Multi-Robot Intelligence: Flexible Strategy for Robotic Teams

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Presentation Outline

• Artificial Intelligence and Robotics

• RoboCup and Our Teams
  – RoboCup Challenges
  – RoboCup Leagues: Simulation (2D, 3D, MR, Rescue), SSL, MSL and SPL
  – Portuguese Teams: FCPortugal, 5DPO, Cambada and PT Team

• Flexible Strategy for Robotic Teams
  – Strategy: Strategic Reasoning and Coaching
  – Formations: SBSP - Situation based Strategic Positioning
  – DPRE – Dynamic Positioning and Role Exchange
  – SetPlays and Graphical Setplay Definition

• Applications and other Projects at LIACC
  – Agent Based Simulation: EcoSimNet, FlightSimNet
  – Educational/Assistive Robotics: Intellwheels, Robot Dancing
  – Strategic Reasoning: Poker Agents
  – Real Sports: Soccer, Indoor Sports (Handball)

• Conclusions and Future Work
Artificial Intelligence

• Intelligence
  – “Capacity to solve new problems through the use of knowledge”

• Artificial Intelligence
  – “Science concerned with building intelligent machines, that is, machines that perform tasks that when performed by humans require intelligence”
# Autonomous Agents and Multi-Agent Systems

- **Agent Traditional Definition:**
  “Computational System, situated in a given **environment**, that has the ability to **perceive** that environment using **sensors** and **act**, in an **autonomous way**, in that environment using its **actuators** to fulfill a given **function**.”

- **Multi-Agent System:**
  - Agents exhibit **autonomous behavior**
  - **Interact** with other agents in the system

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Agents and Multi-Agent Systems

• To build individual autonomous intelligent agents is important, however:
  – Agents don’t live alone... Necessary to work in group...
  – Multi-Agent Applications...

Coordination: “to work in harmony in a group”

– Dependencies in agent actions
– Need to respect global constraints
– No agent, individually has enough resources, information or capacity to execute the task or solve the complete problem

– Efficiency: Information exchange or tasks division
– Prevent anarchy and chaos: Partial vision, lack of authority, conflicts, agent’s interactions
Intelligent Robotics

• Robotics
  – Science and technology for **projecting, building, programming and using Robots**
  – Study of **Robotic Agents (with body)**
  – Increased Complexity:
    • **Environments**: Dynamic, Inaccessible, Continuous and Non Deterministic!
    • Perception: Vision, **Sensor Fusion**
    • Action: Robot Control (humanoids!)
    • Robot Architecture (Physical / Control)
    • Navigation in unknown environments
    • **Interaction** with other robots/humans
    • Multi-Robot Systems
Current State of Robotics

- **Used to Perform:**
  - Dangerous or difficult **tasks** to be performed directly by humans
  - Repetitive tasks that may be performed more efficiently (or cheap) than when performed by humans

- **Robots have moved from manufacturing, industrial applications to:**
  - Domestic robots (Pets – AIBO, vacuum cleaners)
  - Entertainment robots (social robots)
  - Medical and **personal service** robots
  - Military and surveillance robots
  - Educational robots
  - Intelligent buildings
  - Intelligent vehicles (cars, submarines, airplanes)
  - Other industrial applications (mining, fishing, agriculture)
  - Hazardous applications (space exploration, military apps, toxic cleanup, construction, underwater apps)
  - Multi-Robot Applications and Human-Robot Teams!
Agent-Based Simulation

• **Simulation**: Imitation of some real thing, state of affairs, or process, over **time**, representing certain key characteristics or behaviours of the physical or abstract system

• Applications:
  – Understand system **functioning**
  – **Performance optimization**
  – Testing and validation
  – **Decision making**
  – Training and education

• **Applied to complex systems impossible to solve mathematically**

• **Traditional Simulation Drawbacks:**
  – Systems are getting more complex and are difficult to model as a whole
  – Higher level tools available
  – Human behaviour is often neglected or over simplified

• **Agent Based Modeling and Simulation:**
  – Entities represented by Agents with Autonomous Behaviour
Robotic Competitions

- RoboCup – Robotic Soccer
- Robotic Soccer FIRA
- DARPA Grand-Challenge
- Intelligent Ground Vehicle Competition
- European Land Robot Trial
- IEEE MicroMouse competition
- AAAI Grand Challenges
- First Competition (Lego-League)
- RoboGames (former RoboOlympics)
- Manitoba Robot Games
- Robotic Fight: BattleBots, RobotWars, RobotSumo
- Underwater and aerial Robot Competitions
- ...
- Some Portuguese Competitions:
  - Portuguese Robotics Open (including autonomous driving)
  - Micro-Mouse/Ciber-Mouse
  - Firefighting Robots
Robotic Competitions - RoboGames

