Behavior-Based Programming of Robots and Multi-Robot Teams

Part 3: Behavior Based Architectures

IJCAI tutorial SA-4
Presented by Tucker Balch
Behavior-Based Architectures

Definition 1: Reactive

“A reactive robotic system tightly couples perception to action without the use of intervening abstract representations or time history.” --Ron Arkin
A *behavior-based* robotic system generally relies on a tight stimulus-response framework, but may utilize minimal state information as well. --Tucker Balch
Behavior-Based Architectures

Influential Architectures

- Subsumption -- Brooks, 1986
- Motor schemas -- Arkin, 1987
- Distributed Architecture for Mobile Navigation (DAMN) -- Rosenblatt, 1989
- Colony Architecture -- Connell, 1989
- Reactive Action Packages (RAPs) -- Firby, 1989
Motor Schemas

- Multiple independent processes each generate a vector combined by weighted summation
- Computationally simple and fast
- Enables design by composition. Related to artificial potential fields
  - Khatib, Krogh, Payton, Singh
Behavior-Based Architectures: Motor Schemas

Primitive: Move to Goal
Behavior-Based Architectures: Motor Schemas

Primitive: Avoid Obstacle
Behavior-Based Architectures: Motor Schemas

Avoid Obstacle + Move to Goal
Behavior-Based Architectures: Motor Schemas

More Complex Problem: Pushing
Behavior-Based Architectures: Motor Schemas

Approach: Specialized Schemas
Behavior-Based Architectures: Motor Schemas

Video: Pushing
Behavior-Based Architectures: Foraging Case Study

Foraging: A Canonical Task

• Forms the basis for many, more complex tasks
  – Soccer
  – Construction
  – Clean up
  – Rescue

• Investigated by many researchers
  – Arkin, Balch, Mataric, Goldberg, Connell
Behavior-Based Architectures: Foraging Case Study

Foraging Robots (1994)

Behavior-Based Architectures: Foraging Case Study

Foraging Robots (1997)

Behavior-Based Architectures: Foraging Case Study

Foraging Robots (2001)

Behavior-Based Architectures: Foraging Case Study

The Multi-Foraging Task
Behavior-Based Architectures: Foraging Case Study

Multi-Foraging Robots
Behavior-Based Architectures: Foraging Case Study

Multi-Foraging Robots
Behavior-Based Architectures: Foraging Case Study

Multi-Foraging Robots
Behavior-Based Architectures: Foraging Case Study

Multi-Foraging Robots

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Behavior-Based Architectures: Foraging Case Study

Multi-Foraging Robots

• Problem
  – How do solve this task with a set of behaviors?

• Solution
  – Add sequencing (Mackenzie & Arkin)
Behavior-Based Architectures: Foraging Case Study

- **Search**
  - see red
  - ~see red

- **Acquire Red**
  - have red
  - ~have red

- **Deliver Red**

- **Acquire Blue**
  - have blue
  - ~have blue

- **Deliver Blue**

**At red bin**

**At blue bin**

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Behavior-Based Architectures: Foraging Case Study

Behavioral Assemblages

- Wander
  - Avoid-Obstacle
  - Avoid-Robot
  - Noise

- Acquire-Red Acquire-Blue
  - Move-To-Goal (Closest Red Object)
  - Avoid-Obstacle
  - Noise

- Deliver-Red Deliver-Blue
  - Move-To-Goal (Red Bin)
  - Avoid-Obstacle
  - Noise
Behavior-Based Architectures: Foraging Case Study

Perception

- Continuous -- for behaviors
  - Obstacles (by sonar)
  - Attractors (by color vision)
  - Bin locations (by location and color)
- Binary -- for switching behaviors
  - See-red
  - See-blue
  - Have-red
  - Have-blue
  - At-red-bin
  - At-blue-bin
Behavior-Based Architectures

TeamBots Examples