Intelligent Humanoid Robot

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RoboCup : Goal

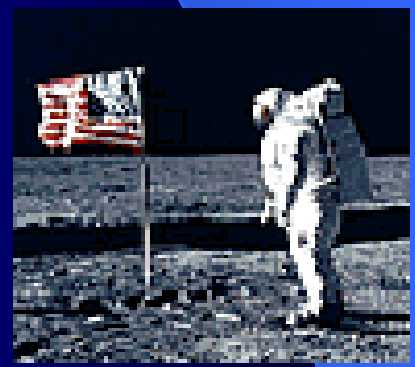
By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champion team.

- 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!**

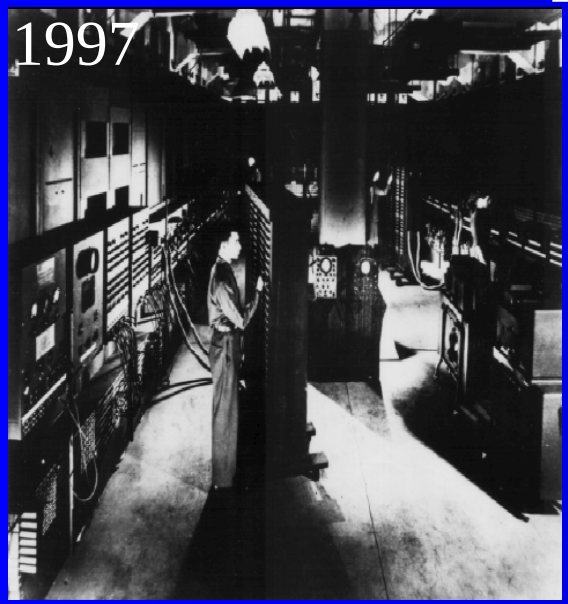


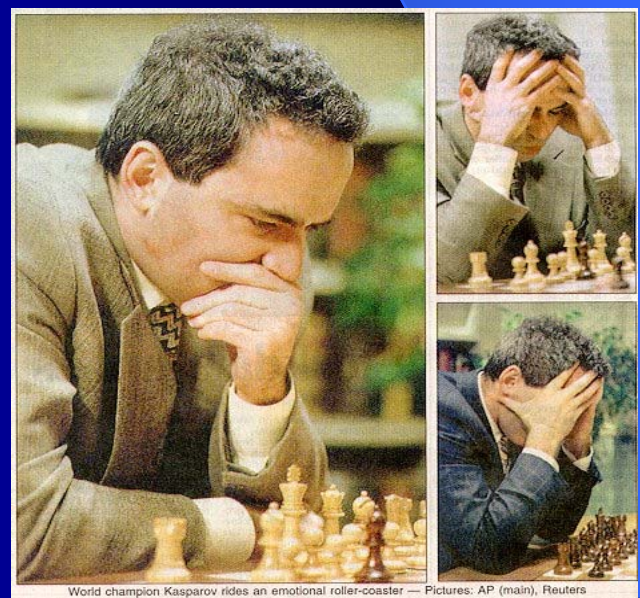
Computer Chess
ENIAC 1946

Deep Blue **Computer Chess**

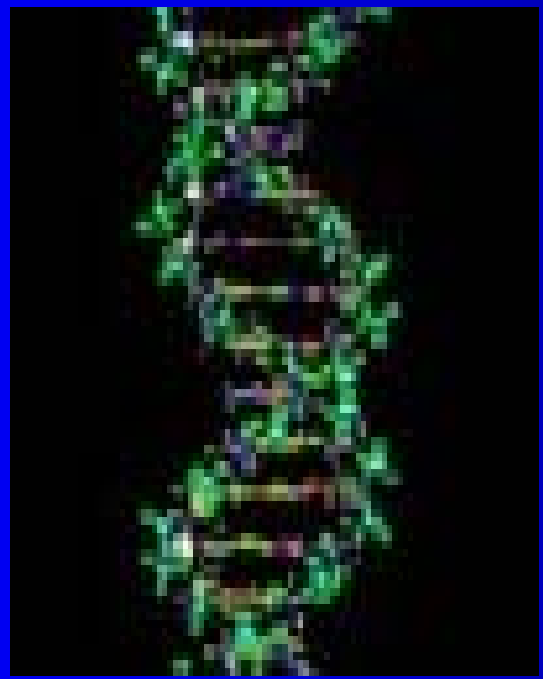
- **Dream: to develop a computer that can beat human chess champion.**
- **Technologies: Search algorithms, parallel computing, parallel compuer architectures, etc.**
- **Effects: Basic computer algorithms, parallel programming, etc.**