• Videos
Robotic Competitions - RoboCup

• videos
Robotic Competitions

• **Benefits**
  - Research inspiration
  - Hard deadline for creating fully functional system
  - Common platform/problem for exchanging research ideas/solutions
  - Continually improving solutions
  - Excitement for students/researchers at all levels
  - Large number of teams/solutions created
  - Encouragement for flexible software/hardware

• **Dangers**
  - Obsession with winning
  - Domain dependent/hacked solutions
  - Cost escalation
  - Difficulty in entering at competitive level
  - Restrictive rules
  - Invalid evaluation conclusions

*based on Peter Stone, 2002*
Research Question

How to Coordinate heterogeneous Multi-Robot Teams executing flexible tasks in a dynamic, adversarial environment?
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• Flexible Strategy for Robotic Teams

• Application in other Projects s at LIACC

• Conclusions and Future Work
RoboCup: Objectives

- Joint International Project:
  - (Distributed) Artificial Intelligence
  - Intelligent Robotics

- Soccer – Central Research Topic:
  - Very complex collective game
  - Huge amount of technologies involved:
    - Autonomous Agents, Multi-Agent/Multi-Robot Systems, Cooperation, Communication, Strategic Reasoning, Robotics, Sensor Fusion, Real-Time Reasoning, Machine Learning, etc

Main Goal of the RoboCup Initiative:

“By 2050, develop a team of fully autonomous humanoid robots that may win against the human world champion team in soccer!”
RoboCup: Official Competitions

- 1997 – Nagoya (Japan)
- 1998 – Paris (France)
- 1999 – Stockholm (Sweden)
- 2000 – Melbourne (Australia)
- 2001 – Seattle (USA)
- 2002 – Fukuoka (Japan)
- 2003 – Padua (Italy)
- 2004 – Lisbon (Portugal)

- 2005 – Osaka (Japan)
- 2006 – Bremen (Germany)
- 2007 – Atlanta (USA)
- 2008 – Suzuhu (China)
- 2009 – Graz (Austria)
- 2010 – Singapore (Singapore)
- 2011 – Istanbul (Turkey)
- 2012 – Mexico City (Mexico)

Local Championships:
- German Open (European)
- Japanese Open
- Australian Open
- American Open
- Portuguese Open
- Iranian Open, AutCup
- China Open
RoboCup - Participants

- Participant/AWARDED
  - Germany
  - USA
  - Japan
  - Iran
  - China
  - Australia
  - Portugal
  - Holland
RoboCup: Global Perspective

• Soccer Leagues
  – Simulation: Sim2D, Sim3D (Humanoids), Coach, MR League
  – Robots Small-Size
  – Robots Middle-Size
  – Standard Platform (Aibo; NAO)
  – Humanoid Robots

• RoboCup Rescue
  – Simulation, Virtual, Robotic

• RoboCup Júnior

• RoboCup@Home
RoboCup: Global Perspective

• Videos
RoboCup Leagues: Simulation 2D

- Virtual Robots
- 105*68m Virtual Field
- Agents controlled by different computers (or processes)
- Simulator sends perception and receives actions from agents
- Teams of 11 players plus a coach
RoboCup Leagues: Simulation 2D

• How the Simulator Works?
  – Client-Server System
  – Agents (player’s brains) control a single player:
    • UDP sockets/Linux
  – Server:
    • Receives agent commands
    • Simulates the movement of objects
    • Sends perceptions to the agents
  – Two teams with 11 players + coach, try to score goals!
RoboCup Leagues: Simulation 2D

- **Simulation Characteristics**
  - Real-Time - Human
  - Distributed – 24 Processes
  - Inaccessible (hidden), Continuous and Dynamic World
  - Errors in: Perception, Movement and Action
  - Limited Resources: Energy and Recovery
  - Limited Communication
  - Multi-Objective, Cooperative and Adverse Environment
RoboCup Leagues: Simulation 2D

- Videos:
  - 1997: League Start -> Simple Play
  - 1998: Simple Passing and Good Individual skills
  - 2000: Formations and Soccer like Playing
RoboCup Leagues: Simulation 3D

- Third dimension adds complexity
- Complexities from real robots
- **Realistic physics**
- **Robot Models:**
  - Started with sphere model in 2004
  - Humanoids started in 2007
  - NAO Robot Model: 2008
- **Strong relation with SPL**
- 6 vs 6 games -> 9 vs 9 -> 11 vs 11?
- Heterogeneous Robots?
- Very difficult to create competitive skills by hand!
Humanoid Robot - Simspark

- Server (*SimSpark*)
- Manages the simulation process
- Updates world state
- Enforces soccer rules - *referee*
- Forces the “*laws of physics*” on objects:
  - collisions, drag, gravity, ...
- Agent connections, updating sensor information (*perceptors*) and executing actions (*effectors*)
- Monitor and Logplayer
Simulation 3D – Spheres model

- 2004-2005: Very Basic playing!
- 2006: Formations/High-level playing!

