CMRoboBits:
Creating an Intelligent AIBO Robot
Multi-Robot Systems I

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15-491, Fall 2007

http://www.andrew.cmu.edu/course/15-491

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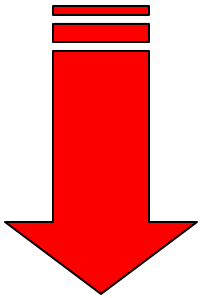
Why Multiple Robots?

- Coverage
- Robustness to failure
- Physics-driven problems
- “achieve” more
- Capabilities

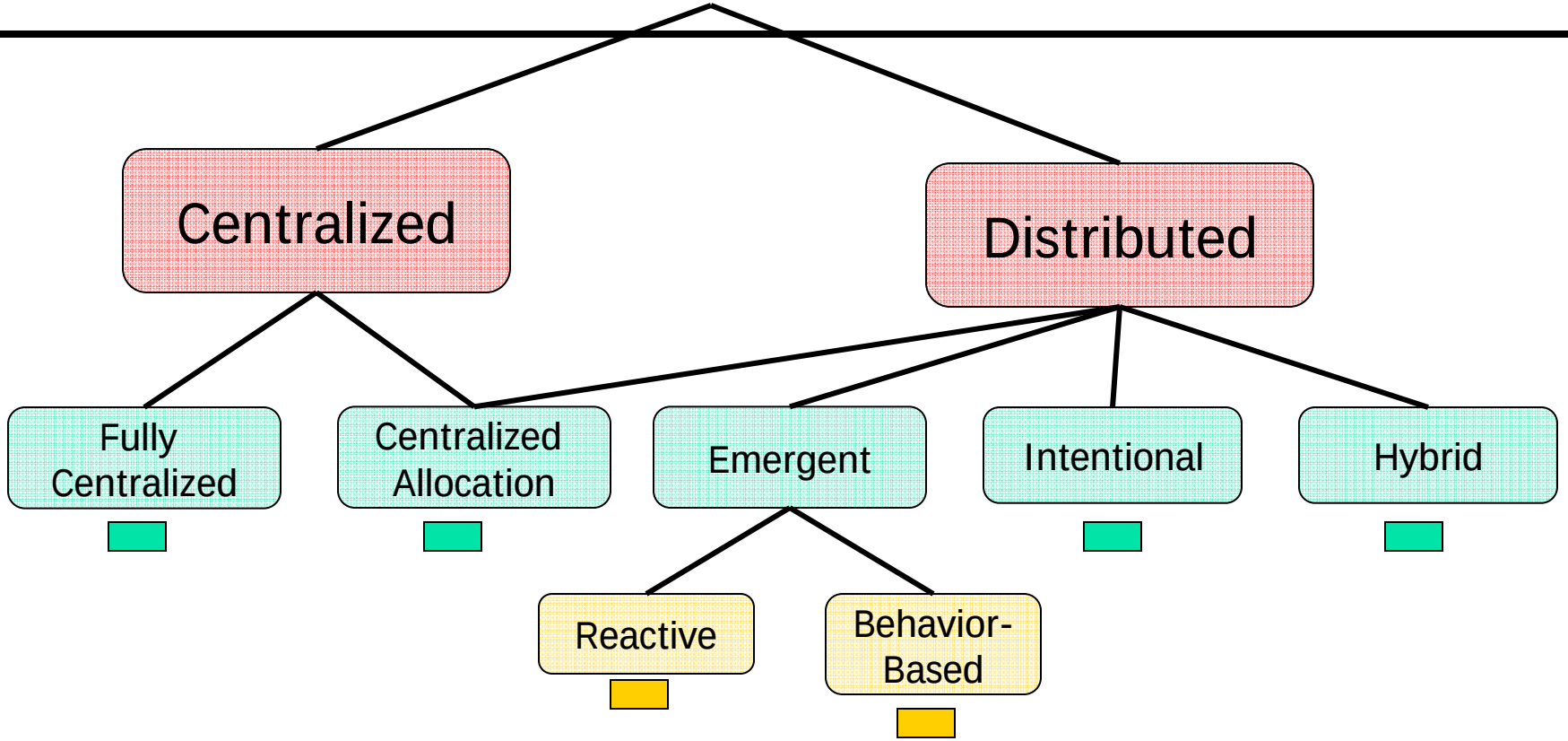


- Factories

Why Not Multiple Robots?

