Coordinated Team Play in the RoboCup Four-Legged League

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Coordinated Team Play in the RoboCup Four-Legged League

Outline

- RoboCup
- Four-Legged League
- Team Coordination
- Implementation
- [Communication]
- Results
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**RoboCup**

- **RoboCup**
  - robotic soccer competition
  - started in 1993/1994 by Hiroaki Kitano in Japan
  - RoboCup federation: [www.robocup.org](http://www.robocup.org)

- **Extensions**
  - RoboRescue: search and rescue missions
  - RoboCup@home, RoboCup Junior, RoboDance

- **Vision**
  - “*By the year 2050, to develop a team of fully autonomous humanoid robots that can win against the human world soccer champions*”
  - 2002 was the first year with a humanoid robot league!
  - "*One small step for a ROBOT, one giant leap for mankind.*"™

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Where do we stand today?
RoboCup Soccer Leagues

- **Simulation League**
  - 11 vs. 11 independent software agents

- **Small-Size Robot League**
  - 5 vs. 5 small robots up to 18 cm in diameter

- **Middle-Size Robot League**
  - 6 vs. 6 robots up to 50 cm in diameter

- **Four-Legged Robot League**
  - 4 vs. 4 Sony AIBO robots

- **Humanoid Robot League**
  - 2 vs. 2 bipedal humanoid robots
Why RoboCup?

- **Research Challenges**
  - can I see clearly? [machine vision]
  - what do I see and where? [object recognition]
  - where am I right now? [localization]
  - what do I do next? [planning]
  - how can I help my teammates? [coordination]
  - how can I move effectively? [motion control]
  - am I sure about what is going on? [uncertainty]
  - do I have to do everything? [integrated solutions]
  - can I take my time? [real-time decision making]

- **Applicability**
  - autonomous teams of robots in dynamic environments
  - search and rescue, planetary exploration, surveillance, ...
## RoboCup Participation

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<td>Nagoya, Japan</td>
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Team Κουρήτες (Kouretes)

- **Team**
  - Kouretes: ancient Cretan warriors
  - founded in January 2006

- **2007 Members**
  - Georgios Kontes
  - Chrysavgi Kontogeorgou
  - Andreas Panakos
  - Alexandros Paraschos
  - Petros Patelis
  - Georgios Pierris
  - Suzanna Volioti
Where the team stands...

- **Pioneer**
  - the first (and only) RoboCup team in Greece

- **Participation**
  - RoboCup 2006 [ Technical Challenges ]
  - RoboCup German Open 2007 [ Four-Legged League ]
  - RoboCup 2007 [ MS Simulation Challenge ]

- **Distinctions**
  - 2nd place [ MS Simulation Challenge – RoboCup 2007]
  - 7th place [ Four-Legged League – RoboCup German Open 2007 ]

- **Website**
  - [www.intelligence.tuc.gr/kouretes](http://www.intelligence.tuc.gr/kouretes)
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Four-Legged League

- **Characteristics**
  - standard robotic platform
  - directed visual perception
  - autonomous operation

- **History**
  - first competition was held in 1998
  - last competition will be held in 2008

- **Future**
  - standard platform league
  - Nao humanoid robots (Aldebaran Robotics)
  - first competition to be held in 2008
Coordinated Team Play in the RoboCup Four-Legged League

Sony AIBO ERS-7 Robots

- Features-front
  - Stereo Microphone
  - Illume-Face LED panel
  - Distance Sensor
  - 350K-pixel Image Sensor
  - Edge Detection Sensor
  - Speaker 64 Chords MIDI Sound
  - IEEE 802.11b Wireless LAN
  - Acceleration Sensor Vibration Sensor
  - Wireless on/off Switch Volume Switch
  - Paw Sensors
Sony AIBO ERS-7 Robots

Features:
- Wireless Status LED
- Mode LED
- Pause Button
- 576 MHz 64-bit RISC CPU
- 64 Chords MIDI
- Tactile Head Touch Sensor
- Chin Sensor
- Back LED
- Tactile Back Sensors
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Four-Legged League Field

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Four-Legged League
Coordinated Team Play in the RoboCup Four-Legged League

Four-Legged Game Flow

- States:
  - Ready
  - Set
  - Playing
  - Penalized
  - Finished

- State Change by:
  - Message from GameController
  - Pressing switch
    - (ERS-210: back, ERS-7: head)
    - Pressing switch > 3 sec
    - Pressing back switch > 1 sec
    - No button interface

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Kouretes in Action
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Four-Legged League Challenges

- **Motion**
  - legged locomotion: 3 degrees of freedom per leg
  - ball handling: grab, dribble, kick with legs, body, head

- **Vision**
  - directed sensing: 3 degrees of freedom on the head
  - “unstable” camera view during locomotion

- **Localization**
  - limited view of landmarks, perceptual aliasing

- **Behavior**
  - behavior planning, team coordination, role assignment
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Team Coordination

- **Problem**
  - what should I do next?
  - how can I collaborate with my teammates?
  - how can the team act in a coordinated manner?

- **Why?**
  - soccer is a team game
  - there are four players in a large field
  - unity is power!

