Intelligent Humanoid Robot

Prof. Mayez Al-Mouhamed
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http://www.ccse.kfupm.edu.sa/~mayez

Computer Engineering Department

King Fahd University of Petroleum and Minerals
**RoboCup**: Goal

By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champion team.

- More than 3000 researchers from about 35 countries / regions.
- The RoboCup Federation: a Non Profit Organization registered in Switzerland.
- National Committees in more than 10 countries. Supporting conferences and coordinating research with industry and related government organization.
Can we accomplish the goal?

Apollo Project
• **Dream:** Send men to the moon and safely return them to the earth.
• **Technologies:** systems science, electronics, aviation, project management, etc.
• **First Airplane and fifty years later a man landed on the moon!**
Computer Chess
ENIAC 1946

Deep Blue Computer Chess
• Dream: to develop a computer that can beat human chess champion.
• Technologies: Search algorithms, parallel computing, parallel computer architectures, etc.
• Effects: Basic computer algorithms, parallel programming, etc.
Discovery of DNA and 50 years later the Completion of genome analysis
What is RoboCup?
RoboCup is like the “Apollo Project in the 21st century”. By achieving a landmark: to develop a humanoid robot team which can compete with human soccer champion team in 50 years, by the year 2050, realize a new era in which robots truly contribute to human society.
The RoboCup Federation

RoboCupSoccer

- Simulation League (2D, 3D)
- Small Robot League (F-180)
- Middle Size Robot League (F-2000)
- Sony 4-Legged Robot League
- Humanoid League
- RoboCupRescue
- Rescue Simulation League
- Rescue Robot League
- RoboCupJunior
- Soccer
- Rescue
- Dance
International project holding annual world championship to promote joint research of artificial intelligence and robotics with the subject of football by fully-autonomous robots

- History of RoboCup Championships -
  • 1997: 1st in Nagoya, Japan
  • 1998: 2nd in Paris, France
  • 1999: 3rd in Stockholm, Sweden
  • 2000: 4th in Melbourne, Australia
  • 2001: 5th in Seattle, USA
  • 2002: 6th in Fukuoka, Japan
  • 2003: 7th in Padua, Italy
  • 2004: 8th in Lisbon, Portugal
  • 2005: 9th in Osaka, Japan
  • 2006: 10th in Bremen, Germany
Application of RoboCup technologies

• Disaster rescue
• Intelligent Traffic Systems (ITS)
• Deep space exploration
• Office robots
• Distributed agents

RoboCup : Activities

• RoboCupSoccer
  Research project using soccer
• RoboCupJunior
  International education project using robots
• RoboCupRescue
  Disaster rescue system research
**Robocup Leagues**

Humanoid League  
Official league of humanoid robots in which those can do penalty kick, walking, free performance and so on. Expected to be a core league in the near future.

Small-sized League  
Soccer by 5 vs. 5 wheel robots within 15 cm diameter with orange golf ball in the table tennis sized court.

Sony 4 legged League  
League utilizing 4 specially-programmed SONY AIBO

Simulation League  
11 virtual robots with AI program play soccer games in the field on the server. Remote participation is possible from anywhere.

Middle-sized League  
Soccer by 4 vs. 4 wheel robots within 45 cm diameter with an orange indoor soccer ball in 9x5 m field.
Some Robocup Leagues

- Legged Robot League
- Small-sized League
- Middle-sized League
- Humanoid League
Humanoid League

1. Standing on one leg
2. Walking
   Walk the distance 5 times of the robot height.
3. Penalty Kick
   40cm, 80cm and 120cm classes.
   5 goals per team.
4. Free Style
   5 minutes free demonstration

Table 1: Soccer field sizes, in cm.

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RoboCup Drives Research in
• Control algorithms,
• Machine vision, sensing and localization,
• Real-time distributed computing,
• Real-time ad hoc networking,
• Mechanical design,
• Machine learning, and
• Autonomous multiagent systems
Why RoboCup?

• A Landmark Project
  Challenging goal and spill-over of technologies

• Outcome-based
  A platform for project-oriented education in science and technology

• A standard problem for AI and robotics.
Why This New Course?

- Robocup matured experience (Germany, Japan, Iran, USA, etc.)
  - Long: since 1996
  - Diversified: simulation, small-size, Sony 4-legged
  - Hard work, frustration, fun, struggle, success
  - A LOT learned on:

Creating teams of completing intelligent robots.
Expanding the experience to highschool  
RoboCup phenomenon started at the primary and secondary school-age levels will prove to be of excellent educational value at the undergraduate level.

Education and social aspects
• contests were held in a public space,
• students were encouraged to invite their friends to come and watch,
• other faculty members also came to observe
• Moral: he excitement of the crowd and the visibility of the event motivated students to work harder after the first (maze) contest in preparing for the second (soccer) contest.
• Motivation
Tournaments are being organized using the robots, and the energy, enthusiasm, and motivation displayed by students is unsurpassed.

• Learning Objective
The ability to demonstrate theoretical models and complex algorithms with a hands-on, accessible medium, strengthens the learning experience for students.

• RoboCup Educational Level
Adv. undergraduate and early graduate courses, a repository of curricular materials, replicate and expand others efforts.

