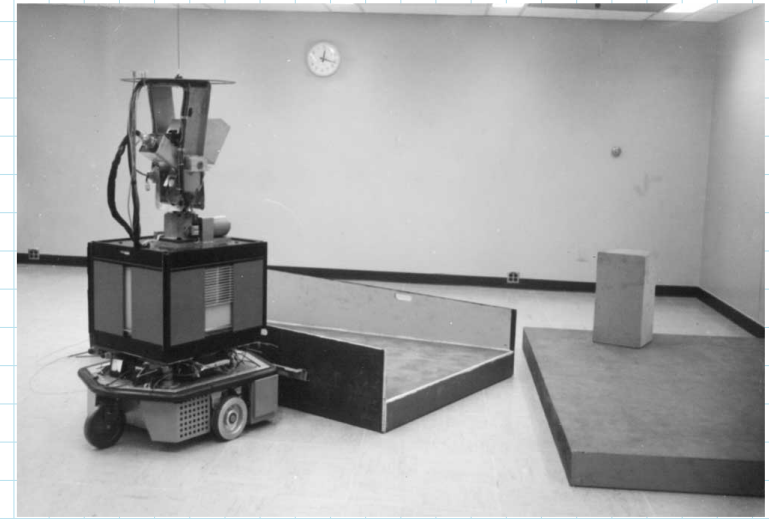
Shakey must get to the block on the raised floor



■ Shakey finds the ramp

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Shakey must get to the block on the raised floor



■ Shakey pushes the ramp to the raised floor

E-6

Shakey must get to the block on the raised floor



■ Shakey goes up the ramp

E-7

Shakey must get to the block on the raised floor



■ Shakey knocks the block off

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Deliberative Control

- Consists of three sequential steps (also called SPA architecture)
 1. Sensing (**S**) – acquire information
 2. Planning (**P**) – process information and search for the best solution
 3. Acting (**A**) – execute the plan
- Strengths
 1. Usually results in optimal solution
 2. Can learn over time (it memorizes things)

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Deliberative Control

- Weaknesses
 1. Needs lots of memory to store lots of information & data
 2. Needs lots of time to think (long time scale)
 - (But the environment may change while the controller thinks)

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Reactive Control

- Immediate and real-time response to the environment (operates on a short time scale)
- Does not think ahead, does not plan
- Based on a tight loop connecting the robot's sensors with its effectors
- Does not usually keep much information, has no memory, no internal representations of the world, and no ability to learn over time
- Simple computation and easier to develop
- Only useful for solving simple problems
- E.g. iRobot Roomba

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Hybrid Control

- Uses the best of both worlds (deliberative: brains, reactive: speed)
- Combines open-loop (long time thinking) and closed-loop (quick reaction) execution
- Combines different time scales (fast response vs. slow planning) and environment representations
- Responds to some urgent requirements, while taking time to think about some others
- Requires waiting for the thinking to finish or interrupting the reaction based on new information

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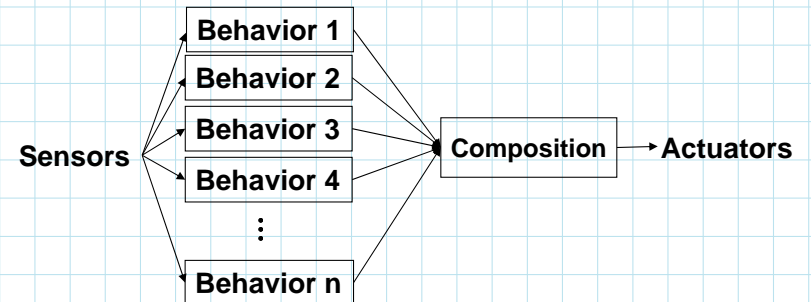
Hybrid Control

- Typically consists of three layers
 1. Reactive layer
 2. Planner (deliberative layer)
 3. Integration (middle) layer to combine them
- Challenge: to allow the reactive & deliberative layers to talk to each other and resolve their conflicts – the job of the middle layer
- E.g. mail delivery robot within a building
 - Path finding: deliberative
 - Obstacle avoidance: reactive

