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**

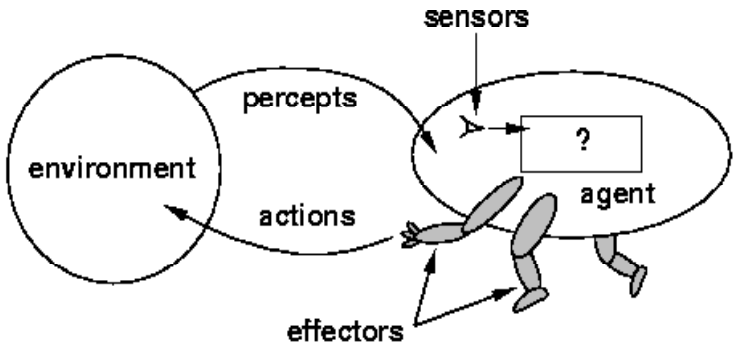
Artificial Intelligence

- **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

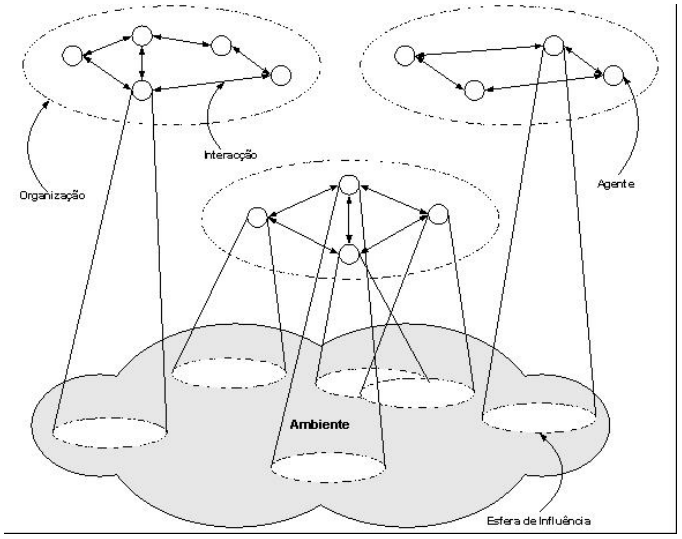
- **Agent Traditional Definition:**

  "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**."



From Russel and Norvig, "AI: A Modern Approach", 1995

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



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

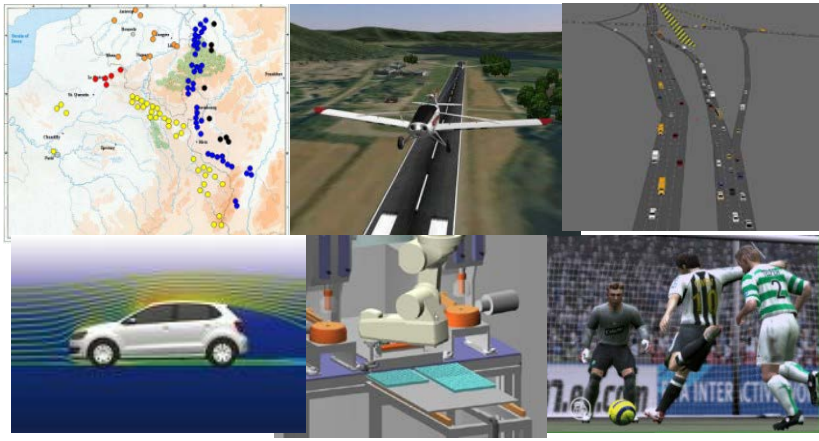
- **Used to Perform:**
  - **Dangerous** or difficult **tasks** to be performed directly by humans
  - **Repetitive tasks** that may be performed more efficiently (or cheap) than when performed by humans
- **Robots have moved from manufacturing, industrial applications to:**
  - **Domestic** robots (Pets – 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

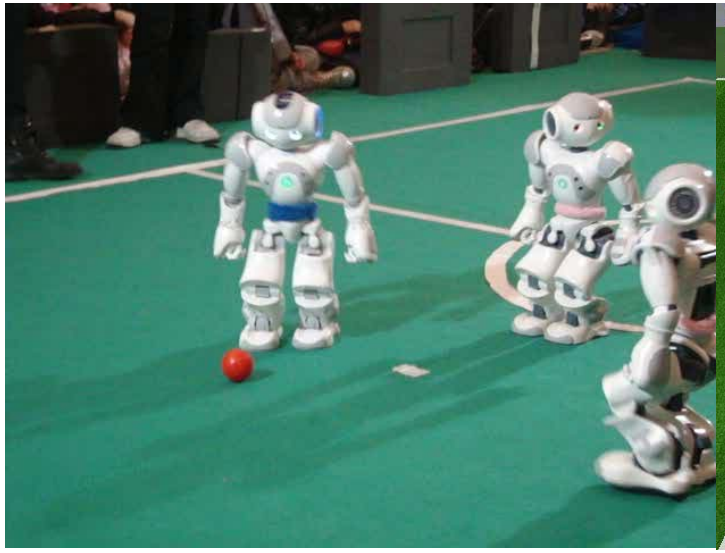
- RoboCup – Robotic Soccer
- Robotic Soccer FIRA
- DARPA Grand-Challenge
- Intelligent Ground Vehicle Competition
- European Land Robot Trial
- IEEE MicroMouse competition
- AAAI Grand Challenges
- First Competition (Lego-League)
- RoboGames (former RoboOlympics)
- Manitoba Robot Games
- Robotic Fight: 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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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)

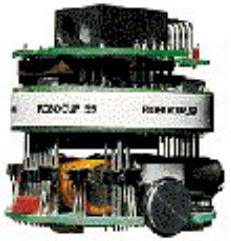
- Local Championships:
  - German Open (European)
  - Japanese Open
  - Australian Open
  - American Open
  - Portuguese Open
  - Iranian Open, AutCup
  - China Open

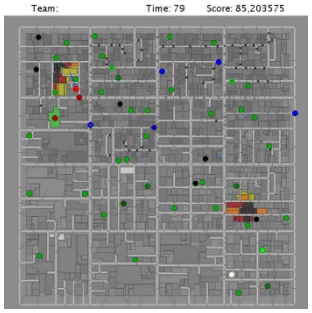
RoboCup - Participants

- Participant/Awarded Countries:
  - 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
- **R**oboCup@Home



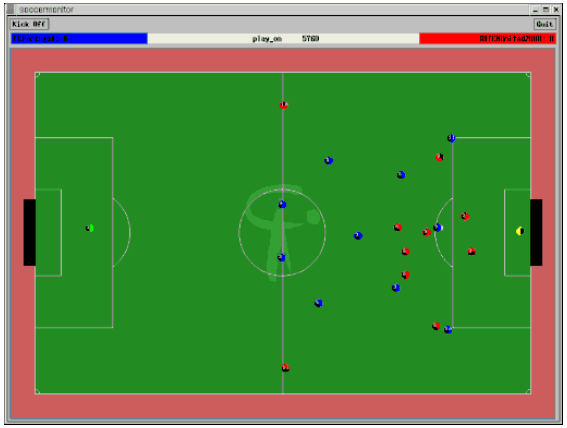


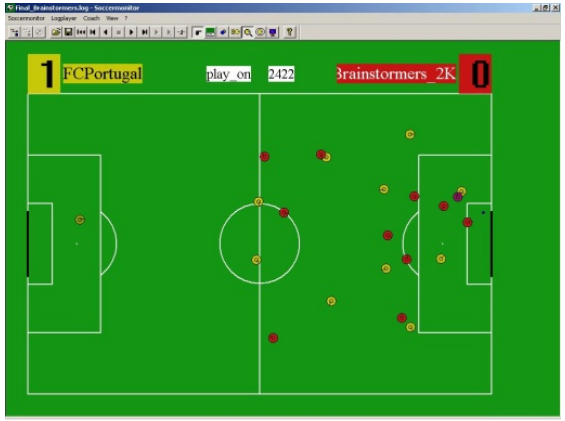
RoboCup: Global Perspective

- **Videos**

RoboCup Leagues: Simulation 2D

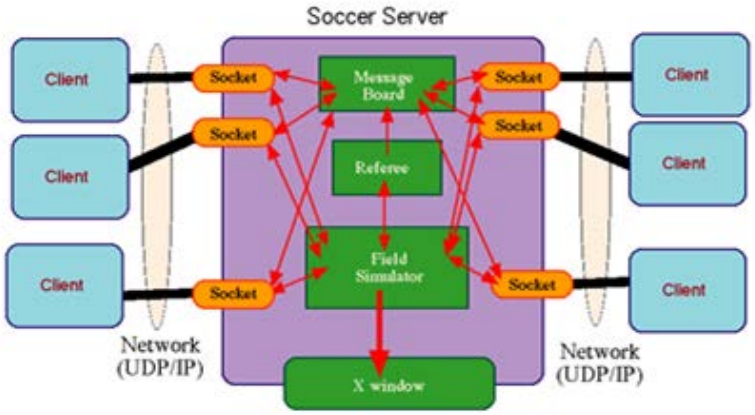
- Virtual Robots
- 105*68m Virtual Field
- Agents controlled by different computers (or processes)
- Simulator sends perception and receives actions from agents
- Teams of 11 players plus a coach





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!



Server Architecture

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

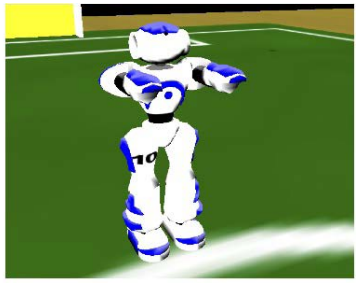
RoboCup Leagues: Simulation 3D

- 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

(a) real robot



(b) virtual robot

Simulation 3D – Spheres model

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

Videos

Simulation 3D – Humanoid model

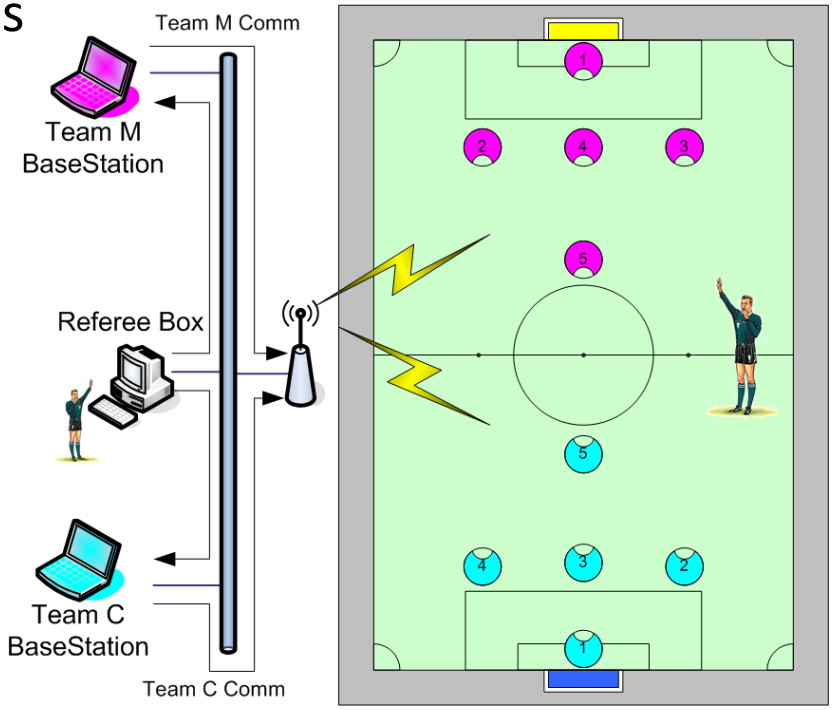
- 2007-2010: Very Basic playing!
- 2011: Formations/High-level playing!

