

# Task decomposition, dynamic role assignment and low-bandwidth communication for real-time strategic teamwork

Peter Stone, Manuela Veloso

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# Overview

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- PTS (periodic team synchronization)
- Methods
  - Teamwork structure
  - Communication paradigm
- RoboCup
- Results





# Periodic Team Synchronization

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- A team of robots works towards a goal
- Alternation of periods with limited (longer) and unlimited (shorter) communication
  - Unlimited: the robots plan strategies, exchange full information;
  - Limited: the robots work autonomously (but part as a team) to implement the agreed strategies.

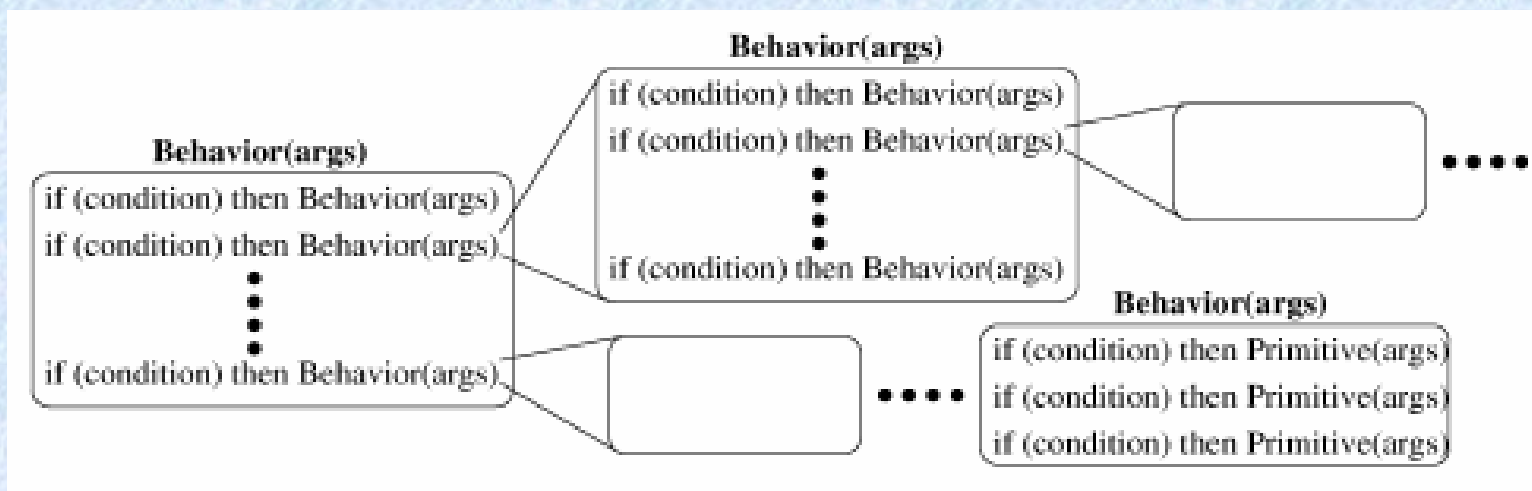
RoboCup: the robots can fully communicate before the game and at half time and plan strategies. They implement the strategies during play-time with minimum of communication.

# Methods - behaviors

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- Behavior = pair of condition action
- A behavior is actually a DAG (directed acyclic graph)
  - Internal behavior: if condition then ... update the internal state
  - External behavior: if condition then ... act in the real world





# Methods – locker room agreements

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- Locker-room agreements
  - Set in the full communication period
  - Defines the teamwork structure and communication protocols:
    - Roles
    - Formations
    - Set plays

RoboCup: define what a defender is; what robot will play defense; the team-layout in the beginning should be (4-4-2); if the team leads by two goals the team-layout should be changed to (8-2-0); what to do in case of a corner kick;



# Methods - roles

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- Role = the specification of an agents internal and external behaviors (a sub-task of the problem that needs to be solved)
  - rigid: the agent must perform the actions exactly
  - flexible: the agent accomplishes the goals within some limits
  - robots are not rigidly assigned to roles; homogeneous robots can switch between roles



RoboCup: a role is the position in the field (midfielder).



# Methods - formations

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- Formation: a set of roles that achieves the global goal.
  - Roles and formations are independent from the agents that need to fill them
  - Formations can be changed dynamically at run-time.
  - There can also be units: small groups of roles assigned to sub-tasks
  - Because of lack of communication there it is desired but not guaranteed that all robots execute the same formation

RoboCup: a formation is the configuration of the 11 players involved in the game: where each player should be and what its tasks are. Formations can be changed during the game depending on the score to make the team more offensive or defensive.



# Methods – set-plays

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- Set-plays: short-term plans that deal with situations that occur repeatedly
  - Have a trigger condition
  - Have set-play roles
  - Have a termination condition
  - There is a function that maps general roles to set-play roles (the function is defined in the locker room agreement)

RoboCup: corner kicks, central kicks, side kicks.