- Replication of hardware
  - Hardware easily obsolete
  - Investment and development cost for suboptimal designs
- Communication, coordination, cooperation, itons…
- Debug

Taxonomy of Approaches- Perception/Control/Actuation



Examples in Multi-Robot Soccer

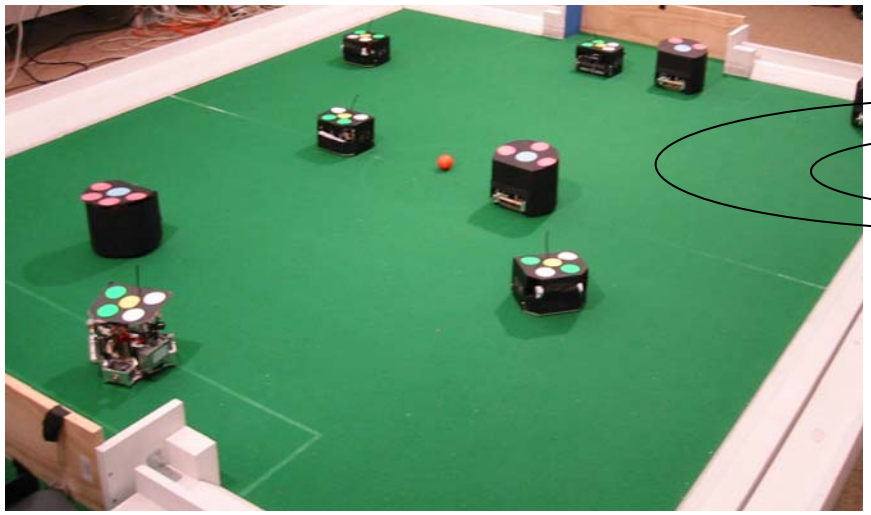
CMTrio, CMPack, CMDash
AIBOs, 4-legged, fully autonomous

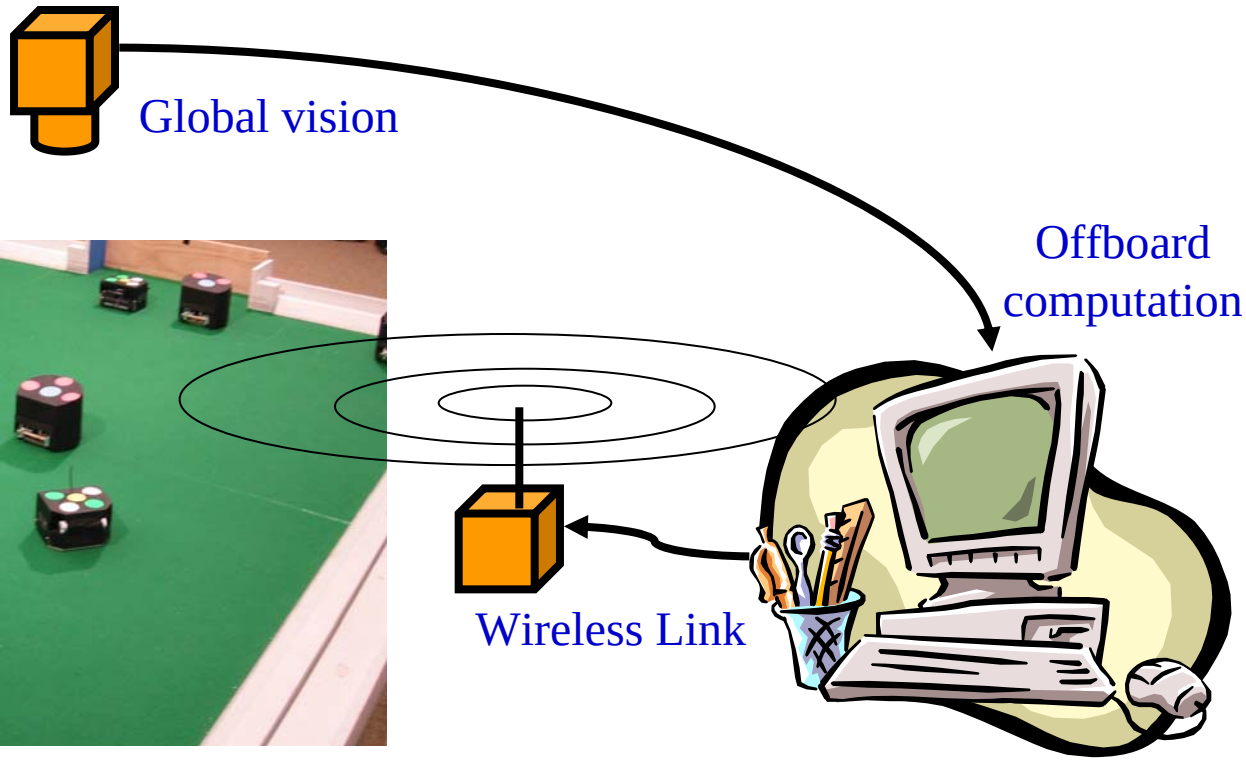
CMDragons
wheeled, offboard vision, computer control