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

- 1998-2007: Very Basic playing! Individual Dribbling!
- 2008: Formations SBSP/High-level playing/Setplays!

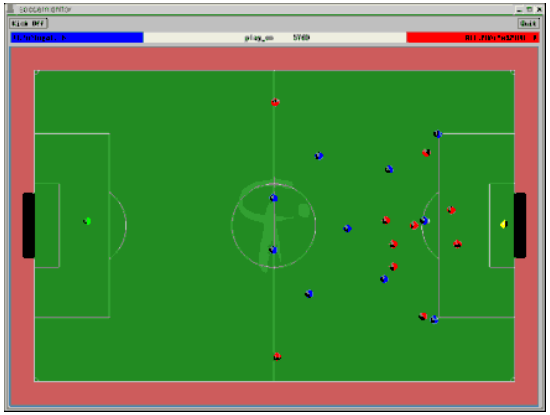
- Videos

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!**

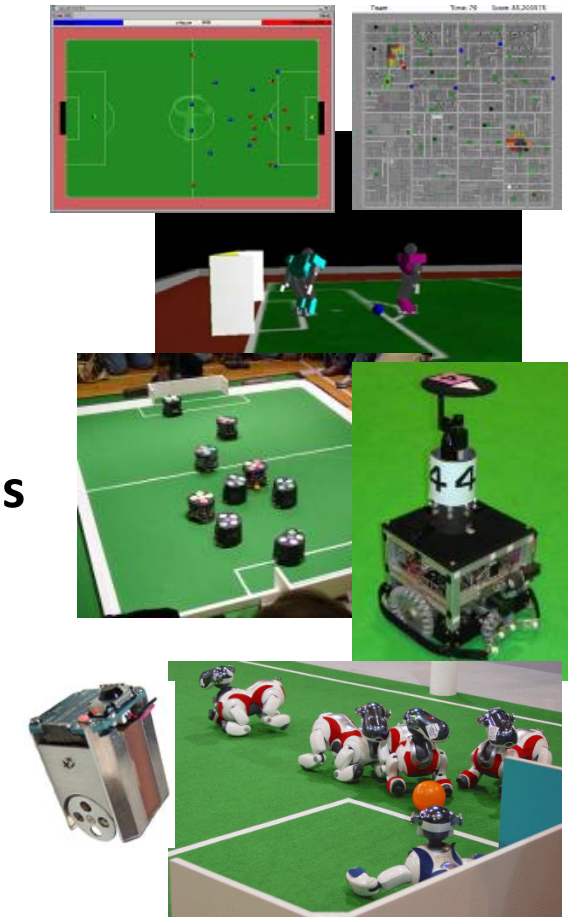
Our Teams: University of Porto/Aveiro

- **Simulation 2D: FC Portugal**
  - Best: Winners RoboCup 2000,
  - Winners Euro 2000, Euro 2001
- **Simulation 3D: FC Portugal**
  - Best: Winner RoboCup 2006,
  - Winners Euro 2006, Euro 2007
- **Simulation – Coach: FC Portugal**
  - Best: Winner RoboCup 2002,
  - 2nd RoboCup 2003, 2004
- **Simulation – MR League: FC Portugal**
  - Best: 2nd 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,
  - Winners Euro 2001, 2006, 2007
- **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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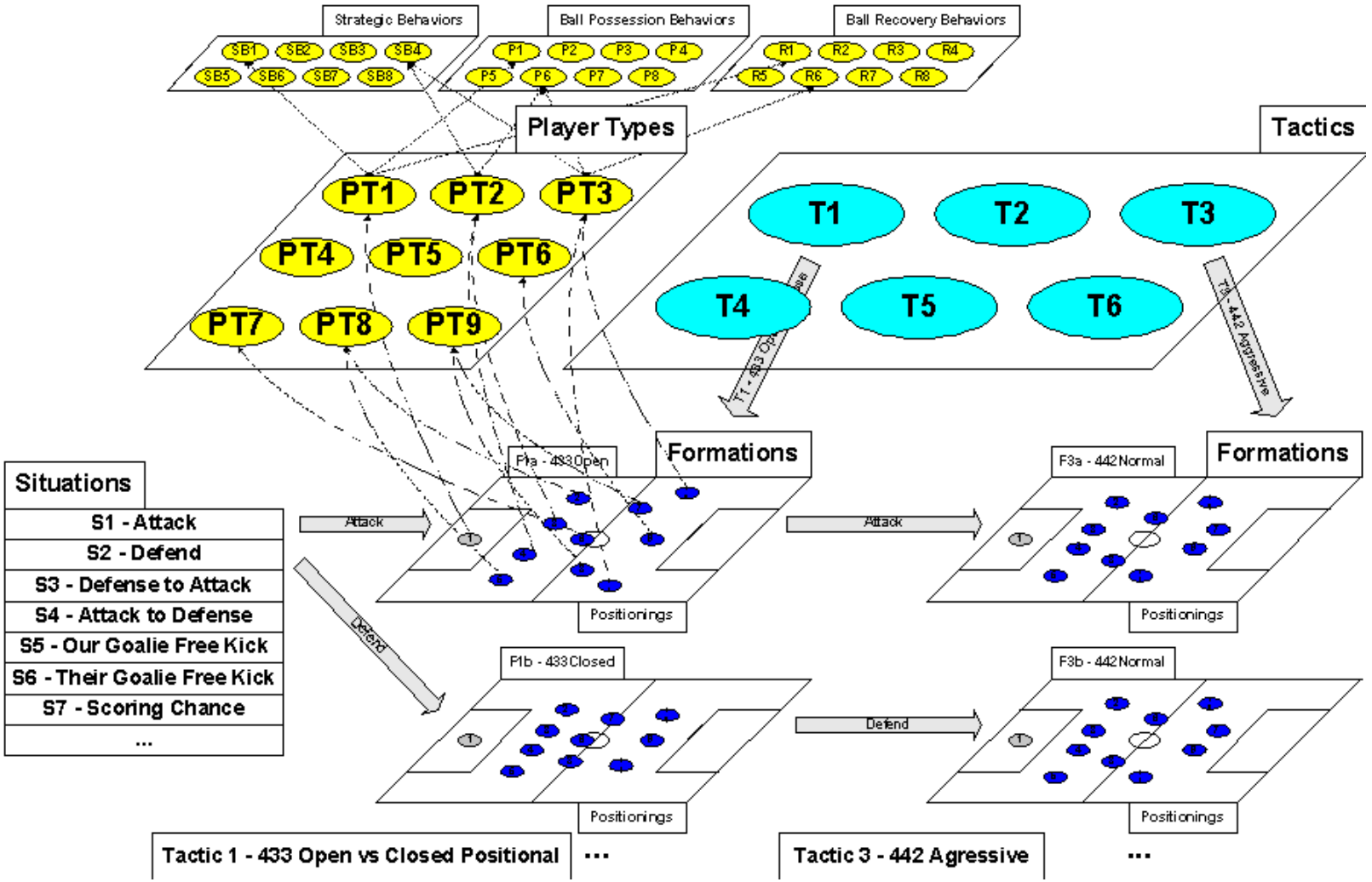
The Coordination Problem

- 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

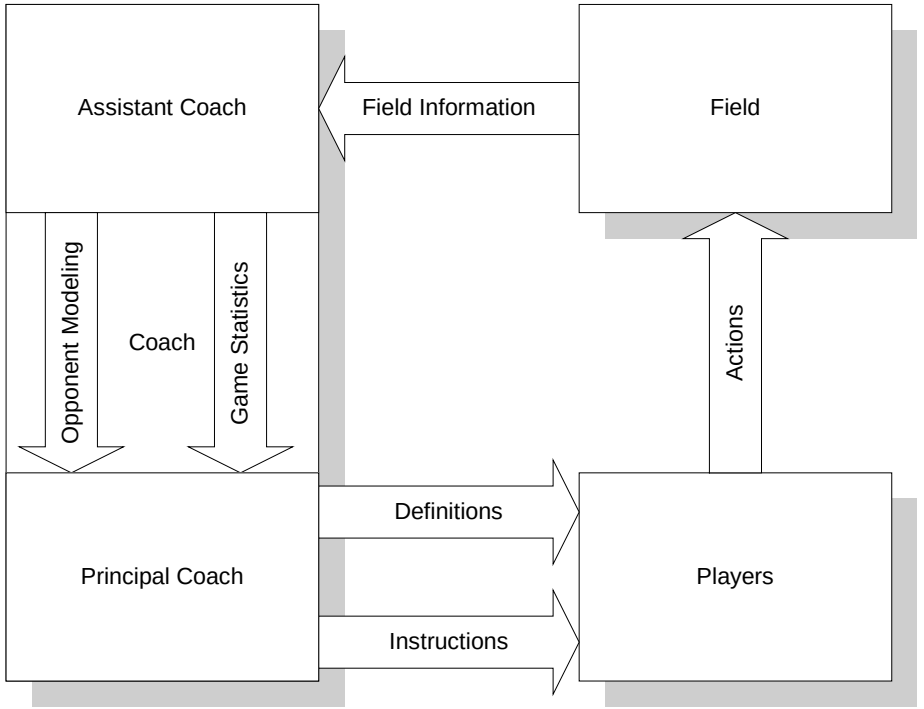
- Common Framework for Cooperative Robotics:
  - Strategical Coordination and Coaching
  - SBSP – Situation Based Strategic Positioning
  - DPRE – Dynamic Position and Role Exchange
  - SetPlay Framework and Graphical Definition
  - Generic Optimizer of Skills/Decisions
  - Bridging the Gap Between Simulation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

Formalization of a Team Strategy

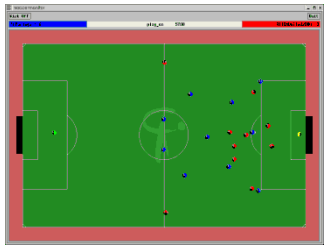


Coaching

- 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.