Videos
Simulation 3D – Humanoid model

- 2007-2010: Very Basic playing!
- 2011: Formations/High-level playing!

Videos
Simulation 3D – Nao model
Middle Size League

- Robots are completely autonomous
- 5 robots per team
- Robots around 50x50cm and 80cm height
- Field 18mx12m, green with white lines
- MSL rules based on official FIFA laws
Middle Size League

- 2008: Formations SBSP/High-level playing/Setplays!
- Videos
Flexible Strategy for RoboCup

- RoboCup Leagues: Simulation 2D, Simulation 3D, Small-Size, Middle-Size, SPL and Search and Rescue

- Applications in four distinct teams:
  - FC Portugal (University of Porto/Aveiro/Minho)
    - Simulation 2D, Simulation 3D, Coach, MR, Rescue, SPL
  - CAMBADA (University of Aveiro) – Prof. Nuno Lau
    - Middle-Size League, RoboCup@Home
  - 5DPO (University of Porto) – Prof. A.P.Moreira
    - Small-Size League, Middle-Size League
  - Portuguese Team (University of Porto/Aveiro/Minho)
    - SPL – Standard Platform League

- More than 30 awards in International Competitions for these 4 Teams!
Our Teams: University of Porto/Aveiro

- **Simulation 2D: FC Portugal**
  - Best: Winners RoboCup 2000,
  - Winners Euro 2000, Euro 2001

- **Simulation 3D: FC Portugal**
  - Best: Winner RoboCup 2006,

- **Simulation – Coach: FC Portugal**
  - Best: Winner RoboCup 2002,
  - 2\textsuperscript{nd} RoboCup 2003, 2004

- **Simulation – MR League: FC Portugal**
  - Best: 2\textsuperscript{nd} RoboCup 2007

- **Rescue Simulation: FC Portugal**
  - Best: Winner Euro 2006
Our Teams: University of Porto/Aveiro

- **Middle-Size: CAMBADA (Univ.Aveiro)**
  - Best: Winners RoboCup 2008
- **Small-Size: 5DPO (Univ.Porto)**
  - Best: 2nd RoboCup 2006,
- **Middle-Size: 5DPO (Univ.Porto)**
  - Best: 3rd Euro 2001
- **Standard Platform (Aibo): FC Portugal/FC Portus**
  - Best: 5th RoboCup 2003
- **Standard Platform (NAO): Portuguese Team**
  - Best: Starting in 2011
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  - Strategy: Strategic Reasoning and Coaching
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- Conclusions and Future Work
The Coordination Problem

- Coordinate autonomous robots decisions to carry out team tasks as efficiently as possible
- Coordination challenges
  - Strategy
  - Role assignment
  - Formation
  - Plan execution
  - Communication
Flexible Strategy for Robotic Teams

• Common Framework for Cooperative Robotics:
  • Strategical Coordination and Coaching
  • SBSP – Situation Based Strategic Positioning
  • DPRE – Dynamic Position and Role Exchange
  • SetPlay Framework and Graphical Definition
  • Generic Optimizer of Skills/Decisions
  • Bridging the Gap Between Simulation and Robotics
Formalization of a Team Strategy

- **Strategic Behaviors**
- **Ball Possession Behaviors**
- **Ball Recovery Behaviors**

**Player Types**
- PT1
- PT2
- PT3
- PT4
- PT5
- PT6
- PT7
- PT8
- PT9

**Tactics**
- T1
- T2
- T3
- T4
- T5
- T6

**Formations**
- F1a - 433 Open
- F1b - 433 Closed
- F3a - 442 Normal
- F3b - 442 Normal

**Positionings**

**Situations**
- S1 - Attack
- S2 - Defend
- S3 - Defense to Attack
- S4 - Attack to Defense
- S5 - Our Goalie Free Kick
- S6 - Their Goalie Free Kick
- S7 - Scoring Chance

**Tactics**
- Tactic 1 - 433 Open vs Closed Positional
- Tactic 3 - 442 Agressive
Coaching

- Game Statistics and Opponent Modeling Information
- Time and Result
- Individual Action: Active/Passive (with/without ball)
- Transitions (Ball losses and Ball recoveries)
- Attacks and Assistances
- Ball Possession
- By:
  - Period
  - Region (from and to)
  - Team
  - Player
  - etc.