- **Current “state-of-the-art”**
  - chase after the ball
  - act independently
Coordinated Team Play in the RoboCup Four-Legged League

The Passing Challenge
Existing Approaches

- **Proximity-based** [GermanTeam, SPQRL, Araibo, ...]
  - estimate the proximity of each player to the ball
  - communicate the estimated distance to all teammates
  - dynamically assign roles according to the estimated distance

- **Auction-based** [Cerberus]
  - compute a numeric bid for a selected available task
  - communicate the bids to all teammates
  - determine the winner(s) and assign roles

- **Shortcomings**
  - short-sighted strategy
  - subject to errors
  - heavy network traffic
Our Approach

- Coordination
  - adopt strategies and tactics from real soccer
  - define clear static roles in each tactic
  - switch tactics according to the current game state

- Benefits
  - exploitation of tested strategies and tactics
  - truly coordinated team play
  - decentralized decision making
  - no confusion in role assignment
  - incorporation of “locker room conventions”
  - expandable and modular coordination module
The 4-4-2 System
RoboCup “4-4-2” System

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Roles and Tactics

- **Roles**
  - goalkeeper
  - defender
  - midfielder
  - attacker

- **Tactics**
  - passive defense
  - pressing defense
  - counter attack
  - passing attack
  - ...

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Coordinated Team Play in the RoboCup Four-Legged League

Tactic #1: Passive Defense
Tactic #2: Pressing Defense
Tactic #3: Counter Attack
Tactic #4: Passing Attack
Dynamic Tactic Selection

Graph showing the dynamic tactics and transitions:
- **Counter Attack**
  - Ball Pass
  - Ball in Opposite Half
  - Won Ball In Opposite Half
  - Ball Lost
- **Pressing Defense**
  - Ball in Opposite Half
  - Won Ball In Opposite Half
  - Won Ball In Own Half
  - Ball Lost
- **Passing Attack**
  - Ball in Opposite Half
  - Won Ball In Own Half
  - Ball Lost
- **Passive Defense**
  - Ball in Own Half
  - Attacker in Opposite Half
  - Won Ball In Opposite Half
  - Ball Lost
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Petri Net Plans (PNPs)

- **Petri Nets** [Peterson, 1981; Murata, 1989; ...]
  - graphical language for modeling dynamical systems
  - weighted directed graph with ...
    - nodes: places or transitions
    - edges: paths of execution or conditions
    - tokens: flow of execution

- **Petri Net Plans** [Ziparo and Iocchi, MOCA 2006]
  - extended Petri Nets with unweighted edges
  - action representation in three phases
    - initiation, execution, termination
  - description of various control structures
    - sequences, loops, splits, joins, parallel branches, interrupts, synchronization
  - hierarchical plan decomposition (reusability)
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A Simple Petri Net Plan

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Roles as Petri Net Plans

- **Role PNPs**
  - each role in each tactic yields a different PNP
  - 12 Petri Net Plans for 3 roles in each of the 4 tactics
  - 1 Petri Net Plan for the goalkeeper role

- **Hierarchy**
  - actions in the PNPs are primitive actions or other PNPs
  - balance between the complexity of primitive actions and PNPs
  - reusable primitive actions in many plans
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Counter Attack Attacker PNP

PLAN NAME: CA_Attacker

MidfielderInPositionClear

startActDribbleForward

startActPassToMidfielder

ex.ActPassToMidfielder
end.ActPassToMidfielder

startActPassSentSignal

ex.ActPassSentSignal
end.ActPassSentSignal

GOAL

NearBall

BallNotGrabbed

BallGrabbed

NearOpponentsGoal

start.Kick

ex.Kick
end.Kick

NotNearBall

start.ActGrabBall

ex.ActGrabBall

end.ActGrabBall

start.ActSwitchTactic

ex.ActSwitchTactic
end.ActSwitchTactic

GOAL

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Software Architecture

- **Evolution**
  - German Team 2004
  - SPQR-Legged 2006
  - Kouretes 2007

- **Code**
  - C++ modules
  - PNP parser and executor
  - PsychoJARP

- **Behavior module**
  - input from 4 modules
  - output to 3 modules
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Robot Communication

- **Constraints**
  - visual or auditory communication is difficult
  - limited wireless data communication is allowed

- **Messages**
  - necessary to trigger tactic selection
  - a single message over the network at each moment

- **Advantages**
  - less network traffic
  - no need for simultaneous messages
  - no need for synchronized messages
Communication Module

- **Experiment**
  - players 1 and 2 seek the ball, while players 3 and 4 stay idle
  - if ball is seen by player 1, the behaviors above reverse
  - player 1 sends message to player 2, if the ball is seen/lost
  - player 2 sends messages to players 3 and 4 to switch behavior

- **Original module**
  - UDP broadcast protocol

- **Enhanced module**
  - UDP broadcast protocol ...
  - ... with message retransmission
  - new tag <time, original sender>
  - circulation of messages
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Communication Tests

![Graphs showing communication tests for Original and Enhanced Modules.](image-url)
Communication Experiment
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Pressing Defense (Defender)
Pressing Defense (Midfielder)
Pressing Defense (Attacker)
Pressing Defense (All Players)
Summary of Results

- **Observed Team Play**
  - even distribution on the field
  - no crowding around the ball

- **Tests in RoboCup Games**
  - RoboCup German Open 2007 Competition
    April 2007, Hanover, Germany
  - HiTech Innovator’s Partenariat Demonstration Games
    October 2007, Thessaloniki, Greece

- **Limitations**
  - sensitive to localization and object recognition failures
  - dynamic role assignment is needed in extreme situations
Conclusion

- **Contribution**
  - soccer strategies, tactics, and roles in RoboCup games
  - flexible and extendable design
  - roles as Petri Net Plans, tactic selection as FSM
  - testing on RoboCup team Kouretes

- **Applicability**
  - multi-robot applications: search-and-rescue, exploration, ...

- **Future Work**
  - additional (learned) tactics and dynamic role assignment
  - TCP/IP communication module (access point)
  - transfer to other leagues: simulation and the new SPL
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Thank you!