Coach Unilang



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

<MESSAGE> ::= (<TIME> <ID> <MESSAGE PART> {<MESSAGE PART>})

<MESSAGE PART> ::= <DEFINITION_MESS> |<STATISTICS_MESS> | <OPP_MOD_MESS> | <INSTRUCTION_MESS>

TACTIC_DEFINITION> ::= <TEAM_MENTALITY> <GAME_PACE> <TEAM_PRESSURE> <FIELD_USE> <PLAYING_STYLE> <RISK_TAKEN> <OFFSIDE_TACTIC> <POSITIONING_EXCHANGE_USE> <FORMATIONS_USED>

<FORMATION> ::= <PREDEFINDED_FORMATION> <FORMATION_NAME> | <FORMATION_DEFINITION>

<PREDEFINED_FORMATION> ::= 433 | 433att | 442 | 343 | 4123 | 352 ...

<FORMATION_DEFINITION>::= {(<PLAYER> <POS_NUMBER> <PLAYER_POSITIONING> <PLAYER_TYPE>)}

<PLAYER_POSITIONING> ::= <VERTICAL_POSITIONING> <HORIZONTAL_POSITIONING>

Formations in Robotic Soccer

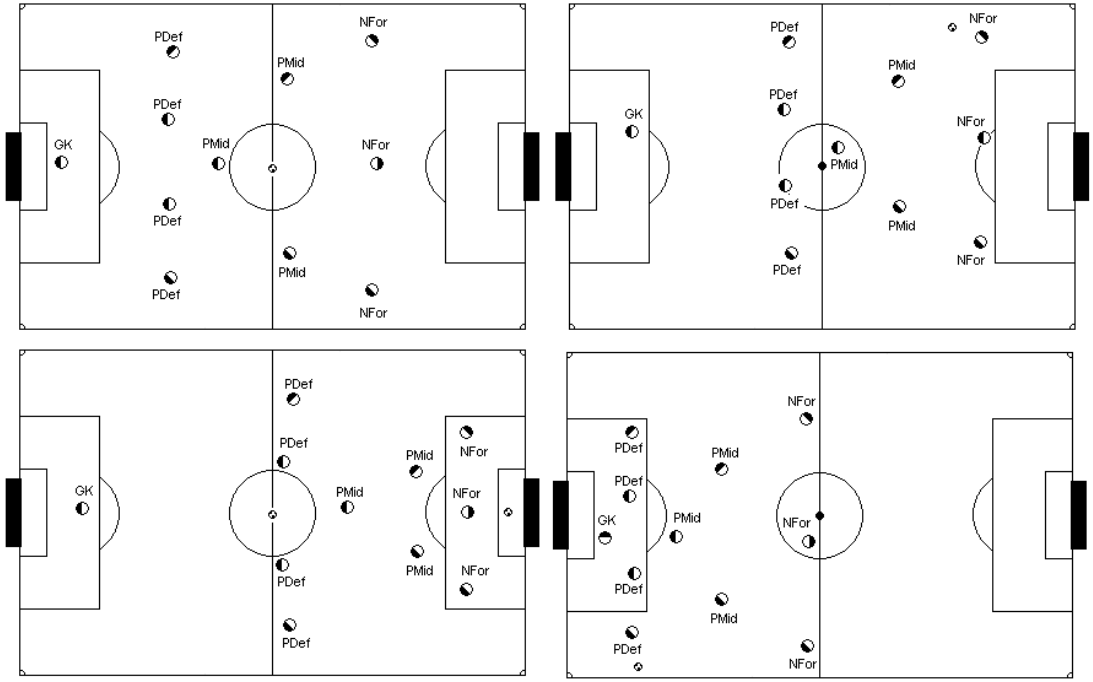
- **Formations are one of the essential concepts in multi-robot strategies:**
  - Provide a coordination framework: tasks/role assignment
  - Real impact on team performance
  - Can/should be adapted to team and opponent capabilities
  - Provide a common concept with military units coordinated movements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

Formation Models

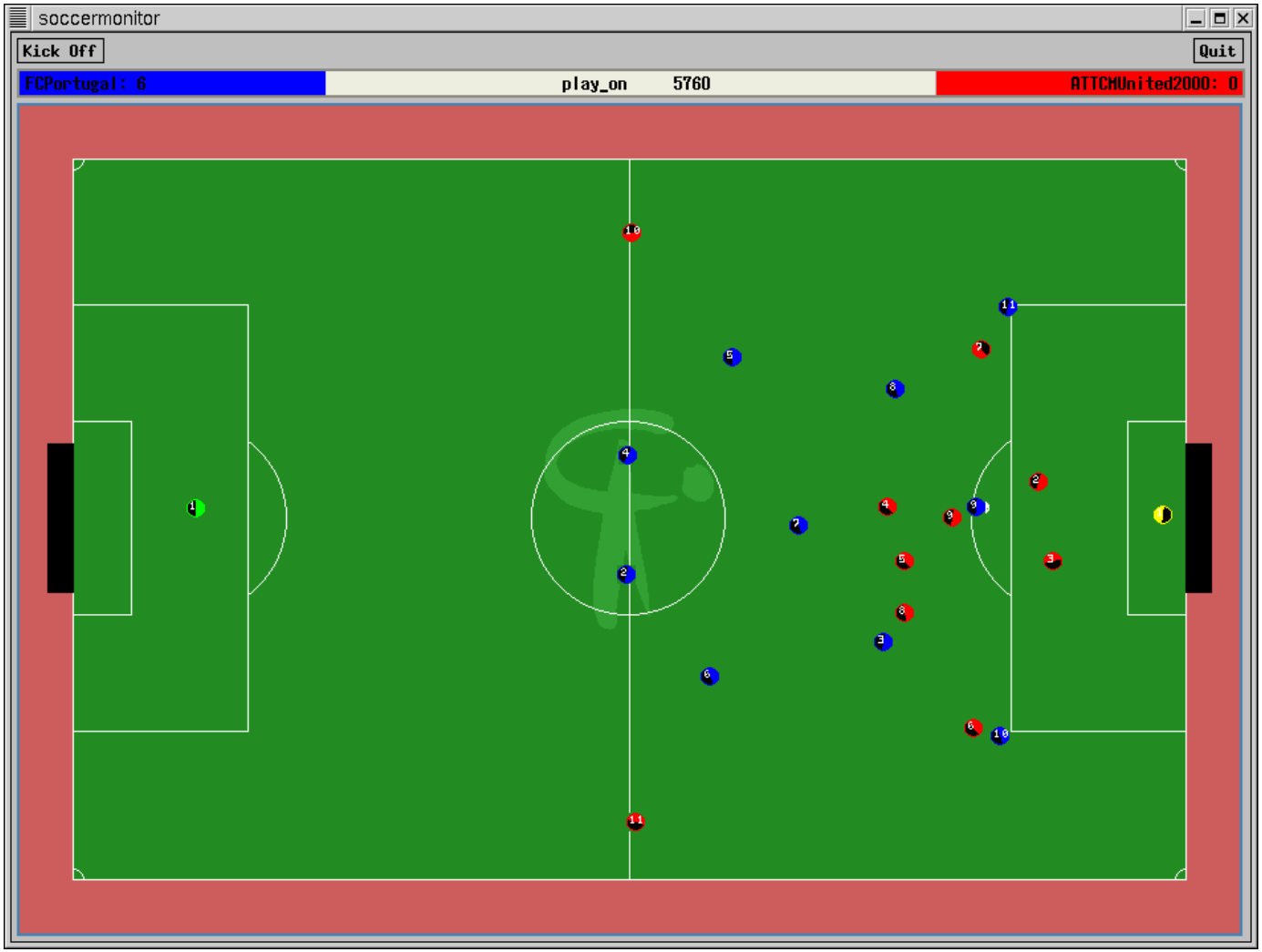
- Role based models
  - Ex: Striker, Supporter, Defender, Goalie
- SPAR – Strategic Positioning with Attraction and Repulsion
  - Locker-Room agreement
- SBSP – Situation Based Strategic Positioning
  - Distinction between active and passive situations
  - Distinct team movements for different situations
  - 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

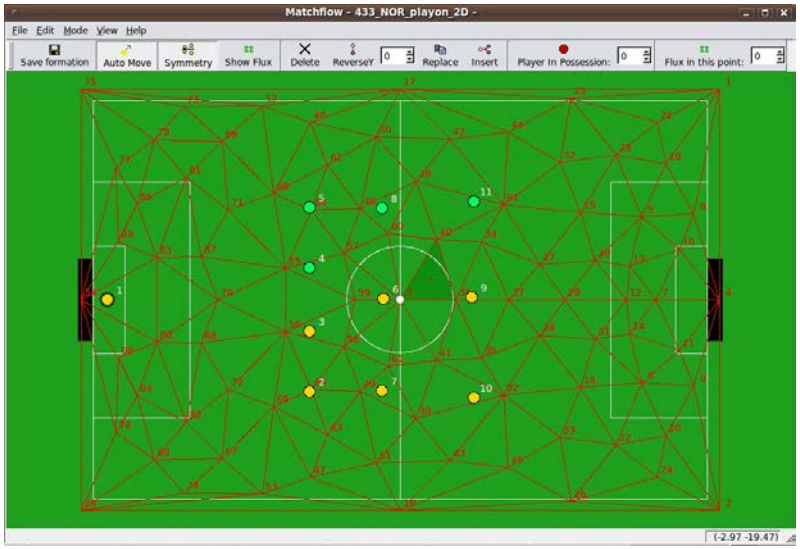
- Strategic Situation: SBSP – Strategic Positioning
- Active Situation (with/without Ball): Active Behavior
- Definition based on: Situation and Shared info (Ball Position)