Diagram:

- Assistant Coach
- Coach
- Game Statistics
- Principal Coach
- Field Information
- Field
- Actions
- Definitions
- Instructions
- Players
Coach Unilang

• Base Concepts:
  – Time Periods, Regions, Tactics, Formations, Situations, Player Types
• Language Defined in BNF
• Examples:

\[
\text{<MESSAGE>} ::= (\text{<TIME>} \text{<ID>} \text{<MESSAGE PART>} \{\text{<MESSAGE PART>}}))
\]
\[
\text{<MESSAGE PART>} ::= \text{<DEFINITION_MESS>} \vert \text{<STATISTICS_MESS>} \vert \text{<OPP_MOD_MESS>} \vert \text{<INSTRUCTION_MESS>}
\]

\[
\text{TACTIC_DEFINITION} ::= \text{<TEAM_MENTALITY>} \text{<GAME_PACE>} \text{<TEAM_PRESSURE>} \text{<FIELD_USE>}
\]
\[
\text{<PLAYER_POSITIONING>} ::= \text{<VERTICAL_POSITIONING>} \text{<HORIZONTAL_POSITIONING>}
\]

\[
\text{<FORMATION>} ::= \text{<PREDEFINED_FORMATION>} \text{<FORMATION_NAME>} \vert \text{<FORMATION_DEFINITION>}
\]
\[
\text{<PREDEFINED_FORMATION>} ::= 433 \mid 433\text{att} \mid 442 \mid 343 \mid 4123 \mid 352 \ldots
\]
\[
\text{<FORMATION_DEFINITION>} ::= \{(\text{<PLAYER>} \text{<POS_NUMBER>} \text{<PLAYER_POSITIONING>} \text{<PLAYER_TYPE>})\}
\]
\[
\text{<PLAYER_POSITIONING>} ::= \text{<VERTICAL_POSITIONING>} \text{<HORIZONTAL_POSITIONING>}
\]
Formations in Robotic Soccer

• Formations are one of the essential concepts in multi-robot strategies:
  • Provide a coordination framework: tasks/role assignment
  • Real impact on team performance
  • Can/should be adapted to team and opponent capabilities
  • Provide a common concept with military units coordinated movements or real soccer formations
Formation Models

• Role based models
  • Ex: Striker, Supporter, Defender, Goalie

• SPAR – Strategic Positioning with Attraction and Repulsion
  • Locker-Room agreement

• SBSP – Situation Based Strategic Positioning
  • Distinction between active and passive situations
  • Distinct team movements for different situations
  • Strategic position based on global information (such as current ball position) keeps the team in the selected formation

• SBSP/DT – Situation Based SP with Delaunay Triangulation
  • Added flexibility in the definition of positionings
SBSP - Situation Based Strategic Positioning

- Strategic Situation: SBSP – Strategic Positioning
- Active Situation (with/without Ball): Active Behavior
- Definition based on: Situation and Shared info (Ball Position)
SBSP vs SPAR
SBSP with Delaunay Triangulation
DPRE - Dynamic Positioning and Role Exchange

ALGORITHM DynamicPositioningExchange(WorldState, Situation, Positionings)
RETURNS Positionings(TeamSize)
PARAMETERS WorldState, Positionings[TeamSize], Situation

{ FOR PL1 = 2 TO TeamSize-1 DO
  FOR PL2 = PL1+1 TO TeamSize DO
    IF PositionValid(PL1) AND PositionValid(PL2) THEN
      { Dist11 = Distance(Position(PL1),SBSPPosition(PL1))
        Dist22 = Distance(Position(PL2),SBSPPosition(PL2))
        Dist12 = Distance(Position(PL1),SBSPPosition(PL2))
        Dist21 = Distance(Position(PL2),SBSPPosition(PL1))
        Adeq11 = PosAdequacy(PL1, Positioning[PL1])
        Adeq22 = PosAdequacy(PL2, Positioning[PL2])
        Adeq12 = PosAdequacy(PL1, Positioning[PL2])
        Adeq21 = PosAdequacy(PL2, Positioning[PL1])
        Util = ExchangePositions(DPREMode, Situation, Dist11, Dist22, Dist12, Dist21,
                                   Adeq11, Adeq22, Adeq12, Adeq21, PosImportance(Positioning[PL1]),
                                   PosImportance(Positioning[[P][2]]))
        IF Util > ThresUtil(Situation) THEN exchange(Positionings[PL1], Positionings[PL2])  }
  RETURN Positionings
}
Flexible Strategy for Robotic Teams

STWorldState <- FillInWSforStrategy();
Actions <- CallStrategy(STWorldState);
ExecuteActions(Actions);

