RoboCup — Multiagent Systems

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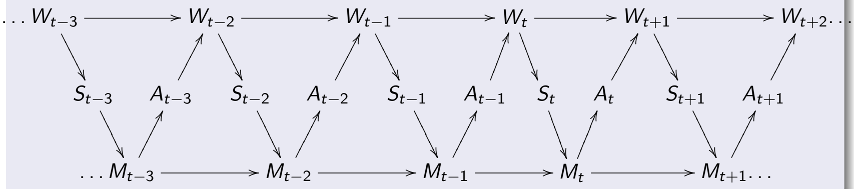
and the International RoboCup Community

Part I

What is an Agent?

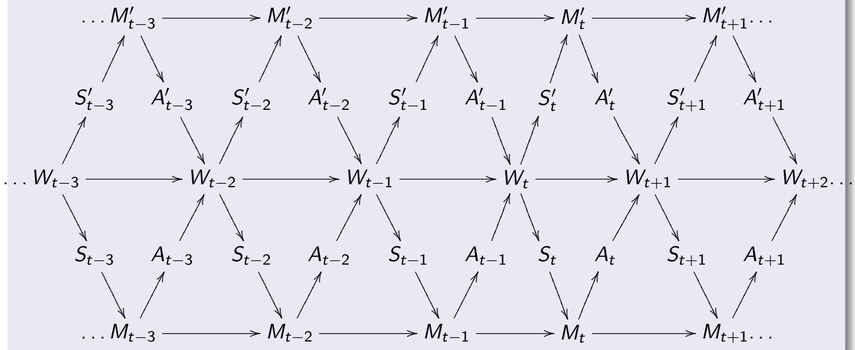
What is an Agent? I

One Agent and a World



What is an Agent? II

Agent with World (and Other Agent)



What is an Agent? III

Initial Observations

Purely Passive World:

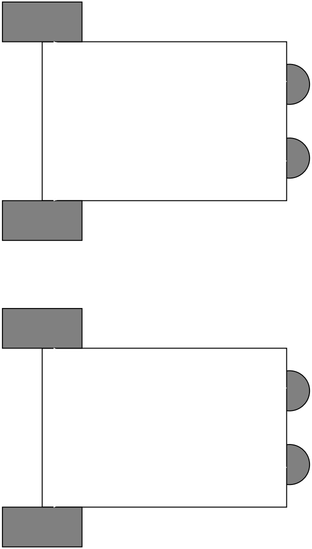
- a passive world has a dynamics
- runs according to fixed dynamics
- "reacts" to agent's actions

World with Active Agent:

- strictly spoken, world with agent has dynamics
- however, dynamics of these agents looks like dictated by a "purpose"

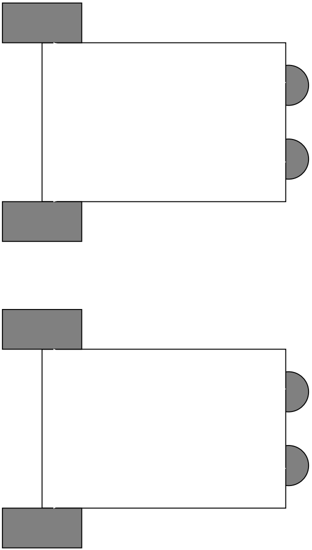
Purposeful Behaviour

- fleeing the light



Purposeful Behaviour through Simple Dynamics

- fleeing the light
- seeking the light



Braitenberg Vehicles

[Braitenberg, 1984]

Purposeful Behaviour through Simple Dynamics

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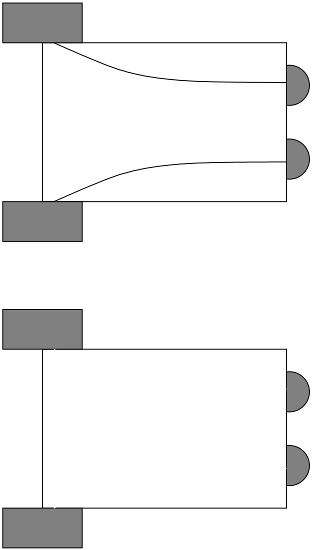

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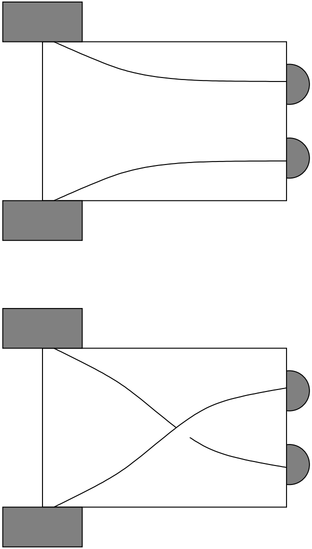

Notes

Passive Objects and Agents

- not always distinguishable
- sometimes by virtue of "camouflage"
- sometimes by simple lack of ability

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Do not attribute to malice what is equally explained by incompetence. NAPOLEON

The "Pizza Tower" Lesson

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The "Pizza Tower" Lesson

Are those agents standing around waiting to spring a trap?