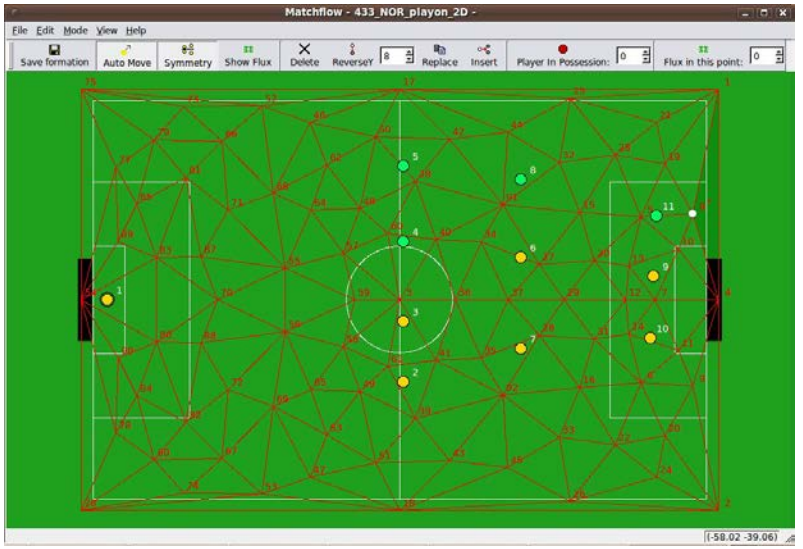


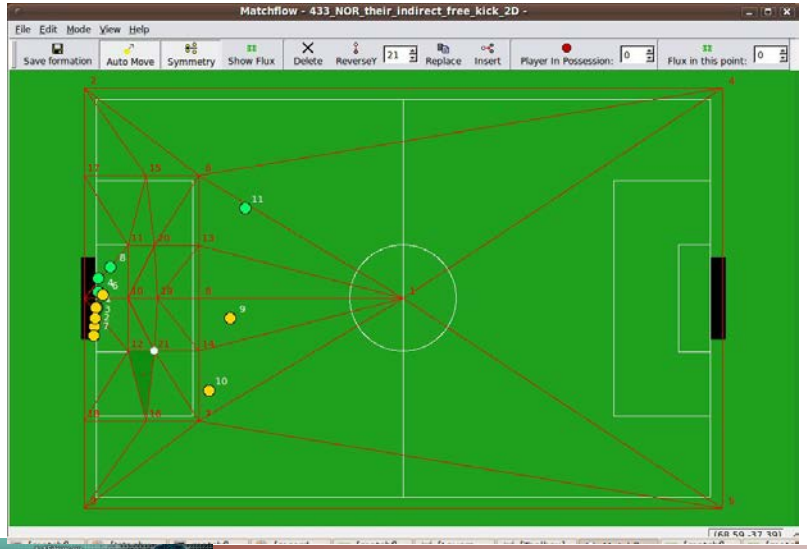
SBSP vs SPAR

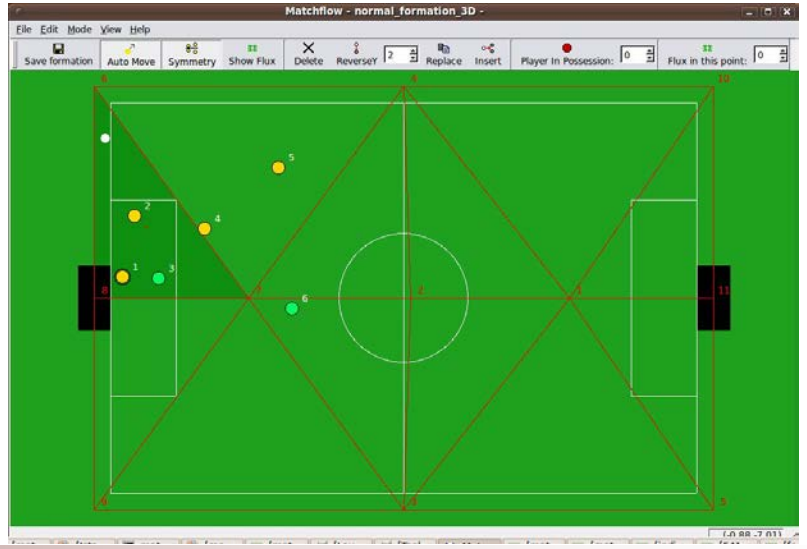

soccermonitor
Kick Off
Quit
FCPortugal: 6
play_on 5760
ATTCHUnited2000: 0

SBSP with Delaunay Triangulation



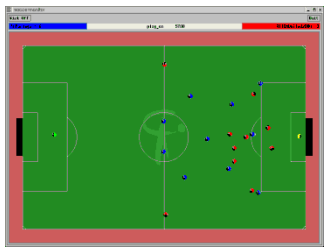






DPRE - Dynamic Positioning and Role Exchange

```
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([Pl2])
    IF Util > ThresUtil(Situation) THEN exchange(Positionings[Pl1], Positionings[Pl2])     }
    RETURN Positionings
}
```



Flexible Strategy for Robotic Teams

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

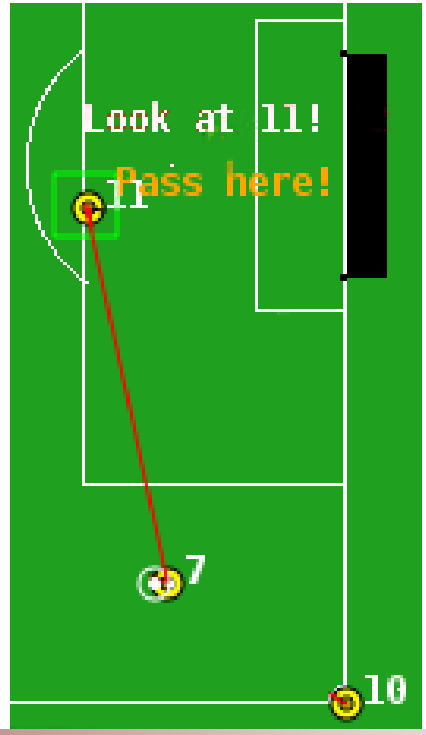
Simple Example (from FCPortugal 3D):