# Methods - communication

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- Environment:
  - multiple agents transmit simultaneously
  - single channel – agents “talk” on single line
  - low-bandwidth
  - unreliable communication: messages can be delayed or not delivered at all



# Methods - communication

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- Challenges:
  - single channel introduces the need of identifying the source and target of a message
  - hostile agents could mimic messages heard at previous times
  - because of low bandwidth: the agents have to avoid talking all at once
  - unreliable: agents must be robust to lost messages
  - teams must maximize the chances that all agents use the same formation



# Methods - Communication

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- Message Fields:
  - Team identifier (target identification)
  - Member ID (target identification)
  - Encoded Time Stamp (hostile agents)
  - Time Samped Team Strategy (formation synchronization)
  - Selected Internal State (formation synchronization)
  - Message Type
    - targeted messages vs. broadcast messages
    - Response messages vs. no-response messages
  - Message Data
  - Target (target identification)



# Methods - Communication

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- Challenges:
  - single-channel introduces the need of identifying the source and target of a message
  - Hostile agents could mimic messages heard at previous times
  - **Because of low-bandwidth: the agents have to avoid talking all at once**
    - If the robot is the only target it responds immediately
    - If there are multiple targets the robot responds after a delay-time that is dependent on its identification number (thus, no two robots respond at the same time)
  - **Unreliable: agents must be robust to lost messages**
    - Nothing bad happens if a message is not received; the robots still act as planned; communication can only improve the behaviors
  - Teams must maximize the chances that all agents use the same formation



# Application to RoboCup

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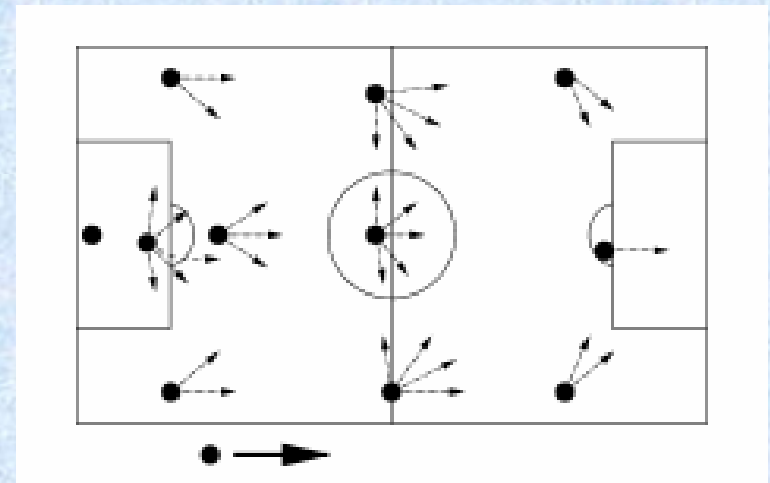
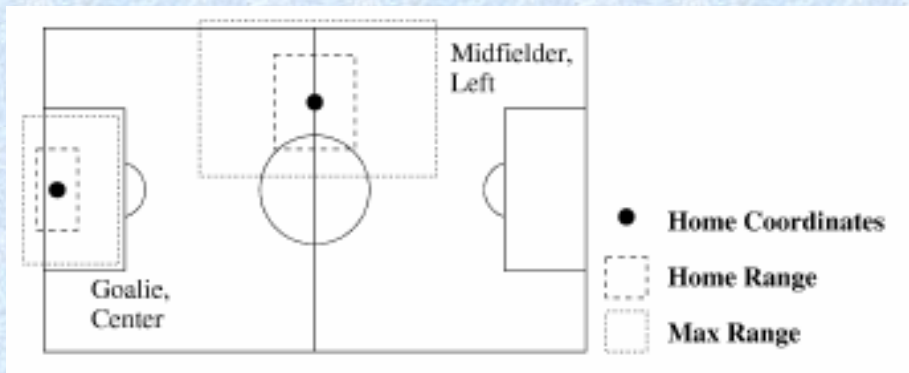
- 2 RoboCup environments:
  - soccer server simulator: the rigorous experimental analysis and the Robocup97 competition
  - real robot RoboCup





# Application to RoboCup

- Role: position in the field, home range, maximum range
- Formation: defines roles and inter-role interactions (passing preferences)
  - Units are: defenders, midfielders, forwards, center players, left and right players





# Application to RoboCup

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- Features:
  - Dynamic switching of formations (defensive, offensive)
  - Positioning flexibility: agents can change roles and they can move within a predefined range
  - Pre-planned set-plays: goal kick, center kick, corner kick etc (triggered by referee)

# Results

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- evaluate flexible positioning, set plays and changeable formations against a “default team” with rigid positions and no set play (behaviors of players in the teams are otherwise identical).
- They also evaluate the communication paradigm
  - Robots ignore fake messages
  - Handle multiple responses well
  - A change in formation is propagated well through the team
- Their system won third place in the RoboCup-97 simulator competition and first place in the real robots competition



# Results

Results when a flexible team plays against a rigid team. The flexible team won 34 out of 38 games with 3 ties

(Game = 10 min.)	Flexible and set-plays	Default
Games won	34	1
Total goals	223	82
Avg. goals	5.87	2.16
Ball in own half	43.8%	56.2%

Results when only using flexible positions and only using set-plays. Each individually works better than using neither

Only flexible positions			Only set-plays		
(Game = 10 min.)	Flexible	Default	(Game = 10 min.)	Set-plays	Default
Games won	26	6	Games won	28	5
Total goals	157	87	Total goals	187	108
Avg. goals	4.13	2.29	Avg. goals	4.92	2.84
Ball in own half	44.1%	55.9%	Ball in own half	47.6%	52.4%

Comparison of the different formations. Entries in the table show the number of goals scored. Total (and percentage) cumulative goals scored against all formations appear in the right-most column

Formations	4-3-3	4-4-2	3-5-2	8-2-0	3-3-4	2-4-4	Totals
4-3-3		68-60	68-54	24-28	59-64	70-65	289-271 (51.6%)
4-4-2	60-68		68-46	22-24	51-57	81-50	282-245 (53.5%)
3-5-2	54-68	46-68		13-32	61-72	75-73	249-313 (44.3%)
8-2-0	28-24	24-22	32-13		27-28	45-36	156-96 (61.9%)
3-3-4	64-59	57-51	72-61	28-27		87-69	308-267 (53.6%)
2-4-4	65-70	50-81	73-75	36-45	69-87		293-385 (43.2%)