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Behavior-based Control

- Like hybrid control, it also thinks and acts at the same time, but spreads out the thinking over multiple distributed computation modules (behaviors)



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What Is a Behavior

- Behaviors achieve and / or maintain particular goals
- Behaviors are time-extended, not instantaneous (it takes some time to accomplish the goal)
- Behaviors can take inputs from sensors and from other behaviors, and can send outputs to effectors and other behaviors
- Behaviors are more complex than actions (actions do not need thinking)

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Behavior-based Control

- The robot's actions are determined by a set of parallel, reactive behaviors which map sensory input and state to actions
- E.g: a robot moving around a building and watering plants whenever they get dry may need the following behaviors
 - *avoid-collision*
 - *find-plant*
 - *check-if-dry*
 - *water*
 - *refill-water-reservoir*
 - *charge-batteries and more ...*

[\(Video – Autonomous plant watering robot \)](#)

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Behavior-based Control

- Robot can react fast to changes (like reactive)
- Each behavior only requires a partial view/model of the world
- System does not depend on complete knowledge of the environment (vs. deliberative)
- Behaviors are easier to design than complete task strategy
- Complex task performance as a result of the combination of all behaviors as they interact with the environment (like deliberative)
- An alternative to hybrid with equal power, but no need for an integration component (because all behaviors have the same time scale)

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Urban Search and Rescue

- What is urban search and rescue (USAR)?
 - It is task to locate, rescue and provide initial medical help to the victims when disaster or attack happens



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Problems Faced during Rescue Operations

- **Hostile environment:** Disasters may initiate fires, building collapses and other incidents which may compromise the security of people in the area.
- **Limited time:** According to statistics, most of the victims were rescued during the first 72 hours after an earthquake. Time may vary but response time is important in all types of disasters.
- Most of the decisions must be made with **incomplete information**. These may include:
 - location of the victims
 - reliability of existing infrastructure: roads, communication infrastructure, etc.

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Can Robots Help?

- Technologically, yes.
- According to William “Red” Whittaker, team leader who won 2nd and 3rd place in DARPA Grand Challenge 2005, technology is there but more money and commitment is needed to develop robots for use in disaster areas.

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Earliest Rescue Robots

- Although the robotics research is still premature to develop fully autonomous robots, teleoperated robots were used in several disasters so far.
 - West Virginia mine explosion (Case Study, Unit E, Coursepack)
 - Hurricane Katrina ([watch video here](#))
 - World Trade Center
 - first really tested rescue robots
 - had trouble working in the rubble and were constantly getting stuck or broken
 - since then many new ideas have been formed about rescue robots



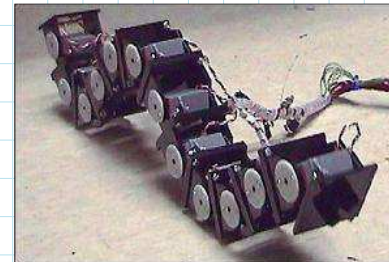
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Rescue Robots (1)

iRobot ATRV – military surveillance robot



blimp robot



crawling robot



tracked robot

NSF E-22

Rescue Robots (2)



balancing robot



bomb removing robot



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Potential Uses of Robots in Rescue Efforts

- Utilization in risky and dangerous tasks
- Locating victims
- Mapping of the disaster area
- Surveillance of the environment for fires, potential gas leaks and structural changes
- Carrying water, food, medicine, oxygen etc. to victims before they can be reached

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Utilizing robots in USAR – Problems

- **Autonomy:** State of the research is still in its infancy. Robots are not fully autonomous and most of the current rescue robots cannot be used without considerable training.
- **Robot cooperation:** Using multiple robots, in theory, will increase the efficiency of tasks. However, cooperation between robots becomes an issue.
- **Human-robot interaction:** Hybrid rescue teams with human assistance seems to be a good approach but requires an interaction mechanism between humans and robots.