Notes

Passive Objects and Agents

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- sometimes by simple lack of ability

Do not attribute to malice what is equally explained by incompetence. NAPOLEON

The "Pizza Tower" Lesson

Are those agents standing around waiting to spring a trap or are they just lost?

Recap

World with Another Active Agent

- world with agent has dynamics
- looking like dictated by a “purpose”
- may or may not be not consistent with one’s own “purpose”

Mottos of Edification and Purpose

Goldfinger's Motto

1. Once is happenstance.
2. Twice is bad luck.
3. Three times is **enemy action**

Mottos of Edification and Purpose

Goldfinger's Motto

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"Kafka's Motto"

The fact that you are paranoid
does not mean they are not after you.

Slightly More Formal: Single Agents

Properties

- single entity controls decisions
- single mind
- single goal
- external world may be noisy
- **challenge**: "optimal" ways of coping with external dynamics constraints and noise

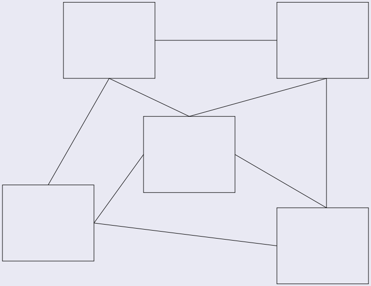
Transition to Multiagent Systems

Agents

- "interests"
- shared goals
- antagonisms

Motto

- multiple agents have inconsistent/conflicting agenda
- but even if consistent agenda, multiple brains
- crisscross interaction



Types of Scenarios

Classification

- single agent
- 2-agent
- multiagent
- cooperative
- antagonistic
- something in-between (real life, economy)

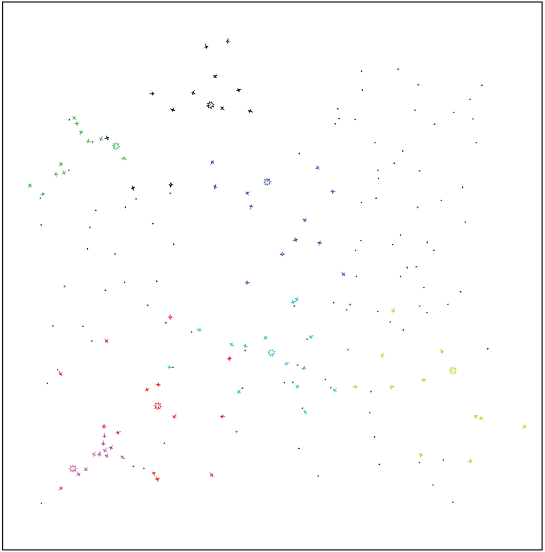
Multiagent Systems

In General

- multiagent (> 2)-systems can produce intricate strategy balances
- even fully antagonistic scenarios can be temporarily cooperative
- rich set of strategies, even for simple agents/dynamics

Introductory Example: Ant Colony Scenario

[Polani and Uthmann, 1998]



Scenario

competition between ant colonies

- feeding
- transporting food
- signaling
- fighting

Variations

1. XRaptor (1997–)
2. Google AI Challenge (2011)

RoboCup as Multiagent System

Notes

- comparatively "simple" case
- clear cooperation/antagonism structure

We will now visit the different levels of multiagenthood

Part II

Behaviour Analysis

Motivation

Analysis

- of processes
- of agent behaviors
- of multi-agent systems
- of RoboCup

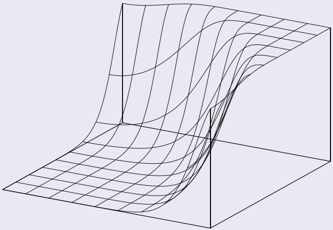
Goal

- automated analysis
- behavior-based (no internal knowledge)
- state-space trajectories
- analysis of:
  - "micro"-behavior of a single player
  - player-ball interaction

Self-Organizing Maps for Analysis

[Wünstel et al., 2001]

What are SOMs?