• Advanced Learning Tool
Empirically witnessed increased excitement, interest, and motivation of the students, need to formalize these observations with a scientific study of the RoboCup learning environment.
Autonomous Robot

- Perception
- Cognition
- Action

Sensors

External World

Actuators
Behaviors, action selection, planning, learning
Multi-robot coordination, teamwork
Response to opponent, multi-agent learning

Sensing, modeling the world

Perception → Cognition → Action

Motion, navigation, obstacle avoidance

Sensors

External World

Actuators
Autonomy

I. Perception
   - sensing, modeling of the world

II. Cognition
   - behaviors, action selection, planning, learning
   - multi-robot coordination, teamwork
   - response to opponent, multi-agent learning

III. Action
   - motion, navigation, obstacle avoidance
Autonomous Robots

The basic software architecture
I - Action: Motion

- Four-legged walking
- Head motion
- Turning, kicking
The Problem of Body Movements

How to walk, jump and run?
How to kick and dribble?
How to stand up?
The Problem of Body Movements

Modeling Motions

Which angles are useful?

Complex Calculations: Direct (given angles compute position)
Indirect (given position compute angles)

How can humans walk? without knowing physics and calculations?
II - Perception: sensing for a better perception

Perception by Humans (Integration):

\[
\text{Belief}_\text{new} := \text{update} (\text{Perception}, \text{Belief}_\text{old});
\]

Perception by Humans (Interpretation):

Competing interpretations
Perception: vision

- Real-time and robust
- Effective calibration
- Colored blobs identified as objects
- Confidence computed
Robot Perception

Example of image processing and features extraction of the ball: Acquire, segmentation, blob detection, and Ball extraction.
The Problem of Perception

Example of image processing and features extraction of several colors: original, quantized, main colors, and recognition.
Perception := sense(SensoryData);
How to Understand the World
Perception means interpretation by integration of
- Old perceptions
- Data from different sensors
- Objects identified from recent percepts
- Knowledge about the world
All information is incomplete and unreliable.
But: Many redundancies can be exploited using methods from statistics and constraint satisfaction.
Exploiting Redundancy

The size of the goal defines a circle of possible positions of the observer.
Exploiting Redundancy

The size of the ball defines a circle of possible positions of the ball relative to the observer.
Exploiting Redundancy

The ball lies on a line before the penalty border line
Exploiting Redundancy

The ball lies on a line between goal post and observer
Exploiting Redundancy

Combination yields 2 possible positions
Exploiting Redundancy

Combination yields 2 possible positions
III - Cognition: Behaviors

How to Understand the World
Parts of a Dialog with the ITA:
Customer: *Would like to travel. Next month during vacations ... Yes, swimming is ok. ... nice picture ... Want to see other people ... No, don't like such rocks. ... Warm water is important for my children ... good food...*

• Information is incomplete and unreliable.
• Integration from different sources is useful (sensor fusion)

Understand the World
• How to “Understand Myself” (cognitive)
• How to use the body? How to stand up, walk, jump and run? (control)
• How to kick and dribble? (decision)
• When to perform a double pass? (cooperation)
Further Questions:

**How to Play**

- Where am I? (self-localization vs landmarks)
- Where is the ball? (localization)
- Where are the others?
- What are they doing?
- What shall I do?

**How to Play:**

- Belief: What is the state of the world
- Desires: What are my wishes
- Intention: Which desires will I realize
- Plans: How can I realize my intentions

**Models for beliefs, goals, intentions plans** (*Agent Oriented Techniques*):

- Program structure for agents/robots
- Models of partners/opponents in the program

**Models of others:**

What are their beliefs/desires/intentions/plans
Three different situations at RoboCup (2006):

(a) Dribbling challenge
(b) Goalkeeper
(c) Ball Search
Behaviors

- Score
  - not see ball
  - next to ball
  - not next to ball

- Recover
  - not see ball
  - timeout

- Approach
  - not see ball

- Search
  - see ball
  - not see ball
Arbiter in context environment.
The finite state machine implemented in RobotCore controlling the behavior of the soccer robot.
Programming Soccer Robots

What can we learn?

How to understand the world.
How to realize rational behavior in the daily world.

*It is not really important, if robots will win in 2050 ...*
Machine Learning
Use „trial and error“.
• Evolutionary Algorithms
• Reinforcement Learning
• Case Based Reasoning
• Neural Networks


Proprioception:
Feeling the own Body
AUTONOMOUS ROBOTICS

Syllabus

- Actuator and control
- Motion and Kinematics
- Sensing and vision
- Intelligent Behaviors
- Behavior Programming
- Localization
- Complex behaviors
- Robocup simulator (project)
Resources and Readings

- Readings and videos are available at:
  http://www.cs.cmu.edu/~coral

- http://www.robocup.org
- The OpenR Web page has a lot of information:
  http://openr.aibo.com
- API for the AIBOs: http://www.cs.cmu.edu/~tekkotsu
Thanks to

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- Prof. Manuela Veloso, Computer Science Department, CMU.
- Dr. Thomas Röfer, Breman University, Germany.
- Dr. E. SKLAR, Brooklyn College, City Univ. of New York
- “A light software architecture for a Humanoid Soccer Robot”, A. Maggi et al., IAS-Lab, Dep. of Information Engineering, University of Padua, Italy