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Research on Rescue Robots

- Low level robotic functions: perception, locomotion
- Path Planning
- Mapping and Localization
- Multi-Robot Coordination, task and resource allocation
- Human Robot Interaction
- Others...

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RoboCup

- An international robotics competition founded in 1993
- The aim is to develop autonomous soccer robots with the intention of promoting research in robotics and artificial intelligence
- Long term goals offer a publicly appealing, but formidable challenge
- The ultimate goal is to build a team of fully autonomous humanoid robot soccer players that shall win the soccer game against the winner of the most recent World Cup by mid-21st century

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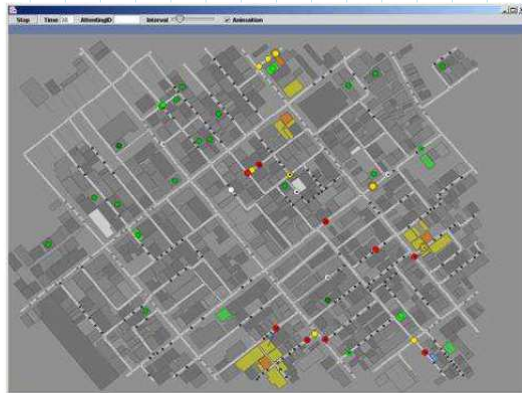
RoboCup

- Provides a common platform where scientists and engineers compare their results and benefit from each other's experience
- Consists of five main leagues:
 - Soccer (*Humanoid: mid-size, small-size; 4-legged; simulation*)
 - Rescue (*Simulation, USAR, USARSim*)
 - Home (*real-world application*)
 - Industrial (*robots in work-related scenarios*)
 - Junior (*Soccer, Rescue, Dance*)

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RoboCup Rescue Simulation

- Objective is to provide a platform which would enable to work on high level interaction and coordination mechanisms among large number of agents.
- A part of a city where an earthquake is simulated causing fires, building collapses with trapped victims. Environment is dynamic and communication is noisy.
- **Need to develop intelligent programs to coordinate USAR efforts**



The rectangles represent the buildings (gray: intact, yellow: in fire). The circles represent agents: Fire Brigade (red), Police Force (yellow), Ambulance Team (white) and Civilians (green).

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RoboCup USAR

- Objective is to develop robots that would search and locate victims in a cluttered area. Mostly, focuses on developing or improving low level robot capabilities such as perception and motion.
- An arena in a large room is designed for competitions, containing obstacles, stairs and test dummies for victims.

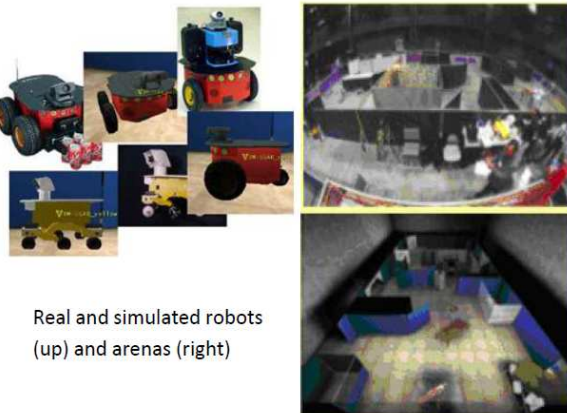


Robots performing search and rescue tasks in confined arena, built to represent similar problems in a disaster environment.

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RoboCup USAR Simulation

- Objective is to provide a intermediary between USAR and city level simulation.
- Built on Unreal Tournament game engine, robots and arenas are modeled for testing programs. It is suitable for researchers with limited means to afford expensive equipment.



Real and simulated robots (up) and arenas (right)

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RoboCup Junior Rescue

- A project-oriented educational initiative designed to introduce RoboCup to high schools and undergraduates.
- Engages robots to identify victims quickly and accurately within recreated disaster scenarios, varying in complexity from line following on a flat surface to negotiating paths through obstacles on uneven terrain.



RoboCup Junior Rescue event in CUNY-GC 2006.

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Homework Assignment

Read the following article:

"Better robots could help save disaster victims"

(Case Study, Unit E, Coursepack)