Properties

- high-to-low dimension mapping
- clustering
- topology preservation
- sequence detection and identification

Trajectory Representation

Steps

SOM Representation:

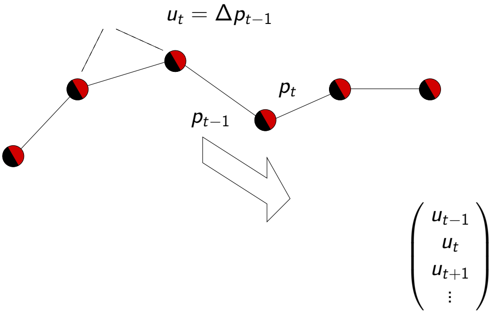
- vector space
- metrics

Task: transform trajectory to a SOM representation

Problem: space of complete trajectories too large

Solution: consider trajectory slices

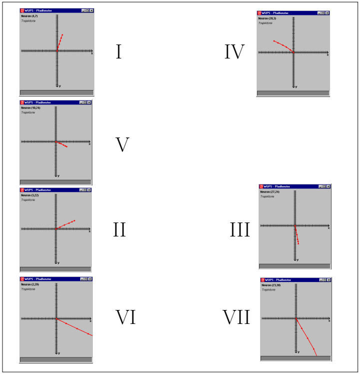
Spatially Focused Representation

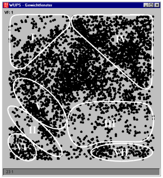


SOM Training

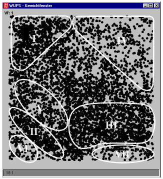
- RoboCup game yields sequence of positions
- conversion to u representation giving
- vector space with
- Euclidean distance

Results SFR



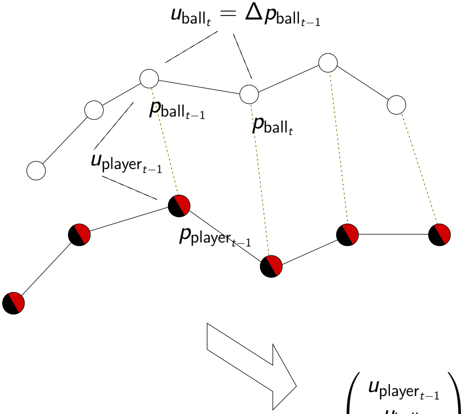


MRB 1999



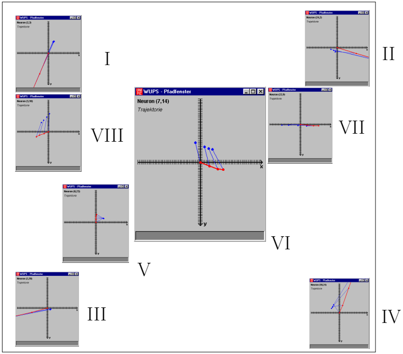
CMU 1999

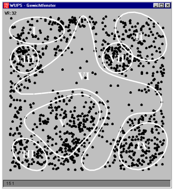
Enhanced SFR (ESFR)



$$\begin{pmatrix} u_{\text{player}_{t-1}} \\ u_{\text{ball}_t} \\ u_{\text{player}_t} \\ u_{\text{ball}_{t+1}} \\ u_{\text{player}_{t+1}} \\ \vdots \end{pmatrix}$$

Results ESFR





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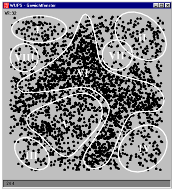
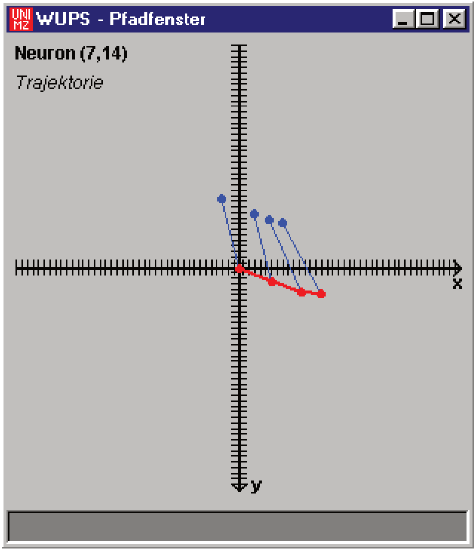


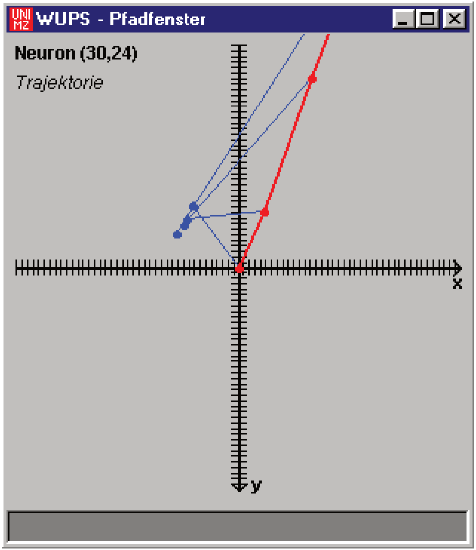
CMU 1999

I	pass to right side
II	pass forward
III	pass backward
IV	pass to left side
V	near-ball game
VI	Dribbling
VII	Dribbling
VIII	Dribbling