1997





Discovery of DNA and 50 years later the Completion of genome analysis



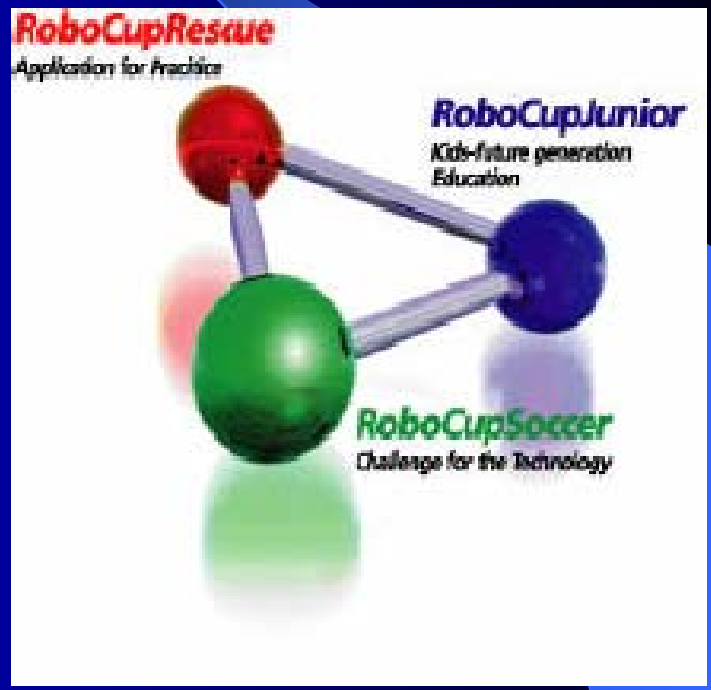
What is RoboCup?

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



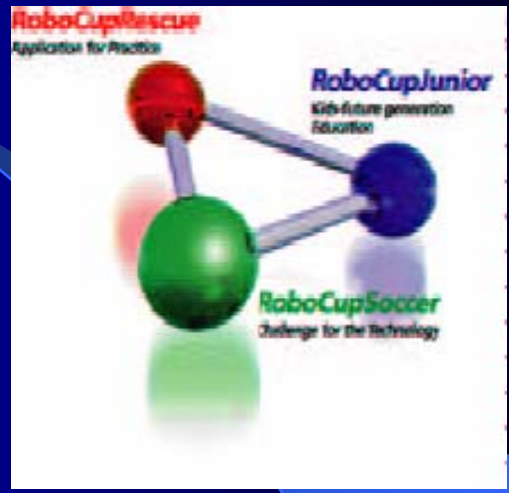
•International project holding annual world championship to promote joint research of artificial intelligence and robotics with the subject of football by fully-autonomous robots

- 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

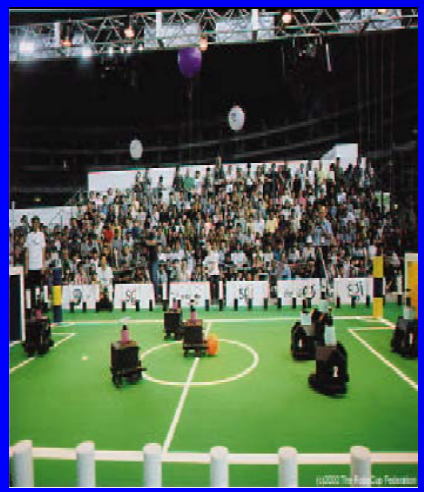
11 virtual robots with AI program play soccer games in the field on the server. Remote participation is possible from anywhere.