Simple Example (from FCPortugal 3D):

void FCPAgentH::FillInWSforStrategy() {
    WorldState& world = SWorldState::getInstance();
    strategy->WS_GameTime = world.gTime;
    strategy->WS_Result = world.game->ourGoals - world.game->opponentGoals;
    strategy->WS_BallPos = world.ball->position.to2d(); /
    strategy->WS_BallOwner = world->ball_owner;
    strategy->WS_BallIntPos = world.ball->finalPos.to2d();
    strategy->WS_MyNumber = world.me->unum;
    strategy->WS_MyDir = world.me->orientation;
    for (int t = 1; t <= strategy->ST_NUM_PLAYERS; t++) {
        strategy->WS_TeamPos[t] = world.getFCPortugalPlayer(t)->position.to2d();
        strategy->WS_TeamPos[t] = Vector((float) t,-strategy->ST_FieldSize.y - 0.3);
        strategy->WS_OppPos[t] = world.getOpponentPlayer(t)->position.to2d();
        strategy->WS_OppPos[t] = Vector((float) t, -strategy->ST_FieldSize.y - 0.3);
        strategy->WS_TeamConf[t] = world.getFCPortugalPlayer(t)->conf;
        strategy->WS_OppConf[t] = world.getOpponentPlayer(t)->conf;
    }
    strategy->WS_PlayMode = world.game->playmode;
}
Setplays: Concept and Definition

Simple, pre-defined but flexible plans, which describe cooperation and coordination between agents/robots

• Defined before the game by a **domain expert** and easy to define and change
• **Human readable language** (high abstraction level)
• Selected, Instantiated and executed at run-time (text file)
Setplay Definition

- (setplay :name simpleCorner
  - :players (list (playerRole :roleName CornerP)
    - (playerRole :roleName receiver) (playerRole :roleName shooter))
  - :steps (seq (step :id 0 :waitTime 15 :abortTime 70
    - :participants
      - (list (at CornerP (pt :x 52 :y 34))
        - (at receiver (pt :x 40 :y 25)) (at shooter (pt :x 36 :y 2)))
    - :condition (playm fk_our)
    - :leadPlayer CornerP
    - :transitions (list
      - (nextStep :id 1 :condition (canPassPl :from CornerP :to receiver)
        - :directives (list
          - (do :players CornerP :actions (bto :players receiver))
          - (do :players receiver :actions (receivePass))))))))
Setplay Definition

- (step :id 1 :waitTime 5 :abortTime 70
  :participants (list (at CornerP (pt :x 52 :y 34)) (at receiver (pt :x 40 :y 25))
  - (at shooter (pt :x 36 :y 2))
  :condition (and (bowner :players receiver) (playm play_on)) :leadPlayer receiver
  :transitions (list
  - (nextStep :id 2
    :condition (canPassPl :from receiver :to shooter)
    :directives (list
      - (do :players receiver :actions (bto :players shooter))
      - (do :players shooter :actions (receivePass))))))

- (step :id 2 :abortTime 70
  :participants (list (at CornerP (pt :x 52 :y 34)) (at receiver (pt :x 40 :y 25)) (at shooter (pt :x 36 :y 2))
  :condition (and (bowner :players shooter) (playm play_on) )
  :leadPlayer shooter :transitions (list
  - (nextStep :id 3 :condition (canShoot :players shooter)
  - :directives (list
  - (do :players shooter :actions (shoot)))))

AI and Robotics | RoboCup and Our Teams | Flexible Strategy for Robotic Teams | Applications and Projects | Conclusions
Setplays - Structure

**SetPlay**
- name: String
  - abortCond: String
  - condition: Condition
  - step: Step
  - next: NextStep
  - action: Action
  - directive: Directive
  - parameter: Parameter

**Condition**
- id: NonNegInt
- waitTime: Milliseconds
- abortTime: Milliseconds

**Step**
- id: NonNegInt
- waitTime: Milliseconds
- abortTime: Milliseconds
- next: NextStep
- transition: Transition
- priority: Decimal

**Transition**
- priority: Decimal

**NextStep**
- priority: Decimal

**Action**
- do: Do
- dont: Dont

**Directive**

**Parameter**
- name: String

**Variable**
- value: Value
  - playerRole: PlayerRole
  - variable: Variable
  - varRegion: VarRegion
  - region: Region

**PlayerRole**
- roleName: String

**VarRegion**
- region: Region

**Region**

**Value**
- integer: Integer
- decimal: Decimal

**PlayerReference**
- player: Player
- at: At

**Player**
- team: String
- number: PosInt
Conditions

- **PlayMode**
- **BallPossession**
- **Position**
  - `min::PosInt`
  - `max::PosInt`
- **Condition**
  - `confirmable::Boolean`
- **Region**
- **PlayerReference**
  - `1..*`
  - `to`
- **ClearPassToRegion**
  - `1` from
  - `to`
- **ClearPassToPlayer**
- **ClearShotAtGoal**
- **And**
- **Or**
- **Not**