Results ESFR II (Details)



Results ESFR III (Details)



Intermediate Bottom Line

Observations

- analysis of micro-behavior by SOMs
- trajectory characteristics made visible and transparent
- implicit representations
- usefulness for particularly for reactive analysis

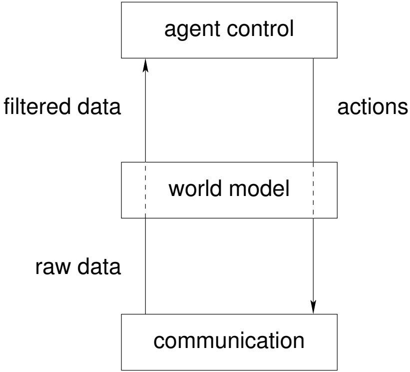
More to do

- higher level analysis of trajectories
- semantic analysis

Part III

Perception, Prediction and (Antagonistic) Action

World Model



- sensor values filtered via world model
- consistent view of past and future
- match between assumptions and observations to identify present

Ball Position Filtering

[Haker et al., 2002]

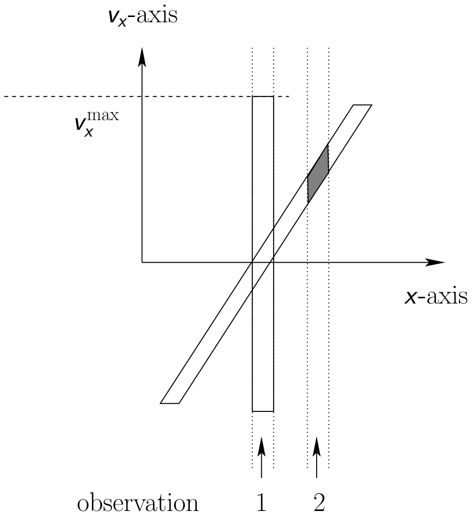
Simulator

state sensor data are noisified and quantized

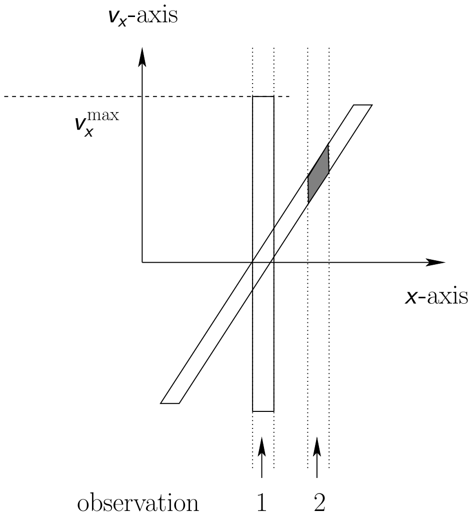
Filtering

- improvement of state information by
  - additional evidence
  - object movement
- related to particle filtering

Ball Position Filtering II



Ball Position Filtering II



However

- observing another agent introduces significantly more variation and unpredictability
- in fact: try to be as unpredictable as possible!

Example: Optimal Goal Scoring

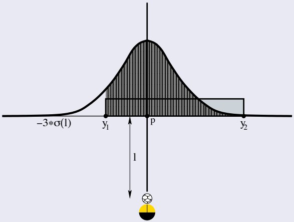
[Kok et al., 2002]

Task

- simplest example of an antagonistic RoboCup problem
- contains all basic ingredients relevant to the RoboCup scenario

Observations/Assumptions

- ball shot in straight direction will deviate by Gaussian with deviation $\sigma(d)$ after travelling d

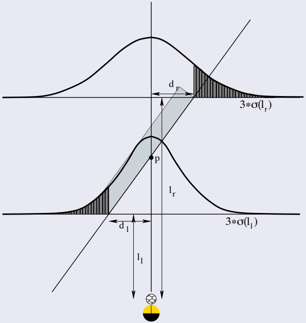


Example: Optimal Goal Scoring II

[Kok et al., 2002]

Observations

- probability of hitting goal can be computed via probability of missing it left and right