CMBalance:
Segway soccer human-robot teams

“Small-Size” Robot Soccer

10 robots + golf ball
5 robots per team
Color markers for ID





Complete system is autonomous as a whole

Global Perception

Perception – World Modeling (review)

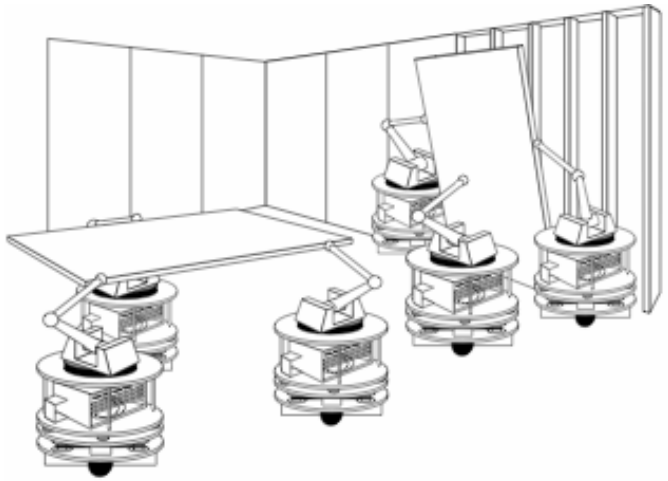
- Sensors – "signal" (data) collectors from the physical world:
  - Vision, sound, touch, sonar, laser, infrared, GPS, temperature,….
- *Signal-to-symbol* task:
  - Recognize the *state* of the environment
  - …wall at 2m… door on the left… green light… person in front… personX entering the room… ball at 1m and 30º East…

Centralized Perception

- Complete view of the world
  - As accurate as possible
- Advantages?
- Challenges?
- Feasible?

Centralized Control

- Single algorithm planning for entire team
- + Task optimization
- + Implicitly encodes coordination
- – Usually computationally intractible



Centralized construction; Khatib et al 1996


CMDragons'06
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STP Behavioral Architecture

- **Skills**
  - Actions
  - Low-level control scripts to achieve *plain* goals
- **Tactics**
  - Sequences of actions
  - Combinations of skills to achieve *task* goals
- **Plays**
  - Web of tactics
  - Plans of tactics to achieve *team* goals