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

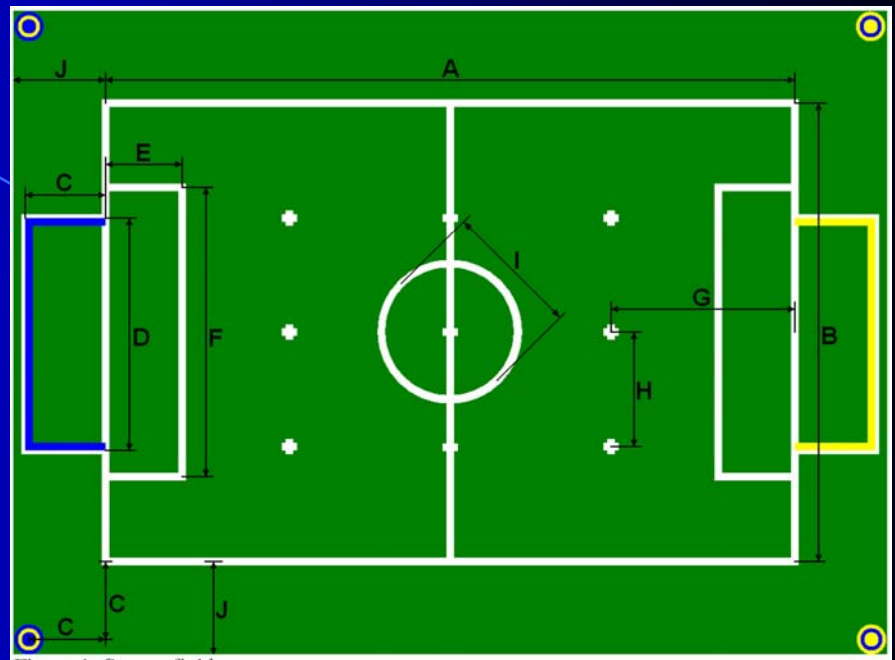


Figure 1: Soccer field.

Table 1: Soccer field sizes, in cm.

		KidSize	TeenSize
A	Field length	**450**	**600**
B	Field width	**300**	**400**
C	Goal length	**50**	**60**
D	Goal width	**150**	**260**
E	Goal area length	**50**	**60**
F	Goal area width	**190**	**300**
G	Penalty kick distance	**120**	**180**
H	Restart marker width	**75**	**100**
I	Center circle diameter	**90**	**120**
J	Border strip width (min.)	**60**	**70**