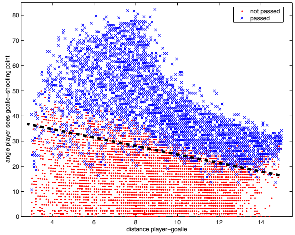


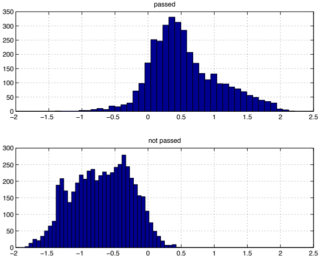
Goal Scoring

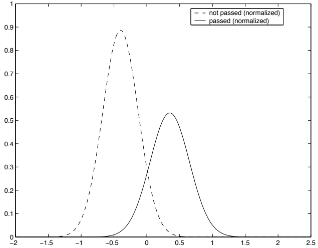
Scoring Success

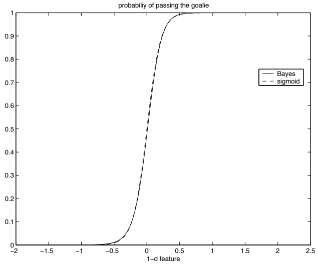
- use given goal keeper for generating tests
- classification problem:
  - given player/goalie positions
  - determine class (interception or not)
- record experiments of interception

parametrization: angle goalie/shooting point and distance player/goalie





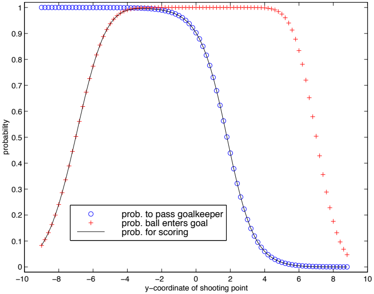


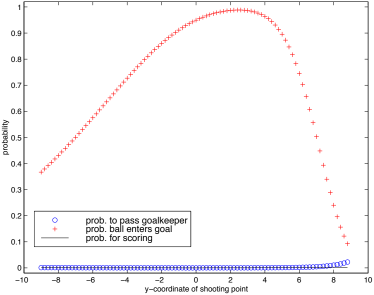


Goal Score Probability

Consider

- goal hitting and interception are independent
- unprotected versus well-defended goal





Part IV

Multiagent Strategies

Some General Principles

[Almeida et al., 2010]

Challenges

- simultaneous multimodal information: difficult to process
- unpredictable environment
- unreliable message reception
- low bandwidth limits conveyance of meaningful knowledge in messages
- uncertainty in perceived world information may lead to conflicting/inconsistent behaviours
  [Penders, 2001]

Concrete Problems

[Almeida et al., 2010]

Perception

- Where, when and how to use vision?
- Whom to listen to?
- How to estimate information of others?

Communication

- What, when and how to exchange information?
- How to use exchanged information?

Action

- Which action of player is best for the team?
- How to evaluate different types of actions (e.g. pass vs dribble)?
- How to execute a given elementary (e.g. kick) or compound action (e.g. dribble)?

Coordination

[Almeida et al., 2010]

Types

Ball-centered: react to ball velocity changes (e.g. after kick)

Active: consider target location of desired action (e.g. a pass to perform)

Strategic: consider strategic location (e.g. find open space for pass)

Global: locker-room agreements
[Stone, 2000]

Time Range

Approach	Usage Scope	Inf. Validity Period
ball-centered	individual	short
active	individual or collective	short to medium
strategic	collective	medium to long

Part V

Meditation: Limits on Cooperation

Principled Limits of Multiagent Coordination

[Harder et al., 2010]

Question

- What's the best two agents can do in terms of coordination?
- How does it compare to "two agents with one brain"?

Principled Limits of Multiagent Coordination

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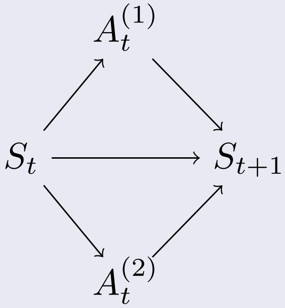
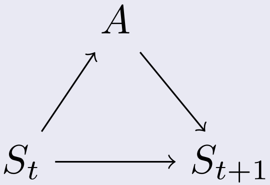
Separate Action Selection

