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

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Overview

• **PTS** (periodic team synchronization)
• **Methods**
  – Teamwork structure
  – Communication paradigm
• **RoboCup**
• **Results**
Periodic Team Synchronization

• 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

- 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

• 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

- Role = the specification of an agent's 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

- 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

- 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

- 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

- 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

- **Message Fields:**
  - Team identifier (target identification)
  - Member ID (target identification)
  - Encoded Timestamp (hostile agents)
  - TimeStamped 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

• 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

• 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

• 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

• 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

The table below presents the results of a flexible team playing against a rigid team. The flexible team won 34 out of 38 games with 3 ties. The table also shows the comparison between only using flexible positions, only using set-plays, and a default strategy.

| 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.

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