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Actions

- ActionSequence
- Shoot
- Hold
- Intercept
- MarkRegion
- Forward
- Position
- Home
- Clear
- Dribble

- MarkPlayer
- Pass

- PlayerReference
- MarkLineTo
- Tackle

- Action

- Region

1..* to
1
2..* to
1
Usage/Interest of Setplay Library

- Setplay Definition/Graphical application
- Implement Conditions and Actions
- Deal with low level Communication
- Decide Setplay start, eventually CBR/ML
- Great flexibility: Application to all RoboCup leagues:
  - Simulation 2D, Simulation 3D, Middle Size, MR League, SPL)
Setplays: Graphical Definition

- Formal Definition (Setplay framework)
- Import
- Export
- Test
- Debug
- Adjust

RCSSMonitor 14.0.1

FCPortugal Debug LogPlayer

RCSSLogPlayer included on SPlanner

SPlanner

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Setplays: Graphical Definition
SetPlays in the Simulation 2D League
Setplays in the MSL

Passes

- Essential for teamplay
- 3 phases
  - Preparation/Alignment
  - Pass
  - Catch ball
- Used by CAMBADA in
  - Playoff
  - Free Challenge 2008
  - Also on Playon!

<table>
<thead>
<tr>
<th>RolePasser</th>
<th>RoleReceiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>PassFlag ← TRYING_TO_PASS</td>
<td></td>
</tr>
<tr>
<td>Align to receiver</td>
<td>Align to Passer</td>
</tr>
<tr>
<td></td>
<td>PassFlag ← READY</td>
</tr>
<tr>
<td>Kick the ball</td>
<td></td>
</tr>
<tr>
<td>PassFlag ← BALL_PASSED</td>
<td></td>
</tr>
<tr>
<td>Move to next position</td>
<td>Catch ball</td>
</tr>
</tbody>
</table>

![Diagram of setplay positions]
Setplays

Videos
Selected Results: FC Portugal

Competition Results:

2000
- 1st place in the 2D Simulation League, European 2000
- **1st place** in the **2D Simulation League, RoboCup 2000**

2001
- 3rd place in the 2D Simulation League, RoboCup 2001
- 1st place in the 2D Simulation League, European (GO) 2001

2002
- **1st place** in the **Coach Competition, RoboCup 2002**

2003
- 2nd place in the Coach Competition, RoboCup 2003

2004
- 2nd place in the Coach Competition, RoboCup 2004

2006
- **1st place** in the **3D Simulation League, RoboCup 2006**
- 2nd place in the Small-Size League, RoboCup 2006
- 1st place in the 3D Simulation League, European 2006
- **1st place** in the **Rescue Sim League, European 2006**
- 2nd place in the 2D Simulation League, European 2006

2007
- **1st place** in the **3D Simulation League, European 2007**
- 2nd place in the 2D Simulation League, European 2007
- **2nd place** in the **Physical Visual. League, RoboCup 2007**

2009
- 3rd place in the 3D Simulation League, European 2009
- 3rd place in the 2D Simulation League, European 2009

2010
- 3rd place in the 3D Simulation League, European 2010
- 3rd place in the 2D Simulation League, European 2010
Selected Results: CAMBADA, 5DPO

Competition Results: FC Portugal

2011  
2\textsuperscript{nd} place in the 3D Simulation League, European 2011 (GO)  
2\textsuperscript{nd} place in the 2D Simulation League, European 2011 (GO)

Competition Results: CAMBADA and 5DPO

1998  
5DPO: 3\textsuperscript{rd} place in the SSL League, RoboCup 2000

2001  
5DPO: 1\textsuperscript{st} place in the SSL League League, European (GO) 2001  
5DPO: 3\textsuperscript{rd} place in the MSL League League, European (GO) 2001

2002  
5DPO: 2\textsuperscript{nd} place in the SSL League, European (GO) 2002

2003  
5DPO: 2\textsuperscript{nd} place in the SSL League, European (GO) 2003

2004  
5DPO: 1\textsuperscript{st} place in the SSL League, European (GO) 2004

2006  
5DPO: 1st place in the SSL League, European 2006  
5DPO: 2nd place in the SSL League, RoboCup 2006

2008  
CAMBADA: 1\textsuperscript{st} place in the MSL League, RoboCup 2008

2009  
CAMBADA: 3\textsuperscript{rd} place in the MSL League, RoboCup 2009

2010  
CAMBADA: 2\textsuperscript{nd} place in the MSL League, European 2010  
CAMBADA: 3\textsuperscript{rd} place in the MSL League, RoboCup 2010