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 technolgoies

- **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

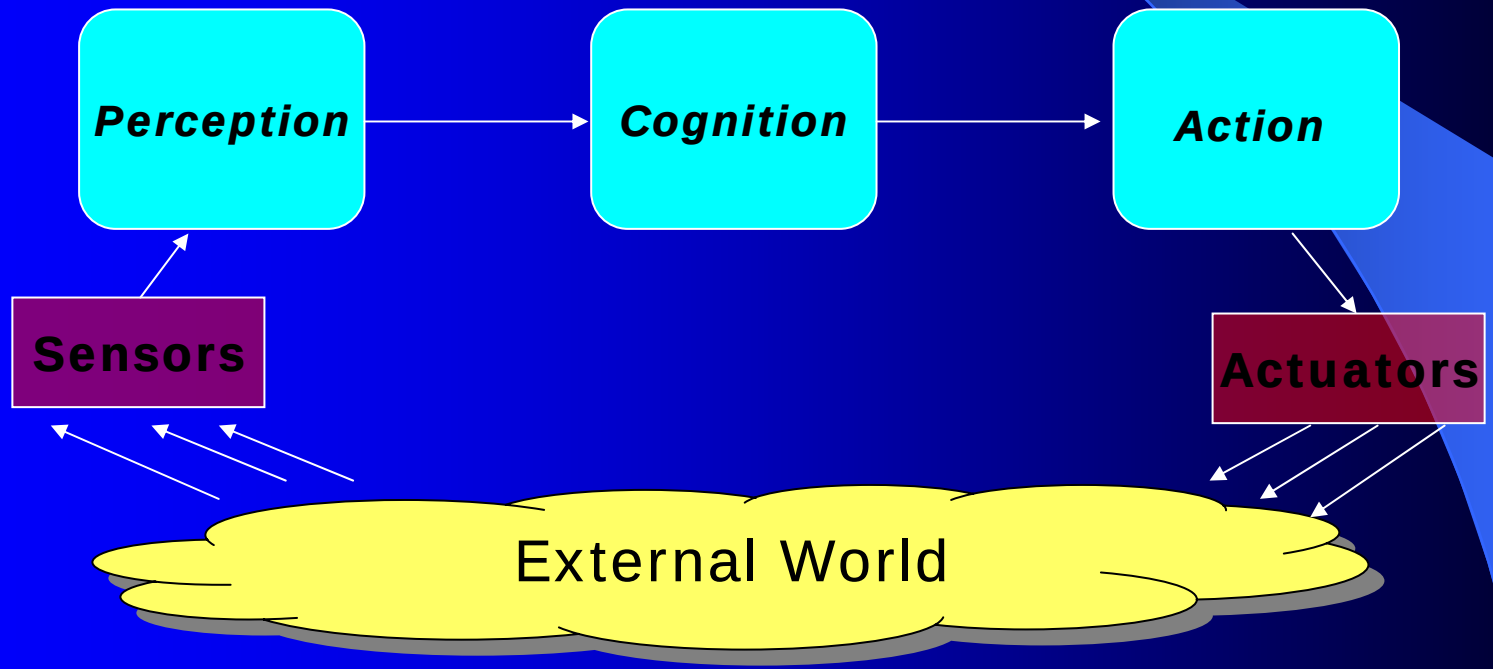
• RoboCup Educational Level

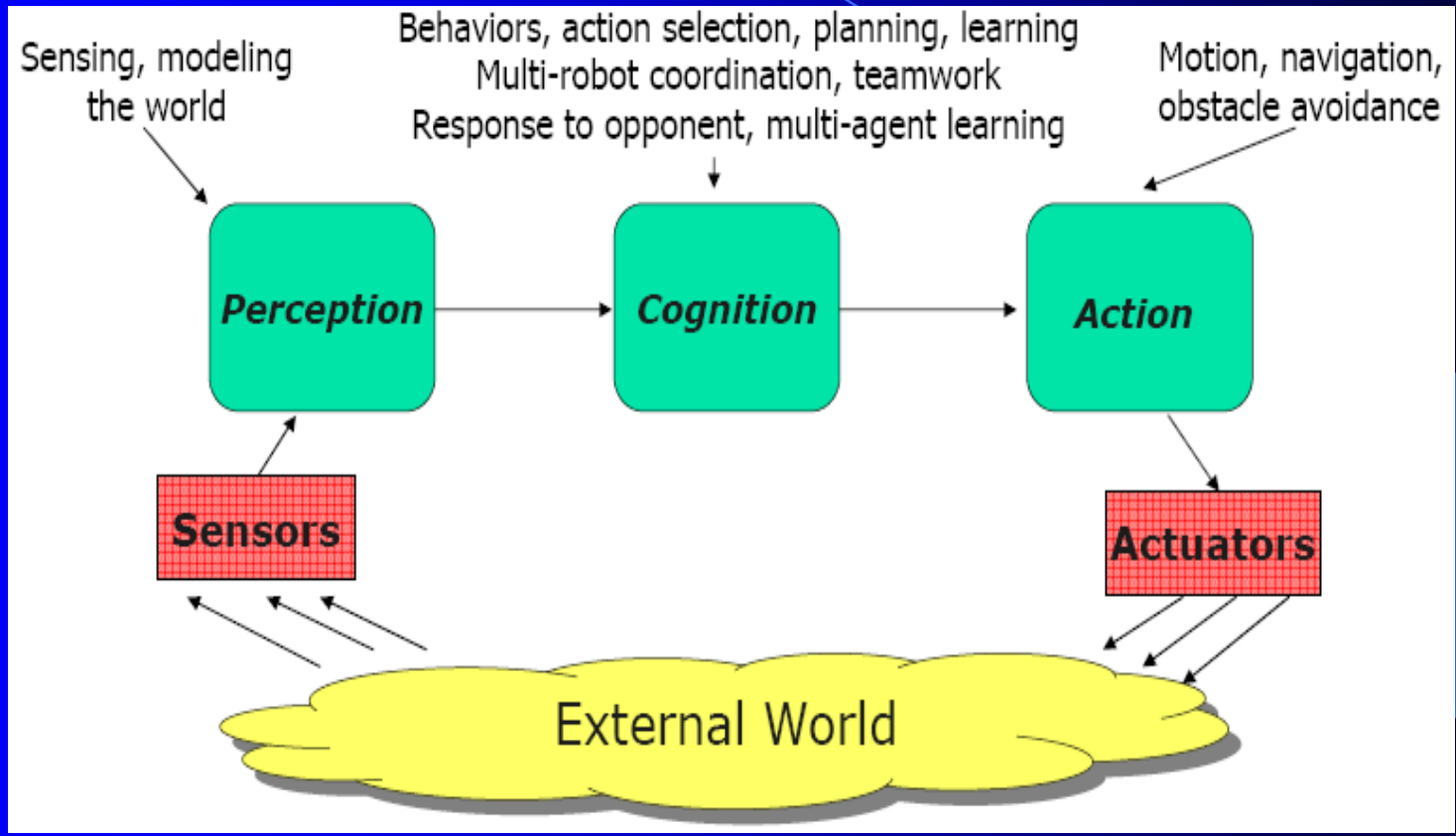
Adv. undergraduate and early graduate courses, a repository of curricular materials, replicate and expand others efforts.