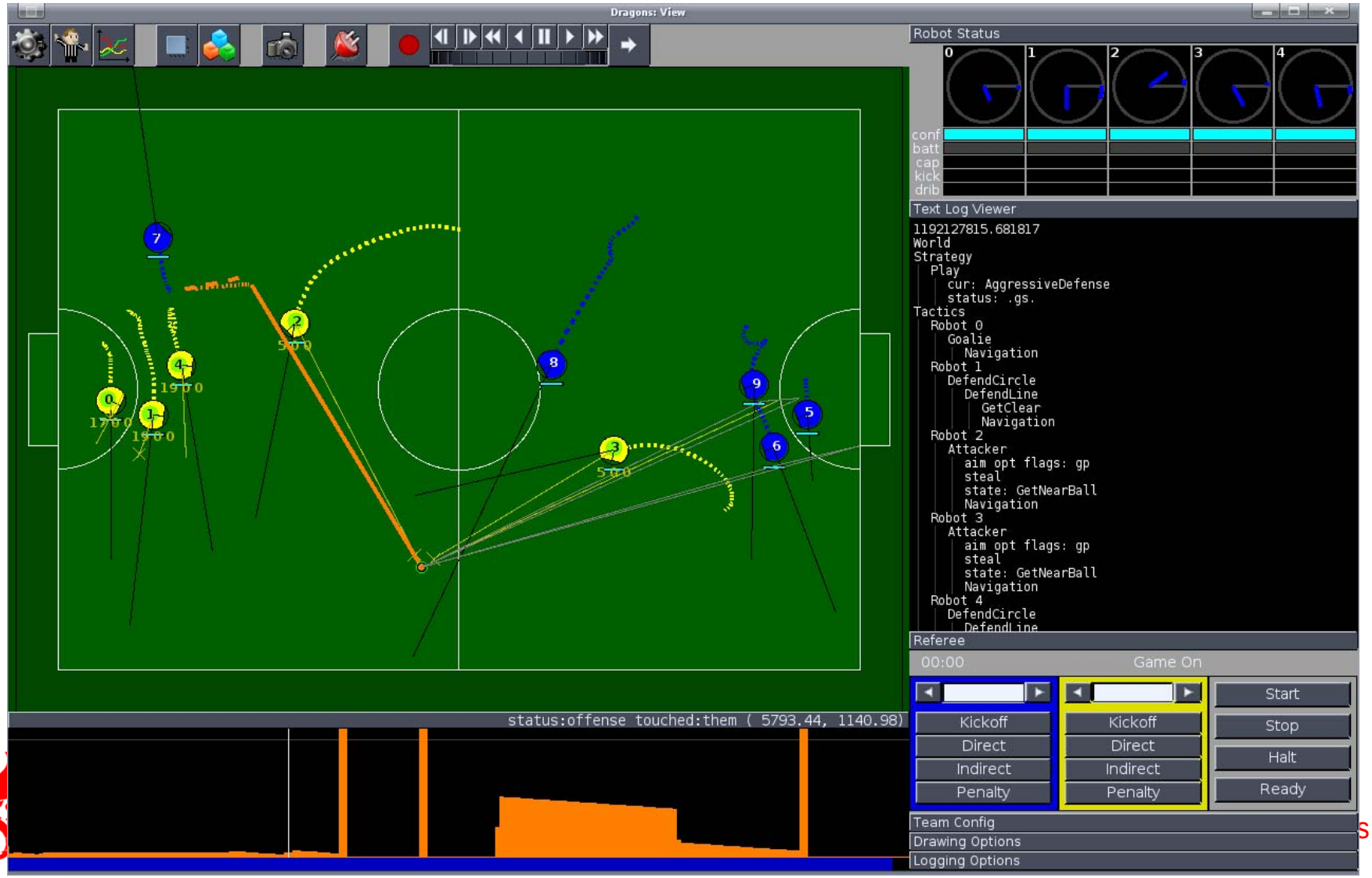
Team Strategies – Plays
Applicability, Termination, Roles

PLAY Two Attackers, Corner Dribble 1

APPLICABLE offense in_their_corner
DONE aborted !offense
TIMEOUT 15

ROLE 1
dribble_to_shoot { R { B 1100 800 } { B 700 800 } 300}
shoot A
none
ROLE 2
block 320 900 - 1
ROLE 3
position_for_pass { R { B 1000 0 } { B 700 0 } 500 }
none
ROLE 4
defend_line { -1400 1150 } { -1400 -1150 } 1100 1400
none

Dynamics: Prediction, Statistics, Layered Behavior Disclosure, Robot State, Tactics, Plays

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CMDragons '07
Carnegie Mellon
RoboCup 2007
Round Robin Game 2 of 4
CMDragons vs. RoboDragons
Final Score 8:0


CMDragons '07
Carnegie Mellon
RoboCup 2007
Final
CMDragons vs. Plasma-Z
Final Score 9:7

Learning by Play Adaptation

- A playbook *(multiple experts)* is composed of multiple plays p_j with:
  - Applicability conditions, an associated weight w_j
  - Success, failure conditions, time limits
- Active play is selected as a function of the weights

$$\mathrm{P}\left(p^* = p_j\right) = \frac{w_j}{\sum_{P_A} w_k}, \forall j \in P_A$$

Weights are adapted by feature observation.
Playbook adapts to the opponent
without explicit modeling.

Discussion

- Multi-robot
- Centralized perception
- Teamwork representation
- Learning teamwork