2011  
CAMBADA: 3\textsuperscript{rd} place in the MSL League, RoboCup 2011
Presentation Outline

• Artificial Intelligence and Robotics
• RoboCup and Our Teams
• Flexible Strategy for Robotic Teams
• Applications and other Projects at LIACC
  – Agent Based Simulation: EcoSimNet, FlightSimNet
  – Educational/Assistive Robotics: Intellwheels, Robot Dancing
  – Strategic Reasoning: Poker Agents
  – Real Sports: Soccer, Indoor Sports (Handball)
• Conclusions and Future Work
EcoSimNet: Agent-Based Ecologic Simulation

- **Realistic simulation of ecological models**
  - Difficult task
  - Mixing complex biological, chemical and physical processes
  - Slowness associated to each simulation
- **Integrate human factor/decisions in the simulation**
- **Provide flexible services to help sustainable management of aquatic ecosystems**
  - Custom solutions to “any” aquatic ecosystem
  - Environmental impact studies/water framework directive
  - Aquaculture optimization/Carrying capacity
EcoSimNet: Agent-Based Ecologic Simulation

- **EcoDynamo**
  - Simulator for aquatic ecosystems

- **Intelligent Agents**
  - Include the human rationality in the scenarios generation and decisions

- **ECOLANG**
  - Communication language for simulations of complex ecological systems

- **EcoSimNet**
  - Platform that integrates all the previous
  - Enables parallel simulations - clusters
Intellwheels: Intelligent Wheelchair

• **Limited mobility:**
  – Increment of the elderly population
  – Physical disabilities: Cerebral Palsy, Tetraplegia
  – Inability to control electric wheelchairs

• **Intelligent Wheelchair: Robotic device provided with sensorial and actuation systems and processing capabilities:**
  – (Semi)Autonomous behavior
  – Obstacle avoidance, navigation and planning
  – Flexible Human-Machine interaction
  – Cooperation with other IW/devices
**Intellwheels: Intelligent Wheelchair**

- **IW useful in practice:**
  - Very low cost and ergonomic impact
  - Simulation/mixed reality
  - Flexible multi-modal interface
  - IW development platform

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**AI and Robotics | RoboCup and Our Teams | Flexible Strategy for Robotic Teams | Applications and Projects | Conclusions**
Intellwheels: Intelligent Wheelchair
Robot Dancing based on RTBT

Motivation:

• Improve human-robot social interaction:
  – by means of bodily communication

• Improve robotic expressiveness:
  – By imitation of human motion

• Dance as a rich case study

Goals:

• Map human movement periodic patterns onto humanoid robots

• Model and generate humanoid dance
  – Samba dance style as first case study
Robot Dancing based on RTBT

Dance Motion Analysis

- Human MoCap Data
- Musical Annotation
- Data Acquisition
- TGA Analysis
- Motion Representation

Dance Motion Generation

- Initial Dance Motion Representation
- Motion Morphological Adaptation
- Key-poses Synthesis
- Synthesized Key-Poses w/ Variability
- Key-pose Retargeting
- Key-poses Refinement
- Joint Trajectories Generation
- Humanized Robot Dancing

- Body Resizing
- Other Physical Restrictions
- Number of joint adaptation
- Quaternion Algebra
- Random Process
- Paramaterizable Metrical Resolution
- Joint Angle Calculation
- Tabu Search Optimization
- Expressive Musical Qualities
Robot Dancing based on RTBT

a) Metric levels
- Bar
- Beat
- 1/2 Beat
- 1/4 Beat

b) Audio
- Classes
  1  2
  1  2
  1  2

b) Audio
- Time domain
- Spatial domain

- Projection
- Discrimination
- LDA

- Topologies
  - Projected points
  - Centroid of the 3d distribution $D_j^m$
  - Euclidean distance
  - Mean of the Euclidean Distance (radius)

- a) Original point cloud
- b) Point cloud after LDA
- c) Spherical distributions

- a) Kinematic chains
- b) Propagation of stochastic processes
  - Joint 11 to 17
  - Joint 17 to 18
  - Joint 18 to 19

- c) Random coordinates
- d) Random rotations

[Diagram of robot dancing with various points, lines, and projections]
Sports Analysis: Handball and Soccer

- Artificial Intelligence x Computer Vision x Intelligent Simulation
- Detection and Tracking of Ball and Players
- Intelligent Game Analysis: Coach Reports (Data Mining)
- Creation of Players and Team Models (High-level models + Data mining)
- Realistic Simulation of Soccer/Handball Games
Indoor Sports Analysis: Handball
Poker Strategy with Online Opp. Modeling