•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




Sensing, modeling
the world
Behaviors, action selection, planning, learning
Multi-robot coordination, teamwork
Response to opponent, multi-agent learning
Motion, navigation,
obstacle avoidance
Perception
Cognition
Action
Sensors
Actuators
External World

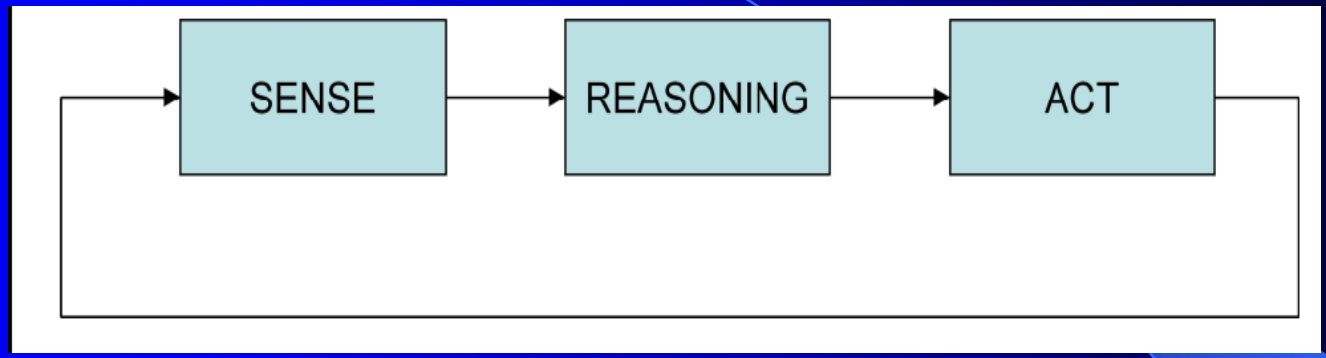
Autonomy

I. Perception
   - sensing, modeling of the world

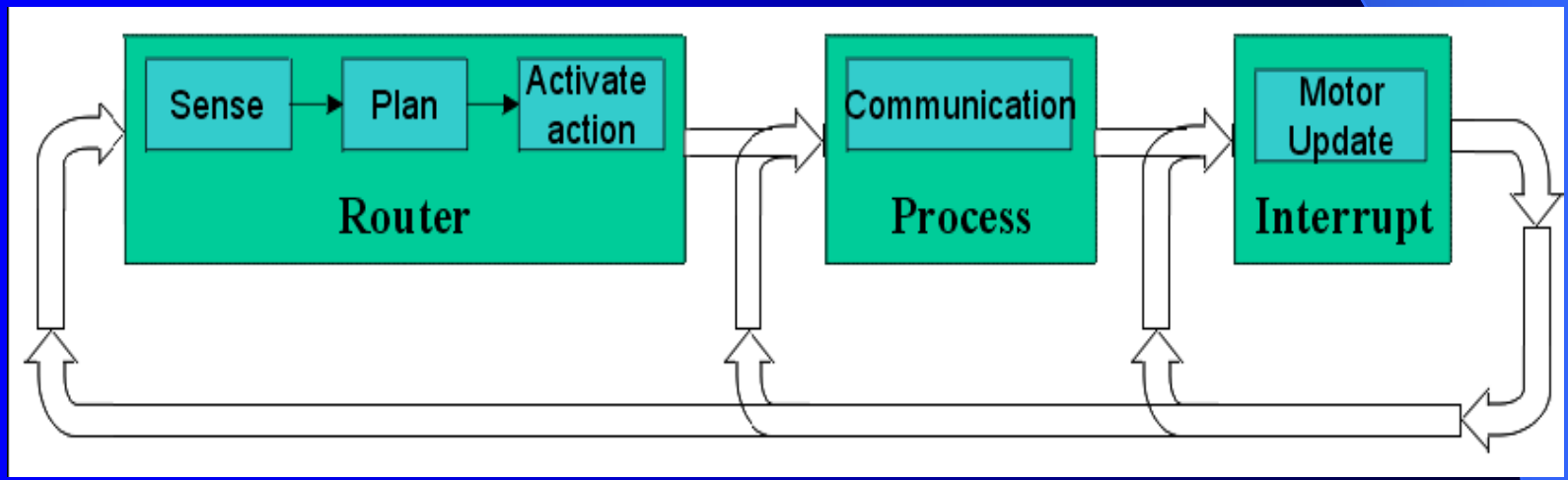
II. Cognition
   - behaviors, action selection, planning, learning
   - multi-robot coordination, teamwork
   - response to opponent, multi-agent learning