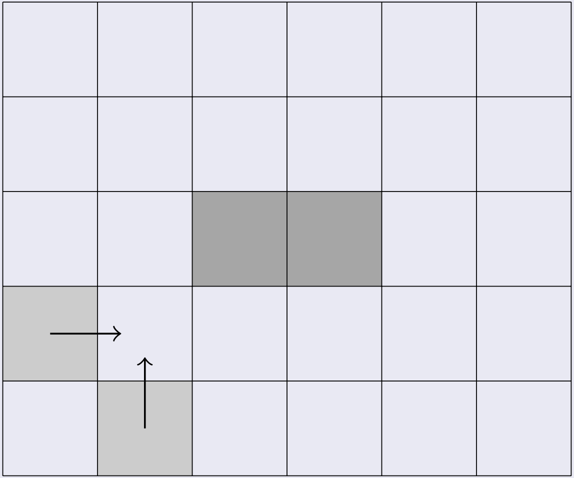


Shared Action Selection

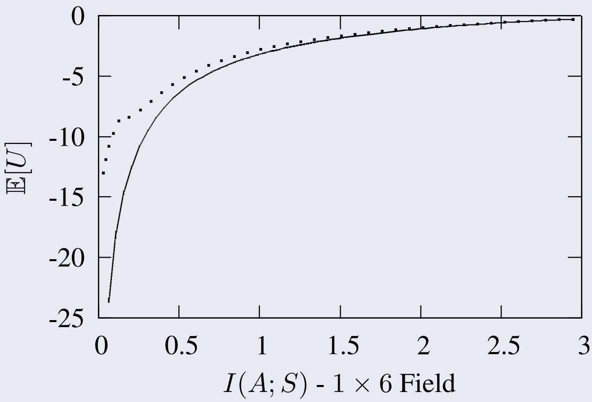


Two Agents: One Goal

Prototypical Scenario

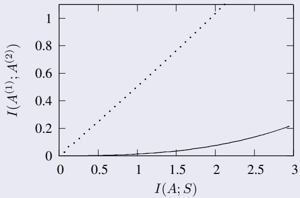


Utility vs. Relevant Information

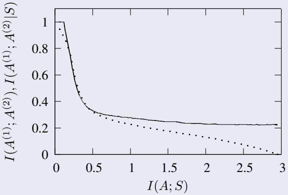


Shared vs. Individual Controllers

Individual Controllers



Shared Controllers



Bottom Line

- coordination $I(A^{(1)}; A^{(2)})$ distinguished by
- intrinsic coordination $I(A^{(1)}; A^{(2)}|S)$ vs.
- coordination via environment

Part VI

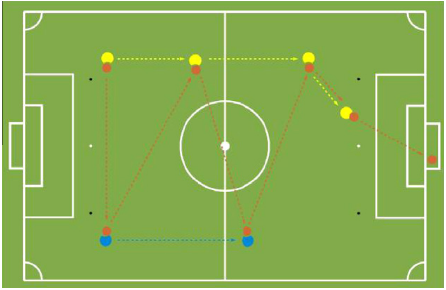
Tactics and Strategy: Case Studies

Tactics and Strategy: Passing

[Lau et al., 2011]

Pass Coordination

RolePasser	RoleReceiver
PassFlag TRYING_TO_PASS	
Align to receiver	Align to Passer
	PassFlag READY
Kick the ball	
PassFlag BALL_PASSED	
Move to next position	Catch ball

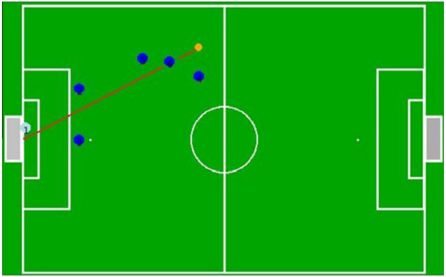


Tactics and Strategy: Goal Defense

[Lau et al., 2011]

Goal Defense

- line ball—goal
- **one player** on this line, as close as possible to ball
- **two players** near penalty area
- **one player** near ball, 45^o from above line to observe ball and report to teammates
- **one player** to oppose progression of ball through closest side of field



Optimization of Opponent Marking

[Kyrylov and Hou, 2007, Kyrylov and Hou, 2010]

Problem Description

Collaborative Defensive Positioning:

- multi-criteria assignment problem
- n defenders are assigned to m attackers
- each defender must mark at most one attacker
- each attacker must be marked by no more than one defender

Pareto Optimization:

- improve the usefulness of the assignments
- simultaneously minimizing required time
  - to execute an action and
  - prevent threat by an attacker

Optimization of Opponent Marking II

[Kyrylov and Hou, 2007, Kyrylov and Hou, 2010]

Parameters

- Angular size of own goal from the opponent's location
- Distance from the opponent's location to own goal;
- Distance between the ball and opponent's location

Optimization of Opponent Marking III

[Kyrylov and Hou, 2007, Kyrylov and Hou, 2010]

Criticisms

[Almeida et al., 2010]

Outnumbered Defenders:

- should not mark specific attackers
- should position themselves to prevent ball/attackers' progression towards goal's center

Outnumbered Attackers:

- more than one defender should mark attacker (e.g. ball owner)
- pursue strategy to quickly intercept the ball
- or compel the opponent to make bad decision/lose the ball

Bold Hearts Example

Formations

- different formations depending on game situations
- e.g. trying to get 2 players around ball

Coordination

- visual
- goalie decides roles according to freed positions and required roles
- crowding rules
- jitter suppression:
  - both go, one decides
  - reinforces decisions

Ball

- 1 or 2 positions fixed to the ball: supporting players
- field/ball equilibrium

Opponent Harassment

- predicting opponent's behaviour
- putting obstacles in opponent's plan

Passing

- dribble
- attack
- pass
- panic kick

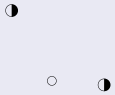
Part VII

Influence

Who gets the Ball?