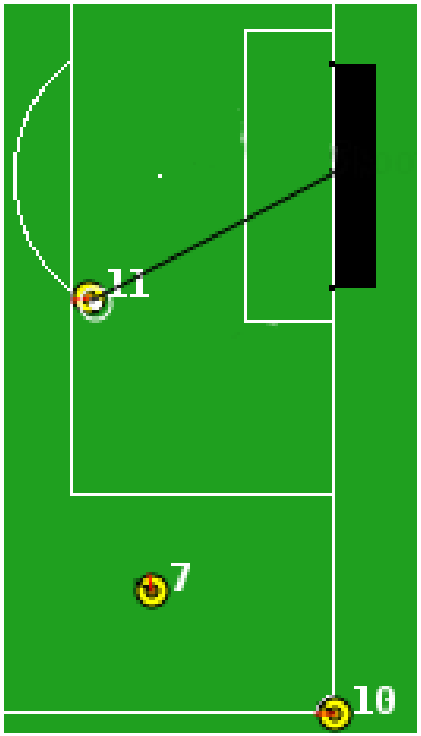
```
void FCPAgentH::FillInWSforStrategy() {
        WorldState& world = SWorldState::getInstance();
        strategy->WS_GameTime = world.gTime;
        strategy->WS_Result = world.game->ourGoals- world.game->opponentGoals;
        strategy->WS_BallPos = world.ball->position.to2d(); /
        strategy->WS_BallOwner = 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)





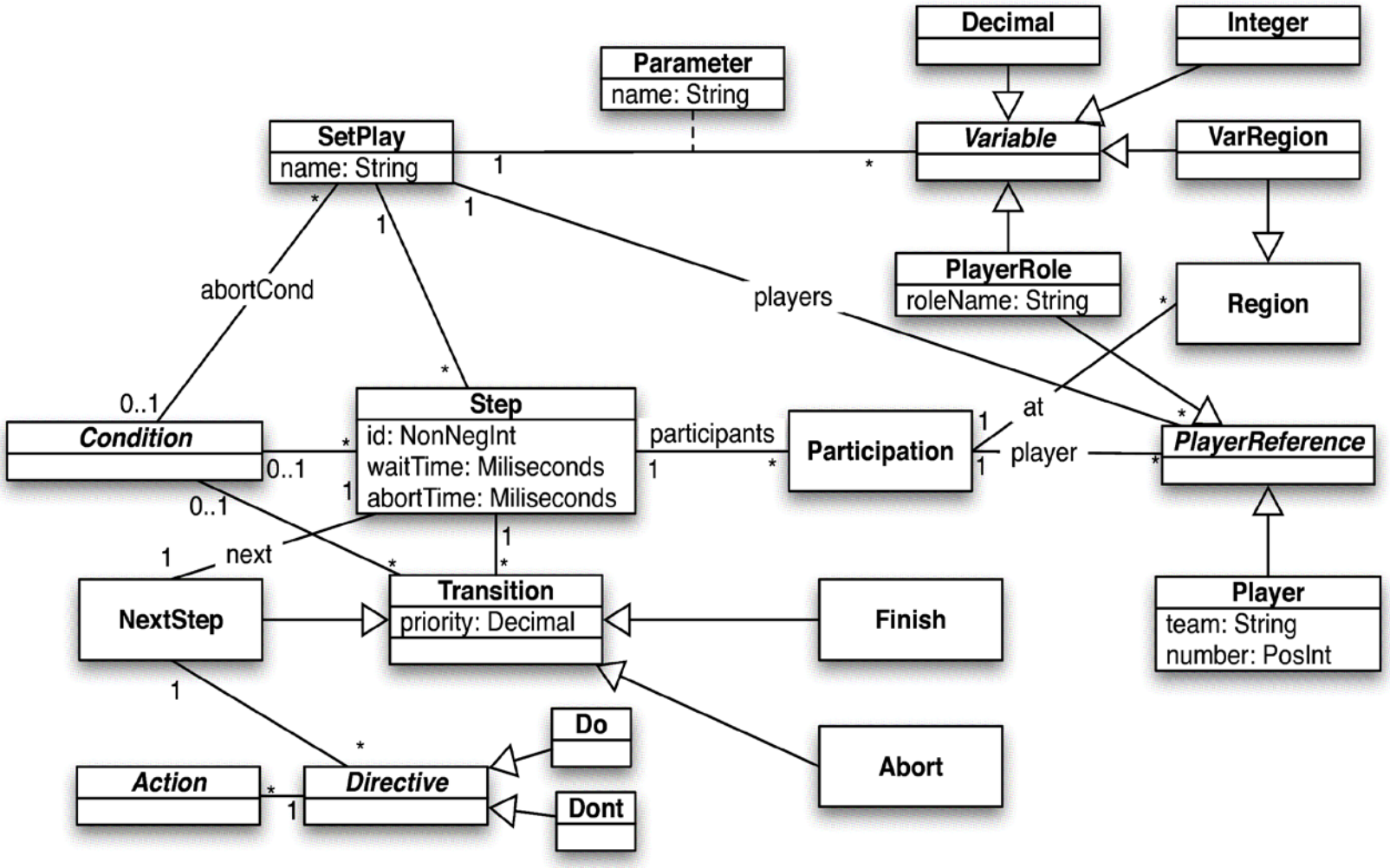
Setplay Definition

- **(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))))))

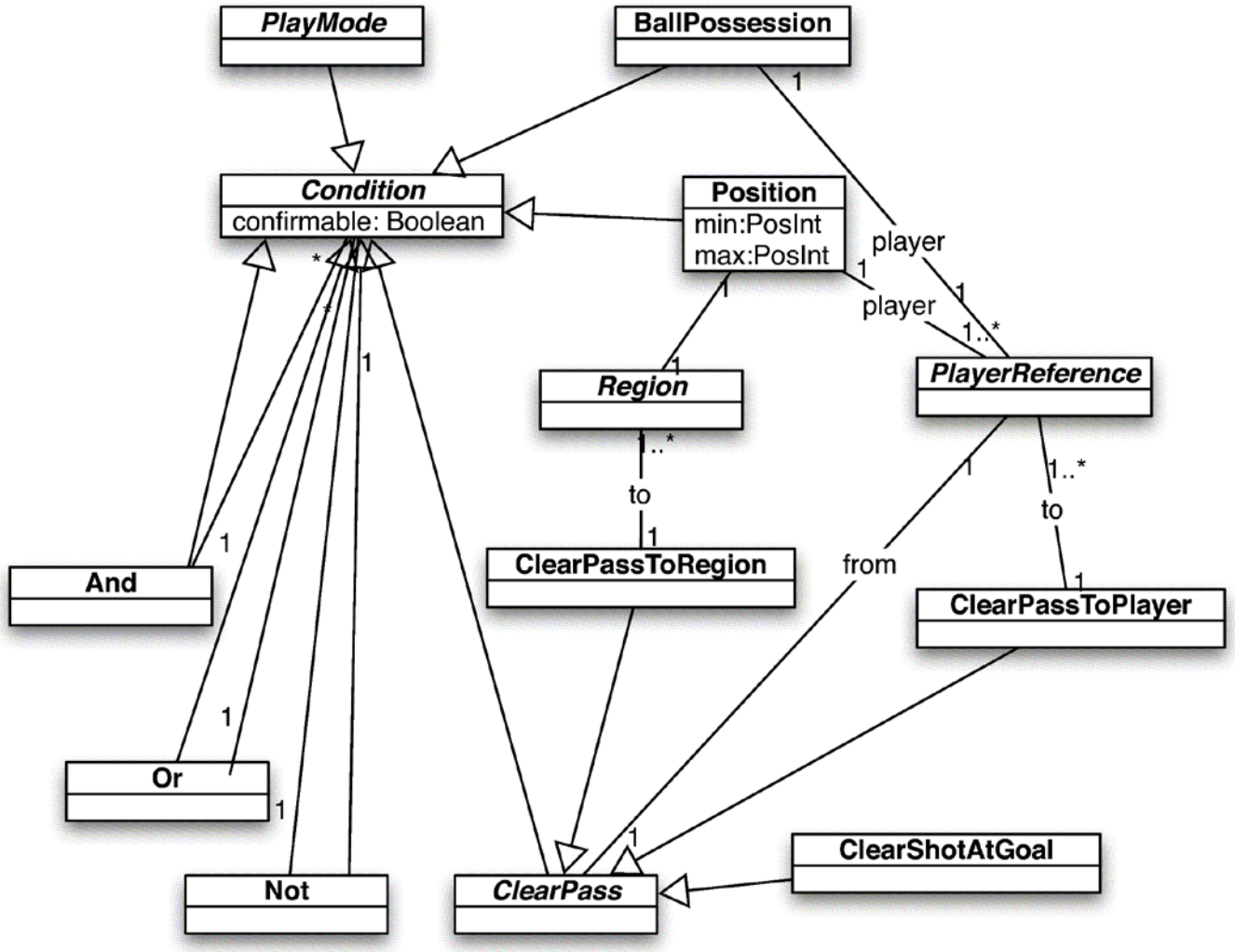
Setplay Definition

- **(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))))))

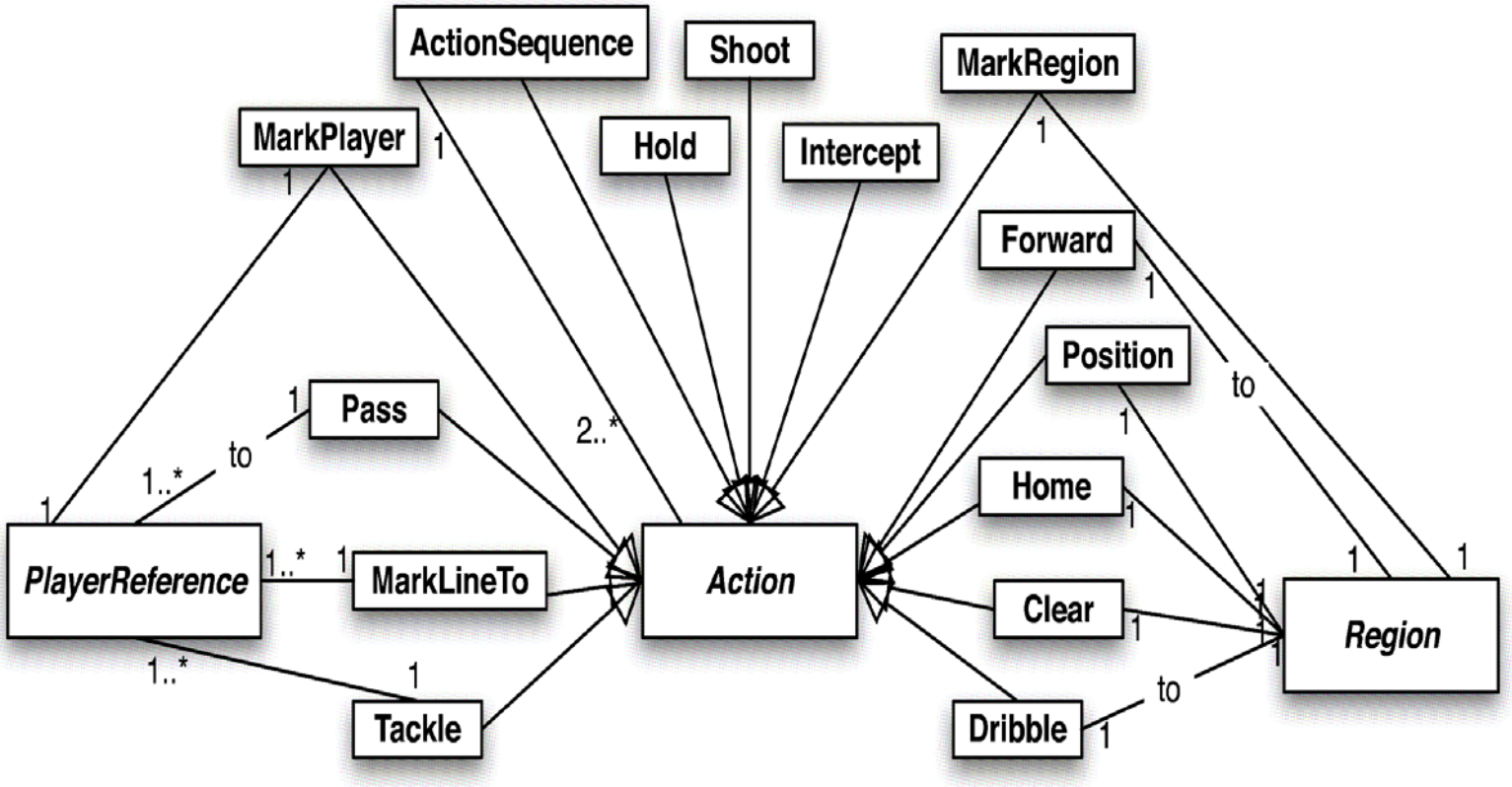
Setplays - Structure



Conditions

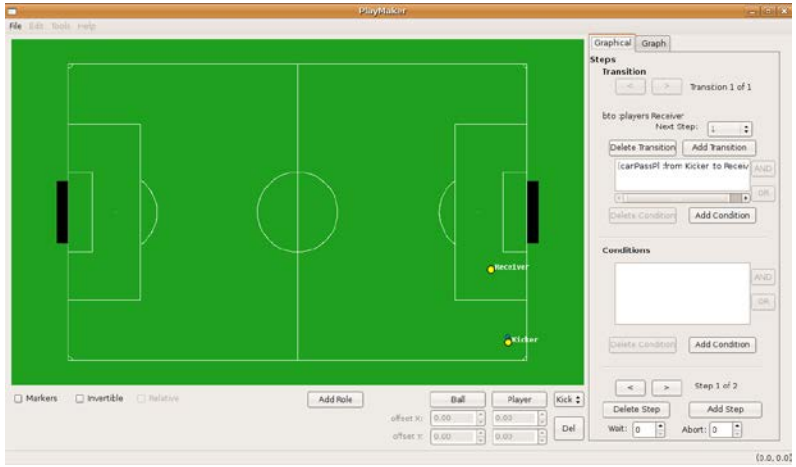

PlayMode
BallPossession
Condition
confirmable: Boolean
Position
min:PosInt
max:PosInt
player
player
Region
PlayerReference
to
to
from
And
ClearPassToRegion
ClearPassToPlayer
Or
Not
ClearPass
ClearShotAtGoal

Actions


ActionSequence
Shoot
MarkRegion
MarkPlayer
Hold
Intercept
Forward
Position
Pass
Home
PlayerReference
MarkLineTo
Action
Clear
Region
Tackle
Dribble
to
1
2..*
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)

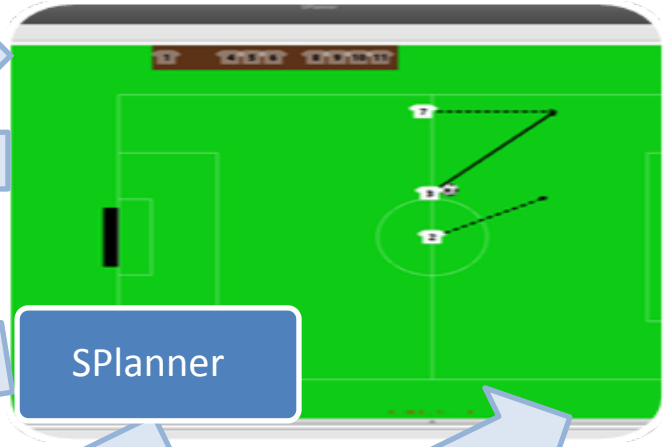


Setplays: Graphical Definition

Formal Definition (Setplay *framework*)

Import

Export

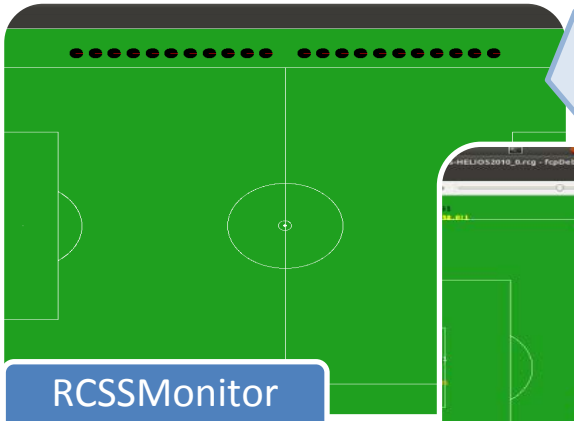


SPlanner

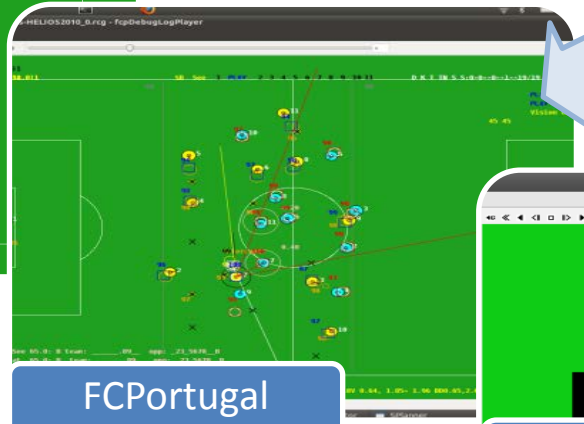
Test

Debug

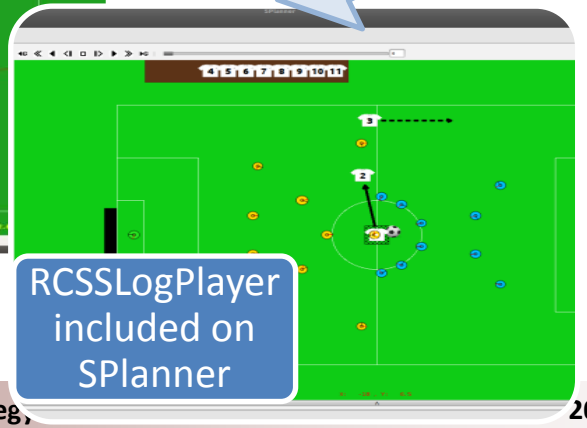
Adjust



RCSSMonitor 14.0.1

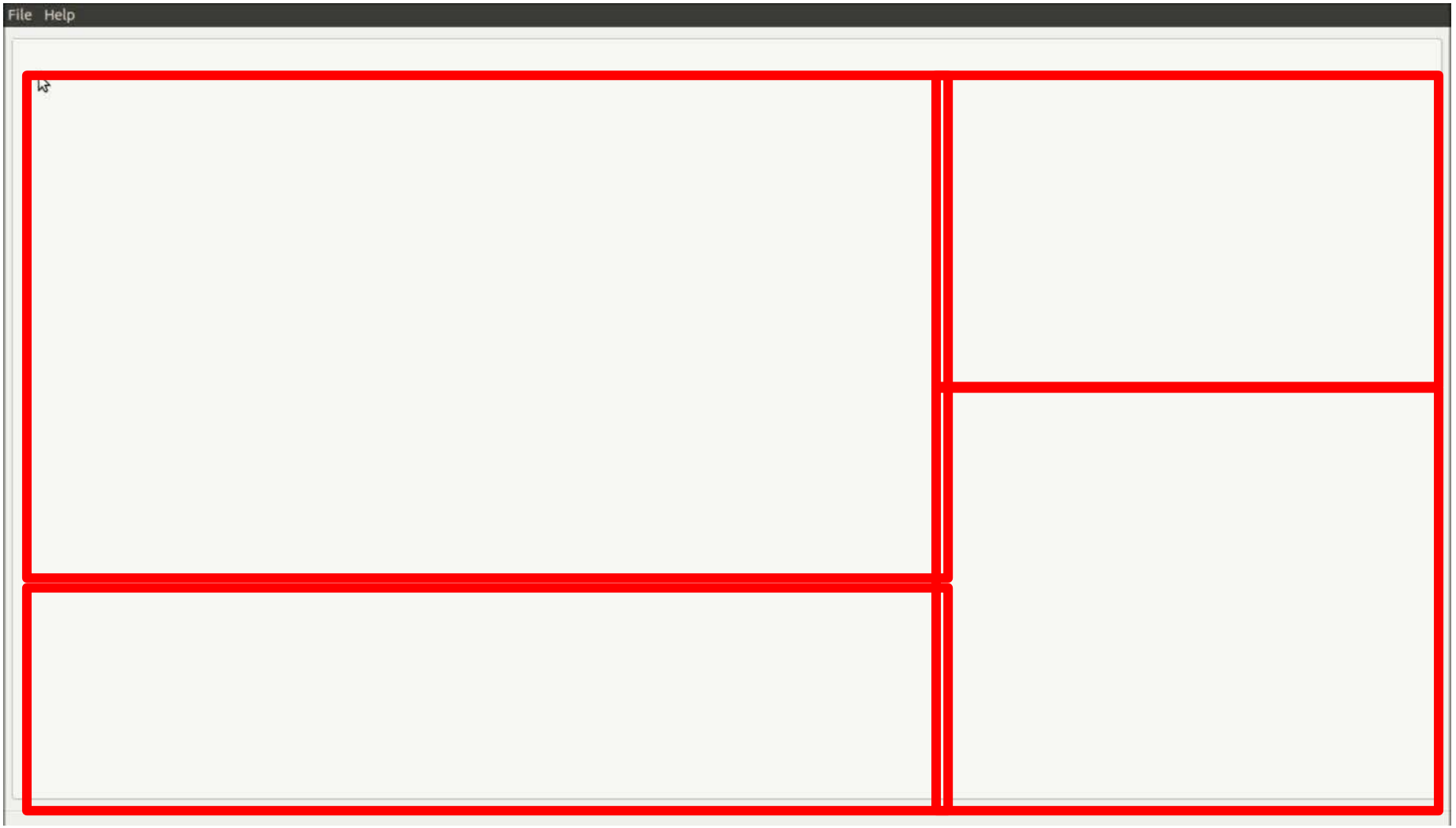


FCPortugal Debug LogPlayer



RCSSLogPlayer included on SPlanner

Setplays: Graphical Definition



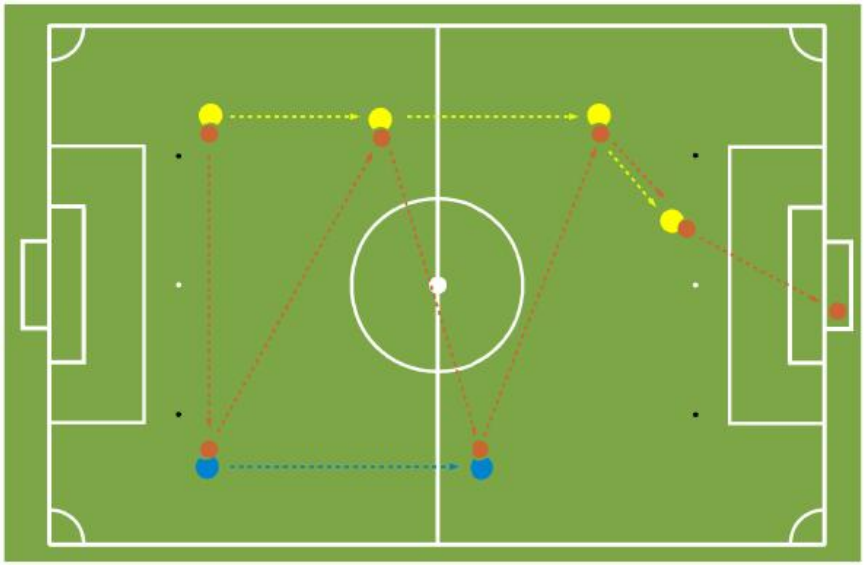
SetPlays in the Simulation 2D League

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!

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



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	2nd place in the 3D Simulation League, European 2011 (GO)
	2nd place in the 2D Simulation League, European 2011 (GO)

Competition Results: CAMBADA and 5DPO

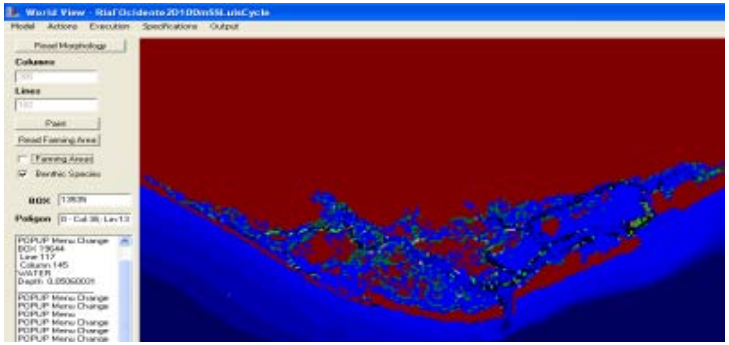