III. Action
   - motion, navigation, obstacle avoidance

Autonomous Robots



The basic software architecture

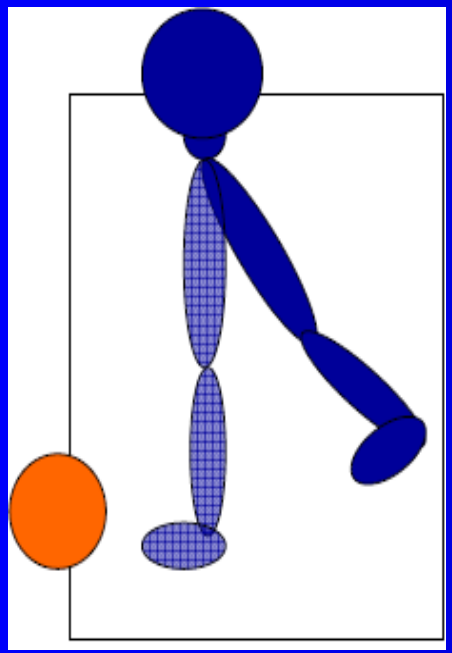


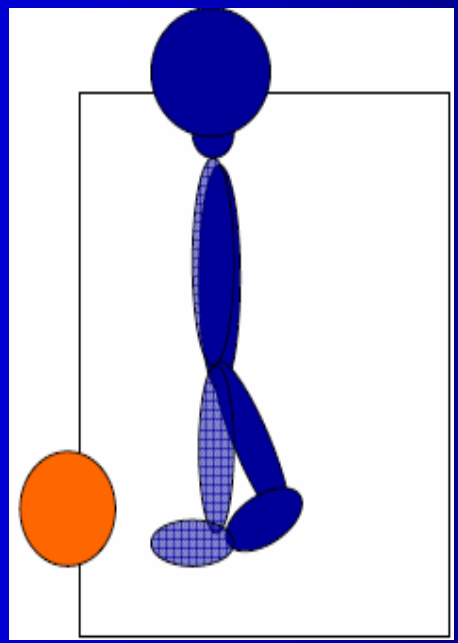
I - Action: Motion

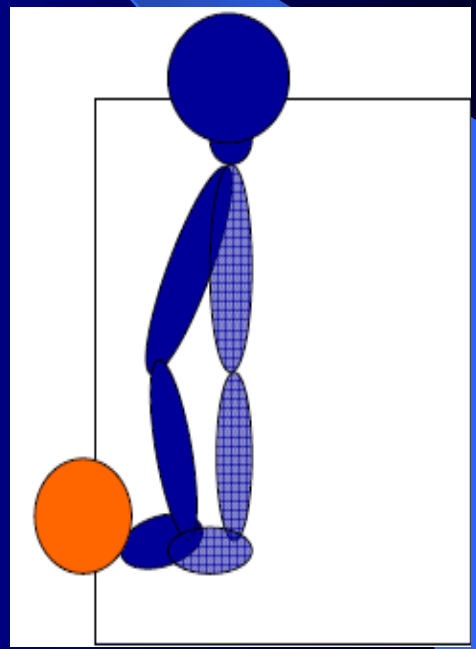
- Four-legged walking
- Head motion
- Turning, kicking

The Problem of Body Movements

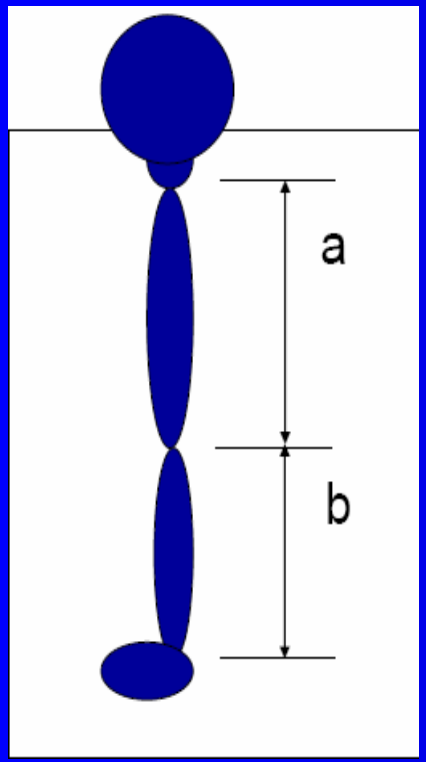
How to walk, jump and run?
How to kick and dribble?
How to stand up?