Simplest Case

- both agents move immediately and with same speed



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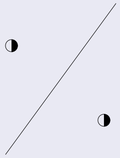

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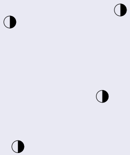

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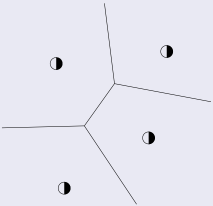


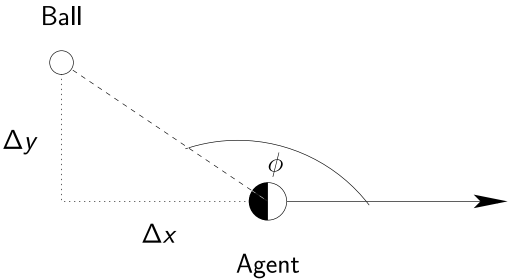
- Voronoi Cells/Delaunay Triangulation
  [Almeida et al., 2010, Prokopenko et al., 2012, Akiyama et al., 2013]

Turn to the ball

Task

Goal: turn to the ball and go there

Assume:
- agent looks along x-axis
- turning is elementary action in 2D simulator
  - of course, not in humanoids
  - (not necessary in PythoCup)



Getting to the Ball

Task

Goal: go to the ball

Assume: ball is not moving

Steps

1. assume we have angle ϕ
2. elementary turn by ϕ
3. move to the ball
4. **duration:**
   - d: distance
   - v: maximum velocity
   - $t = d/v$

Getting to the Ball

Task

Goal: go to the ball

Assume: ball is not moving

Steps

1. assume we have angle ϕ
2. elementary turn by ϕ
3. move to the ball
4. **duration:**
   - d: distance
   - v: maximum velocity
   - $t = d/v - \underbrace{1}_{\text{time for turning}}$

Getting to the Ball — Ball is Moving I

Task

Goal: go to the ball

Assume: ball is moving in given direction

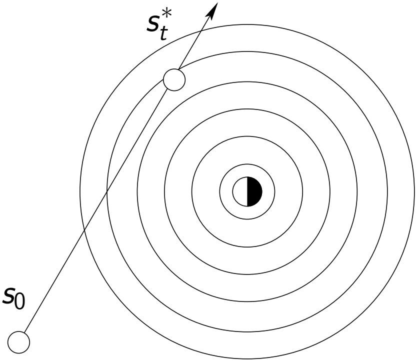
Approach

- movement of ball
- movement of agent
- could compute contact point directly

Getting to the Ball — Ball is Moving II

Steps

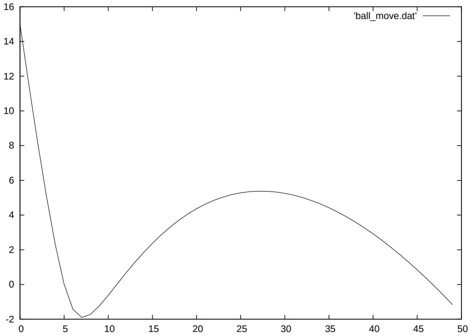
- however, easier to do step-wise
- consider circle of radius $d_t = v_{\text{player}} \cdot t$ for $t = 0, 1, 2, 3 \ldots$
- consider $s_t^* = s_0 + v_{\text{ball}} \cdot t$ for $t = 0, 1, 2, 3 \ldots$
- if $\|s_t^*\| \leq d_t$, agent can — in principle — catch ball at this position if agent moves in relevant direction



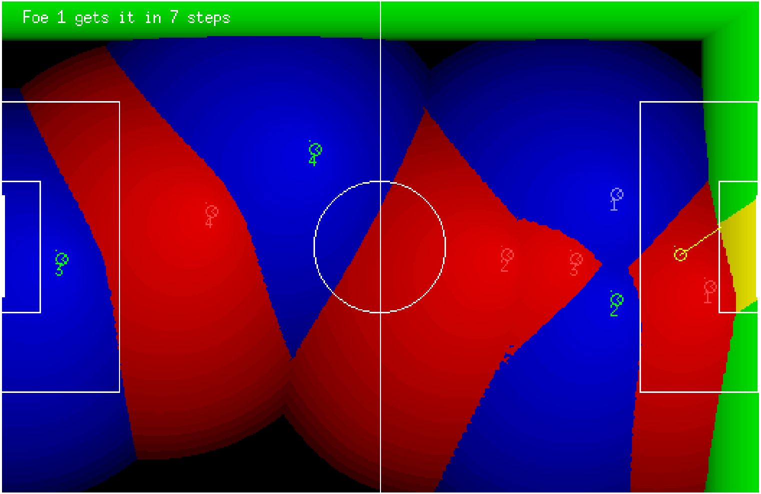
Getting to the Ball — Ball is Moving III