1998	**5DPO: 3rd place in the SSL League, RoboCup 2000**
2001	**5DPO: 1st place in the SSL League League, European (GO) 2001**
	5DPO: 3rd place in the MSL League League, European (GO) 2001
2002	5DPO: 2nd place in the SSL League, European (GO) 2002
2003	5DPO: 2nd place in the SSL League, European (GO) 2003
2004	**5DPO: 1st 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: 1st place in the MSL League, RoboCup 2008**
2009	**CAMBADA: 3rd place in the MSL League, RoboCup 2009**
2010	CAMBADA: 2nd place in the MSL League, European 2010
	CAMBADA: 3rd place in the MSL League, RoboCup 2010
2011	**CAMBADA: 3rd 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

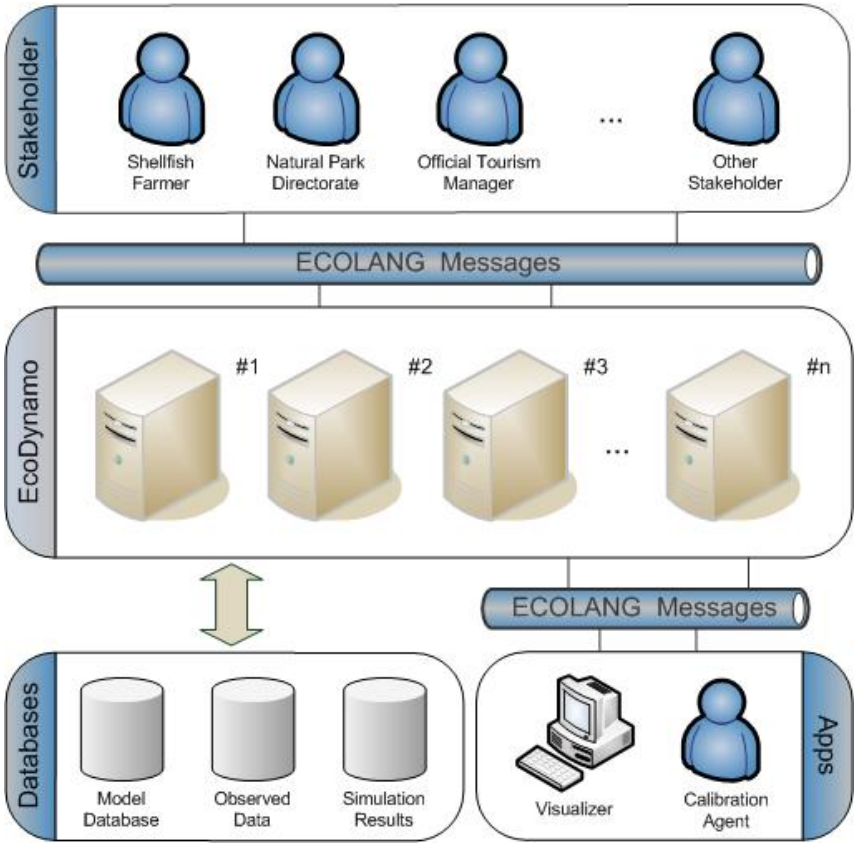
EcoSimNet: Agent-Based Ecologic Simulation

- **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

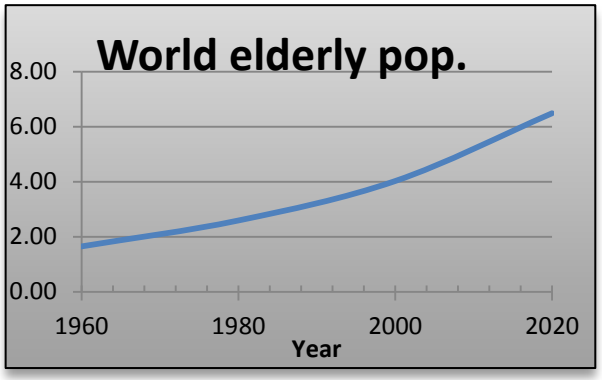


EcoSimNet: Agent-Based Ecologic Simulation

- **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



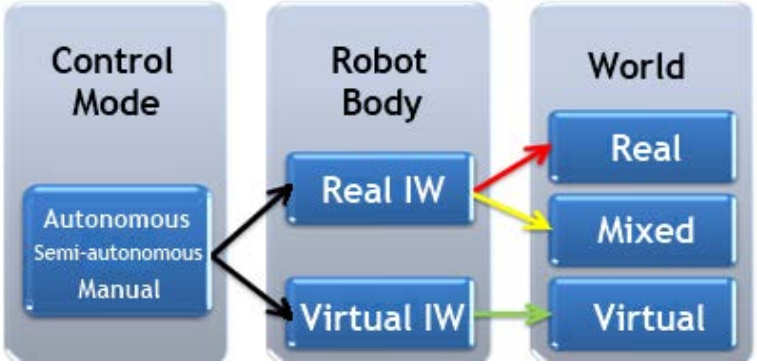
- **Limited mobility:**
  - Increment of the elderly population
  - Physical disabilities: Cerebral Palsy, Tetraplegia
  - Inability to control electric wheelchairs
- **Intelligent Wheelchair: Robotic device provided with sensorial and actuation systems and processing capabilities:**
  - (Semi)Autonomous behavior
  - Obstacle avoidance, navigation and planning
  - Flexible Human-Machine interaction
  - Cooperation with other IW/devices

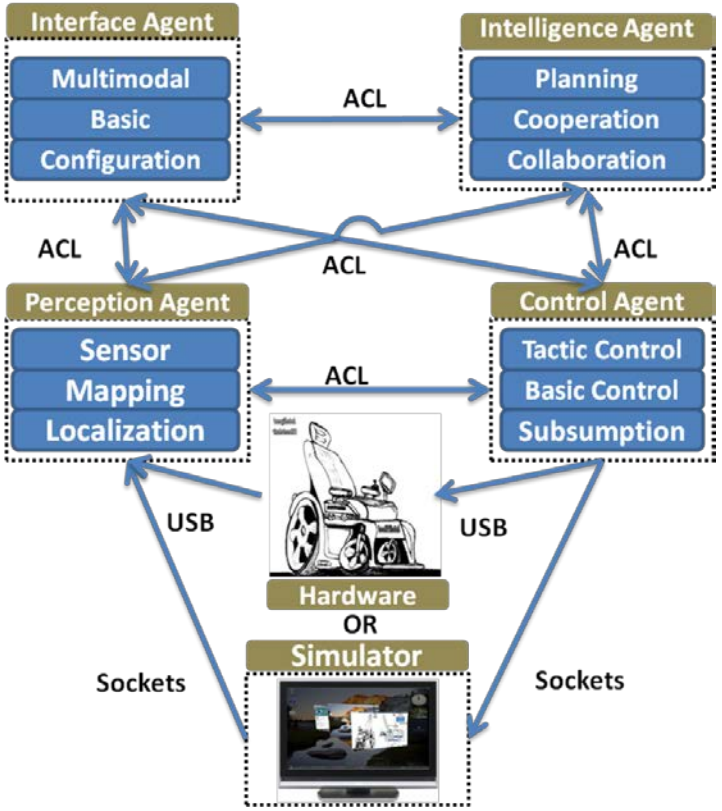




Intellwheels: Intelligent Wheelchair

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





Intellwheels: Intelligent Wheelchair

Robot Dancing based on RTBT

Motivation:

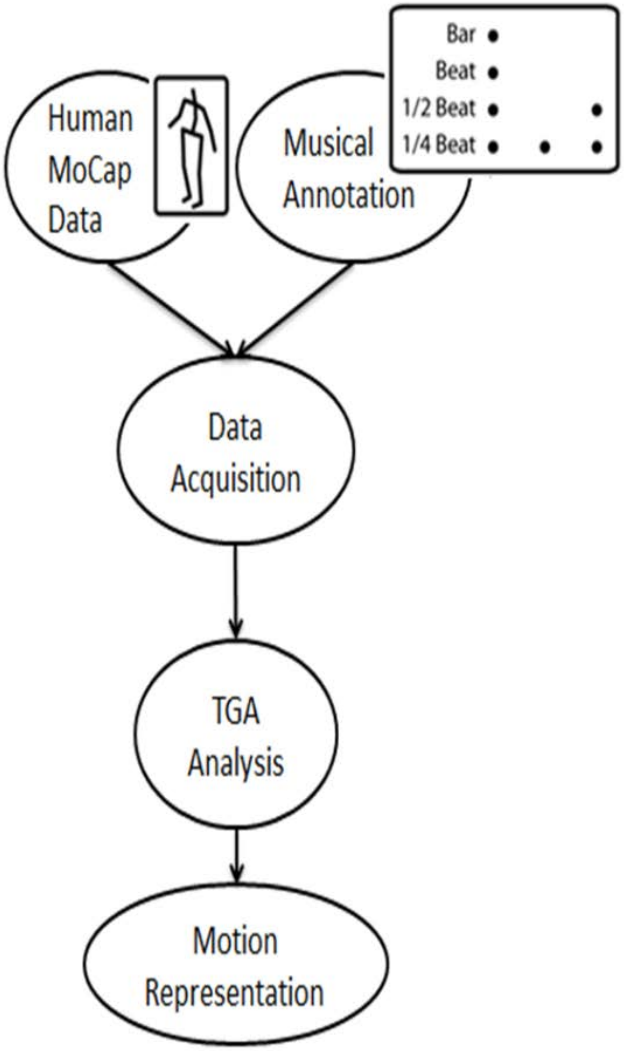
- Improve human-robot social interaction:
  - by means of bodily communication
- Improve robotic expressiveness:
  - By imitation of human motion
- Dance as a rich case study

Goals:

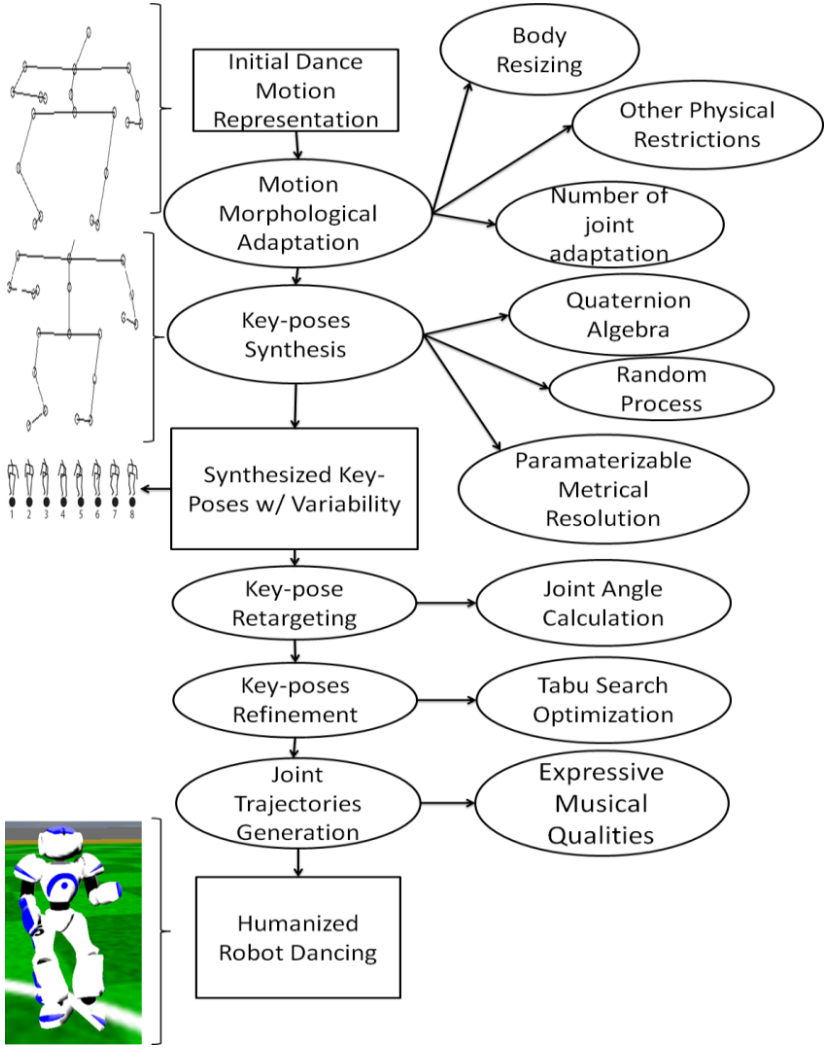
- Map human movement periodic patterns onto humanoid robots
- Model and generate humanoid dance
  - Samba dance style as first case study

Robot Dancing based on RTBT