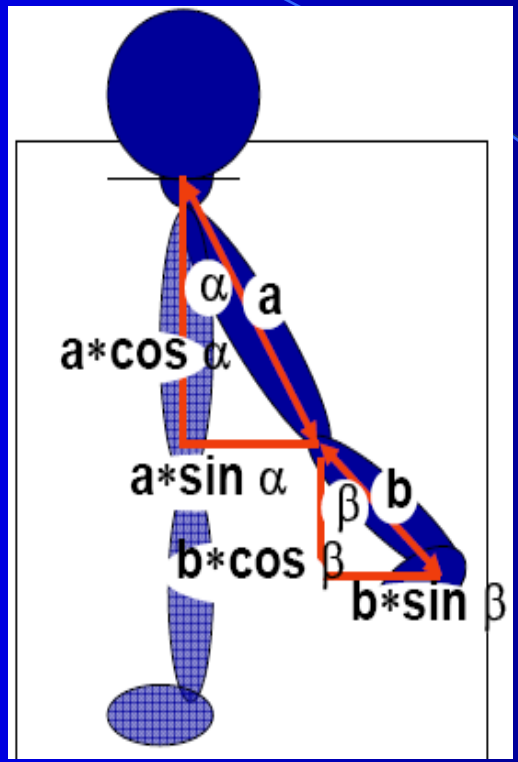


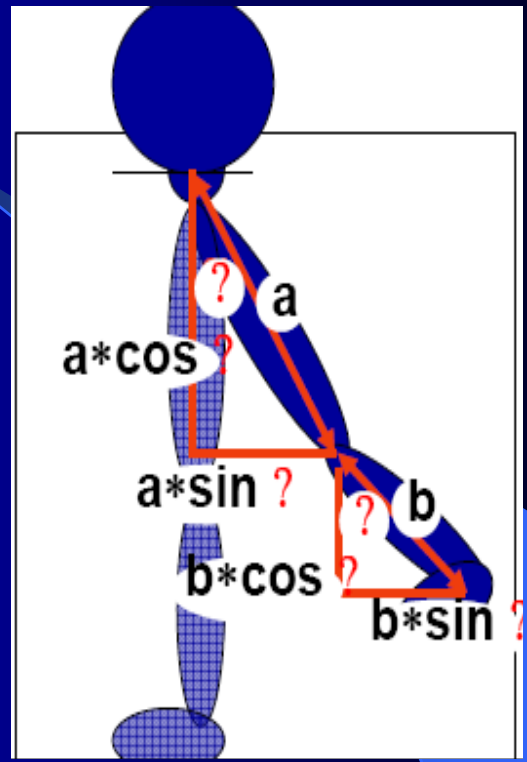




The Problem of Body Movements





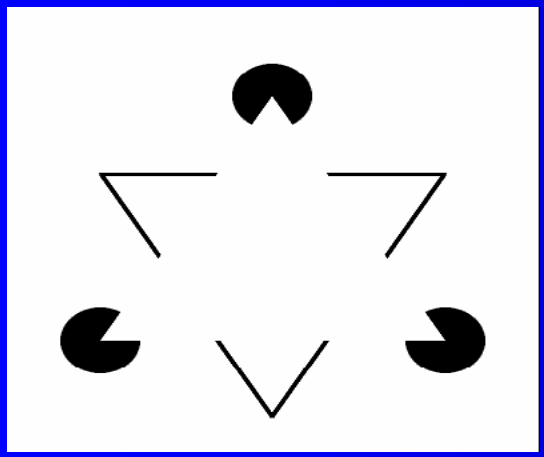


Modeling Motions Which angles are useful?

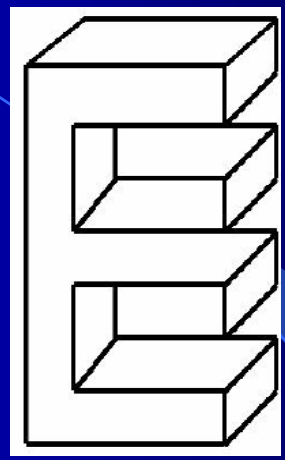
Complex Calculations: Direct (given angles compute position)
Indirect (given position compute angles)

How can humans walk? without knowing physics and calculations?