Notes

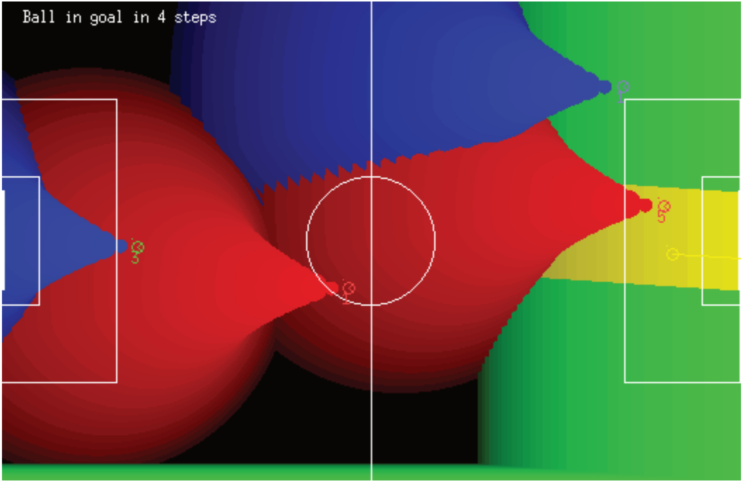
- allows handling of slowing-down ball
- allows handling of turn delay
- if ball fast, consider catch to fail
- may need to consider running after the ball, until slower



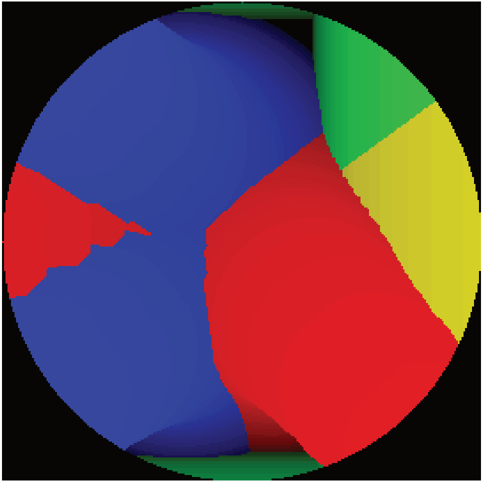
Influence Regions: "Grass-Chess"



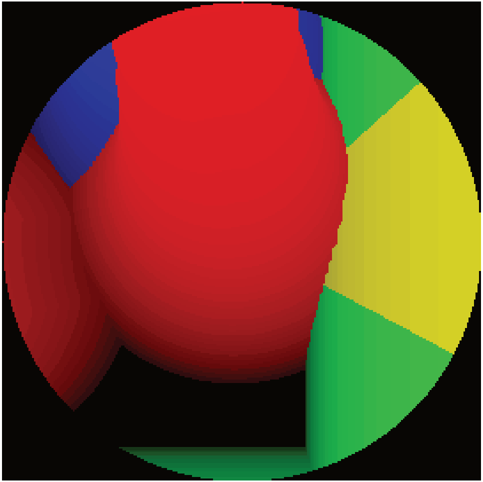
Influence Regions II: "Grass-Chess"



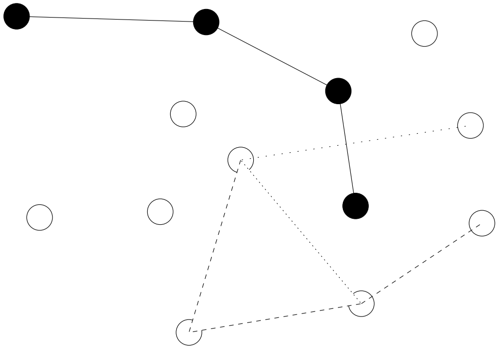
Example Insights III: “Grass-Chess”



Example Insights IV: “Grass-Chess”



Pass Optimization



Pass Value Iteration

$$V_i^{(n+1)} = \begin{cases} \max\limits_{j \in N(i)} \left(p_j V_j^{(n)} + (1 - p_j) V_{\hat{j}}^{(n)} \right) & \text{if } i \text{ friend} \\ \min\limits_{j \in N(i)} \left(p_j V_j^{(n)} + (1 - p_j) V_{\hat{j}}^{(n)} \right) & \text{if } i \text{ foe} \end{cases}$$

Part VIII

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