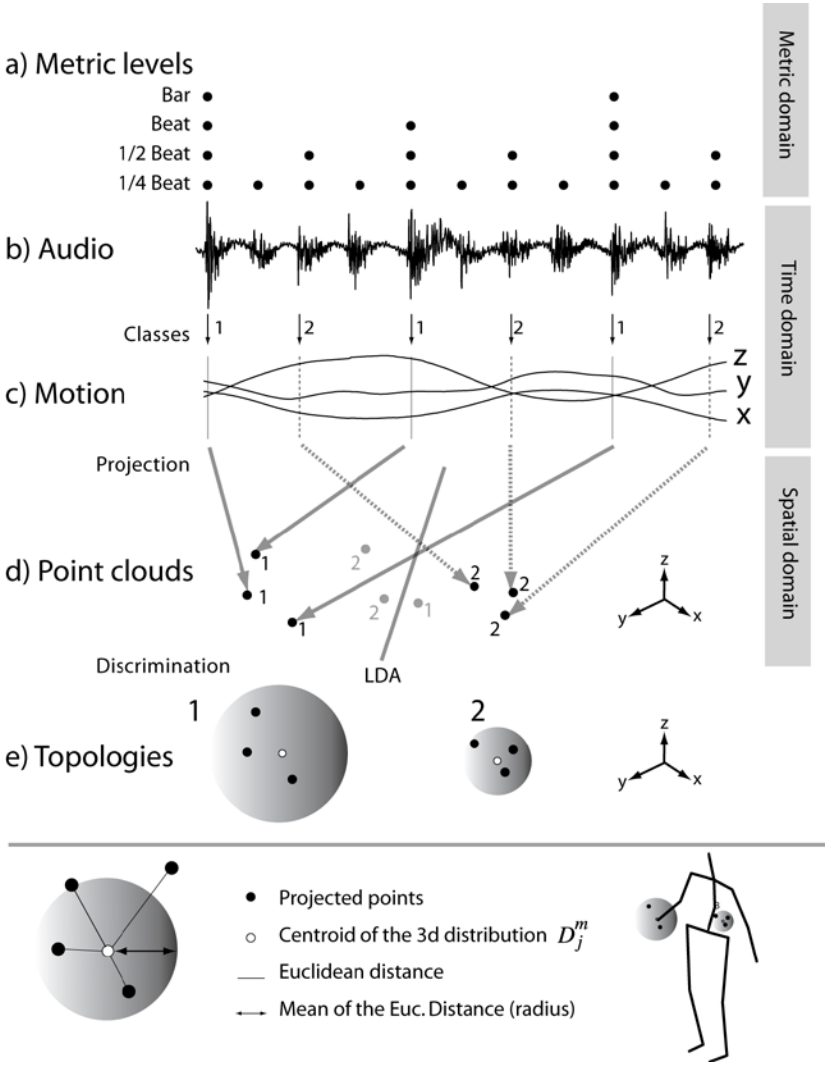
Dance Motion Analysis

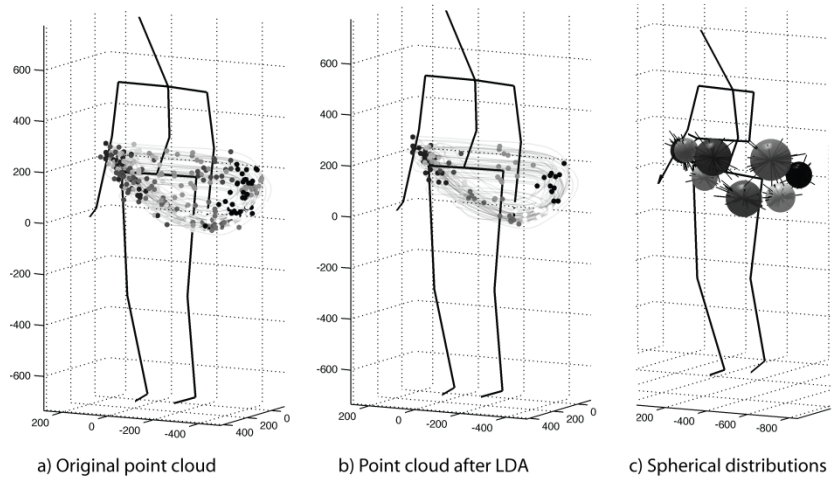


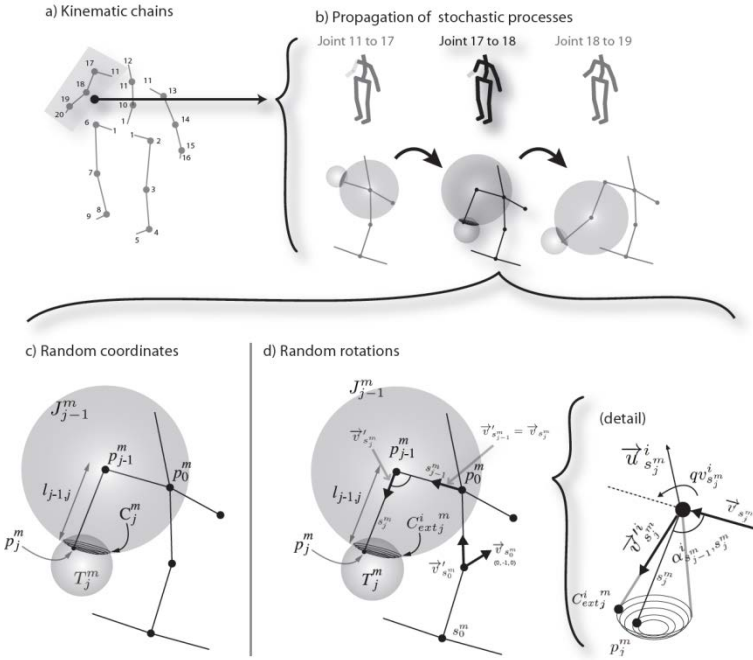
Dance Motion Generation



Robot Dancing based on RTBT

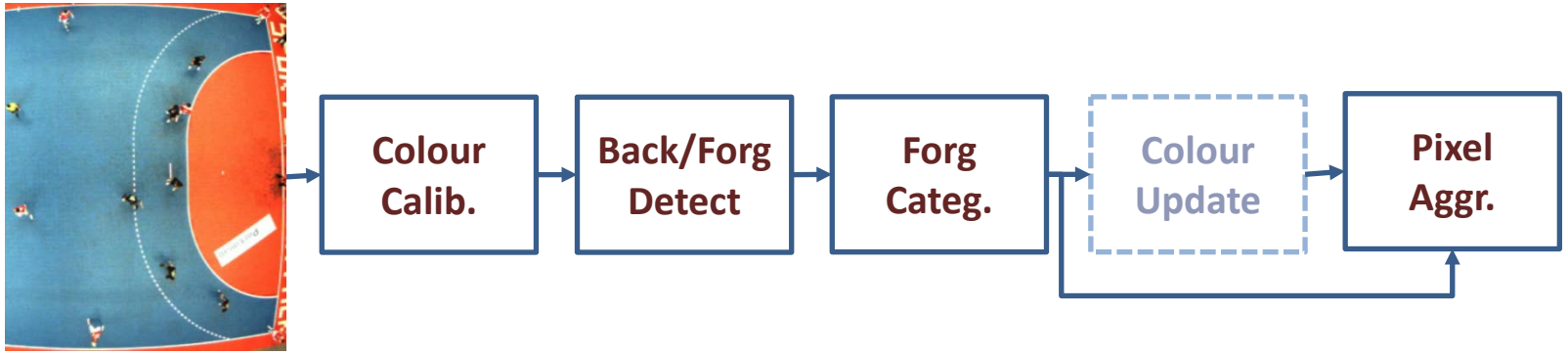






Sports Analysis: Handball and Soccer

- 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

Human Player

POKERLANG

<STRATEGY>::= {<ACTIVATION_CONDITION> <TACTIC>}
<ACTIVATION_CONDITION>::= {<EVALUATOR>}
<TACTIC>::= <PREDEFINED_TACTIC> | <TACTIC_NAME><TACTIC_DEFINITION>
<PREDEFINED_TACTIC>::= loose_agressive | loose_passive | tight_agressive | tight_passive
<TACTIC_NAME>::= [string]
<TACTIC_DEFINITION>::={<BEHAVIOUR> <VALUE>}
<BEHAVIOUR>::= {<RULE>}
<RULE>::= {<EVALUATOR> | <PREDICTOR>} <ACTION>
<EVALUATOR>::= <NUMBER_OF_PLAYERS> | <STACK> | <POT_ODDS> | <HAND_REGION> | <POSITION_AT_TABLE>
<PREDICTOR>::= <IMPLIED_ODDS> | <OPPONENT_HAND> | <OPPONENT_IN_GAME> | <STEAL_BET> | <IMAGE_AT_TABLE>
<ACTION>::= {<PREDEFINED_ACTION><PERC> | <DEFINED_ACTION><PERC>}
<PREDEFINED_ACTION>::= <STEAL_THE_POT> | <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)

- L.Mota, L.P.Reis and N.Lau, **Multi-robot Coordination using Setplays in the Middle-size and Simulation Leagues**, **Mechatronics, Elsevier**, Vol. 21, Issue 2, pp. 434-444, March 2011, Elsevier, ISSN: 0957-4158
- P.HAbreu, J.Moura, D.C.Silva, L.P.Reis, J.Garganta, "**Performance analysis in soccer: a Cartesian coordinates based approach using RoboCup data**", **Soft Computing - A Fusion of Foundations, Methodologies and Applications, Springer**, ISSN: 1432-7643 (In Press, Accepted Mar2011)
- R.A.M. Braga, M.Petry, L.P.Reis, A.P.Moreira, "IntellWheels: A Modular Development Platform for Intelligent Wheelchairs". **JRRD - Journal of Rehabilitation Research and Development**, ISSN: 0748-7711, Dec 2011, Vol. 48, Issue 9, pp. 1061-1076.
- D.Silva, R.A.M.Braga, L.P.Reis, E.Oliveira. "Designing a Meta-Model for a Generic Robotic Agent System using GAIA Methodology". **Information Sciences, Elsevier**, ISSN: 0020-0255 (accepted Dec2010) to appear