- Poker is a game humans find fascinating
- Huge and growing market:
  - Casinos, tournaments, online, television
- Challenge of Poker for DAI: Many new and interesting problems not faced in Chess, Go, or Backgammon:
  - Random, hidden information, bluffing and trapping, need for opponent modeling
- Poker is a simple game that demands for complex strategies

- Project General Objective:
  - Develop an agent capable of beating the best human players in “No Limit, Multi-Player, Texas Hold’em, Poker”
Poker Strategy with Online Opp. Modeling

POKERLANG

\[ \text{<STRATEGY> ::= \{<ACTIVATIONCONDITION> <TACTIC>\}} \]

\[ \text{<ACTIVATIONCONDITION> ::= \{<EVALUATOR>\}} \]

\[ \text{<TACTIC> ::= \{<PREDEFINEDTACTIC> | <TACTICNAME><TACTICDEFINITION>\}} \]

\[ \text{<PREDEFINEDTACTIC> ::= loose_aggressive | loose_passive | tight_agressive | tight_passive} \]

\[ \text{<TACTICNAME> ::= \{string\}} \]

\[ \text{<TACTICDEFINITION> ::= \{<BEHAVIOUR> <VALUE>\}} \]

\[ \text{<BEHAVIOUR> ::= \{<RULE>\}} \]

\[ \text{<RULE> ::= \{<EVALUATOR> | <PREDICTOR>\}} \text{<ACTION>\}} \]

\[ \text{<EVALUATOR> ::= \{<NUMBEROFPLAYERS> | <STACK> | <POTODDS> | <HANDREGION> | <POSITIONATTABLE>\}} \]

\[ \text{<PREDICTOR> ::= \{<IMPLIEDODDS> | <OPPONENTHAND> | <OPPONENTINGAME> | <STEALBET> | <IMAGEATTABLE>\}} \]

\[ \text{<ACTION> ::= \{<PREDEFINEDACTION><PERC> | <DEFINEDACTION><PERC>\}} \]

\[ \text{<PREDEFINEDACTION> ::= \{<STEALTHEPOT> | <SEMI_BLUFF> | <CHECK_RAISE_BLUFF> | <SQUEEZE_PLAY> | <CHECK_CALL_TRAP> | <CHECK_RAISE_TRAP> | <POST_OAK_BLUFF>\}} \]
Conclusions

• **Coordination** of Teams in Adversarial Environments: **Strategy**, Formations (SBSP/DT), DPRE, Setplays

• Complete **Tactical/Formation Framework** including graphical interface

• Complete **Setplay Framework** including graphical interface

• **Generic Coordination Framework/Library:**
  • May be used for coordinating any team: World State -> High-Level Decision!
  • Useful for researching on low-level Robotics!

• Several MAS/MRT coordination methodologies developed with competition success

• Applications to **different robots** for **distinct cooperative robotic** tasks and also to **other domains**: Rescue, surveillance, military apps
Future Work

• **Strategy based on Tactics, Formations, Flux and Setplays:**
  – Formations: *flexible use of global vs local info*
  – Apply and test in *other leagues*
  – Test Strategy definition by *domain experts* (using graphical application)
  – *Heterogeneous Robot Teams and Human-Robot Teams*

• **Setplays Framework**
  – Learning/optimizing setplays using ML
  – Apply and test in *other leagues*
  – Test Setplay definition by *domain experts* (using graphical application)
  – *Heterogeneous Robot Teams and Human-Robot Teams*

• **Release Strategy and Setplay Frameworks for the community**

• **Other Current Work:**
  – Bridging the Gap between Simulation and Real Robotics: MSL Simulation, SPL League (3D Sim), Real Sports
  – Apply Strategy to other domains: Computer Poker
  – **Real Soccer/Sports Research:** Individual/team decision, game analysis, and realistic players/game simulation
Related Publications (1)

Related Publications (2)

Related Publications (3)

- Brígida Monica Faria, Luis Paulo Reis, Nuno Lau, Gladys Castillo, Machine Learning Algorithms applied to the Classification of Robotic Soccer Formations and Opponent Teams, IEEE Int. Conf. on Cybernetics and Intelligent Systems and IEEE Int. Conf. Robotics, Automation and Mechatronics (IEEE CIS & RAM 2010), Singapura, 2010.
- Luís Mota, Nuno Lau, Luis Paulo Reis, Coordination in RoboCup’s 2D Simulation League: Setplays as flexible, Multi-Robot plans, IEEE International Conference on Cybernetics and Intelligent Systems and IEEE International Conference on Robotics, Automation and Mechatronics (IEEE CIS & RAM 2010), Singapura, 2010
Related Publications (4)


Related Publications (5)


Questions?

Multi-Robot Intelligence: Flexible Strategy for Robotic Teams

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