- P.Abreu, I.Costa, D.Castelão, J.Moreira, L.P.Reis, J.Garganta, "**Human vs. Virtual Robotic Soccer: A Technical Analysis about two Realities**", **European Journal of Sport Science, Taylor & Francis,** ISSN: 1746-1391 (accepted Nov2010, to appear)
- J.L.Oliveira, L.Naveda, F.Gouyon, L.P.Reis, P.Sousa, M.Leman "A Parameterizable Spatiotemporal Representation of Popular Dance Styles for Humanoid Dancing Characters". Special Issue on Music Content Processing by and for Robots, **EURASIP Journal on Audio, Speech, and Music Processing,** (accepted Nov2011, to appear)

Related Publications (2)

- B.M.Faria, G.Castillo, N.Lau, L.P.Reis, "**Classification of FC Portugal Robotic Soccer Formations: A Comparative Study of Machine Learning Algorithms**", Robotica Magazine, n. 82, 1st Trim., pp. 4-9, 2011, ISSN: 0874-9019
- C.B.Santiago, A.Sousa, L.P.Reis, M.L.Estriga, "**Real Time Colour Based Player Tracking in Indoor Sports**", Comp. Vision and Medical Image Processing, Comp. Meth. in Applied Sciences, 2011, Vol. 19, 17-35, (Springer)
- L.F. Teófilo, L.P.Reis, "Building a no limit Texas hold'em poker agent based on game logs using supervised learning", (2011), 6752 LNAI, pp. 73-82. (Springer)
- P.Martins, L.P.Reis, L.Teófilo, "Poker vision: Playing cards and chips identification based on image processing", (2011), 6669 LNCS, pp. 436-443. (Springer)
- P.Abreu, I.Costa, D.Castelão, L.P.Reis, J.Garganta, "**Human vs. robotic soccer: How far are they? A statistical comparison**", (2011), 6556 LNAI, pp. 242-253. (Springer)
- N.Shafii, L.P.Reis, N.Lau, "**Biped walking using coronal and sagittal movements based on truncated Fourier series**", (2011) , 6556 LNAI, pp. 324-335. (Springer)
- E.Domingues, N.Lau, B.Pimentel, N.Shafii, L.P.Reis, A.J.R.Neves, "**Humanoid behaviors: From simulation to a real robot**" (2011), 7026 LNAI, pp. 352-364. (Springer)
- A.S.Pinto, A.Pronobis, L.P. Reis, "Novelty detection using graphical models for semantic room classification", (2011) 7026 LNAI, pp. 326-339. (Springer)
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Questions?

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