II - Perception: sensing for a better perception

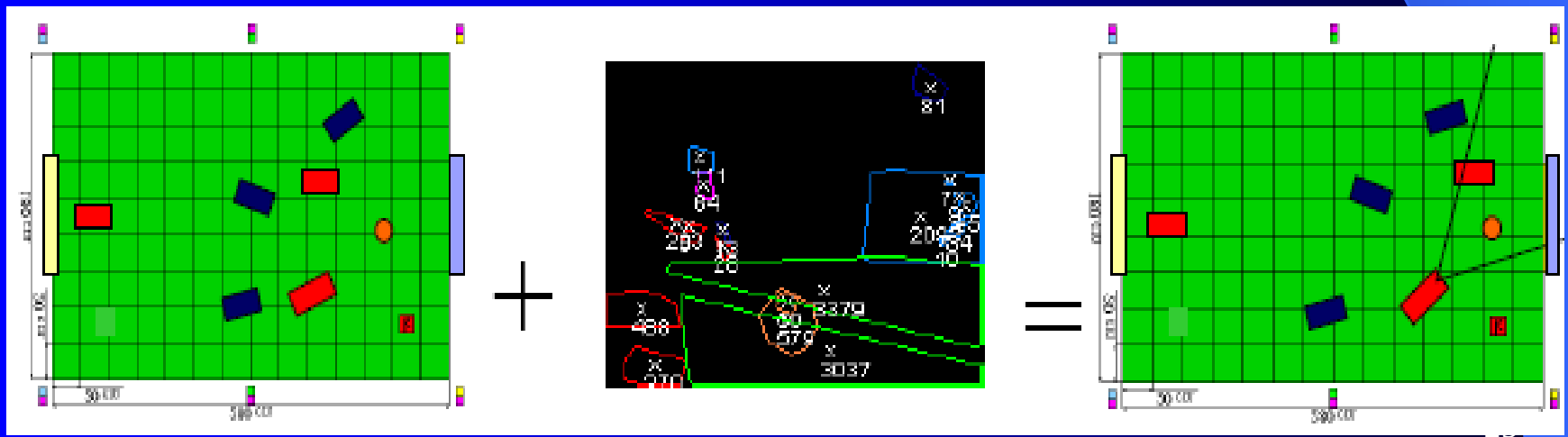


Perception
by Humans
(Integration)

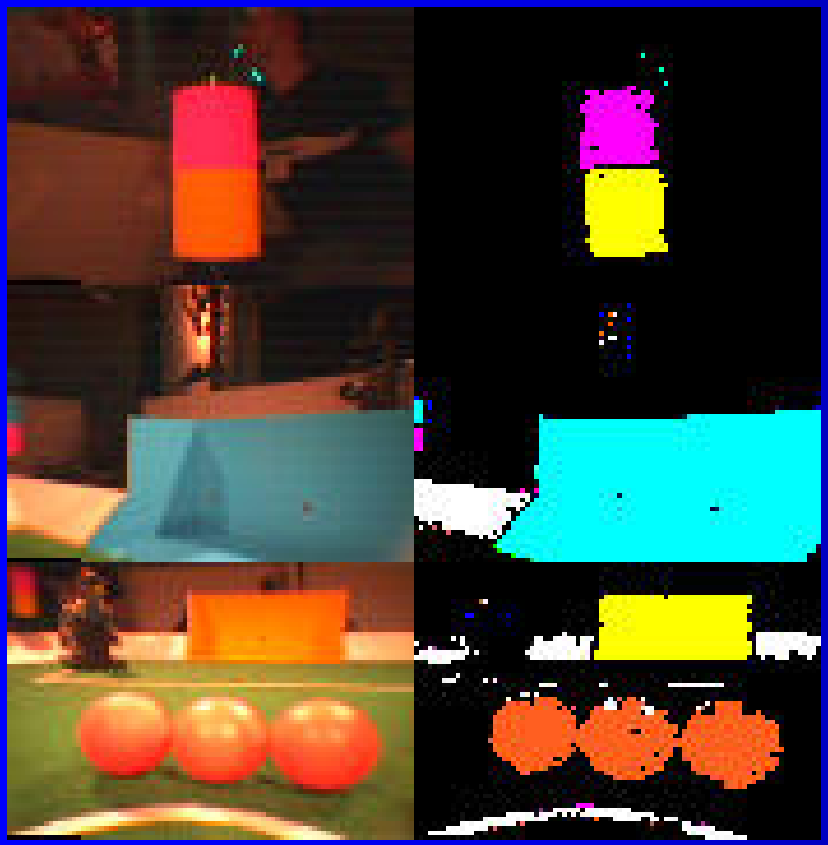


Perception by
Humans
(Interpretation)
:
Competing
interpretations

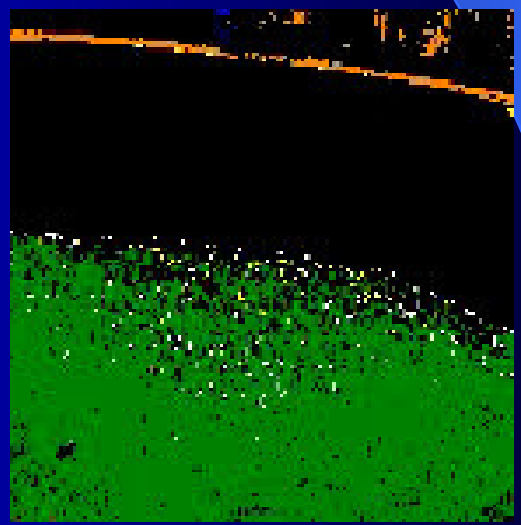
Belief_new := update (Perception, **Belief_old**);



Perception: vision

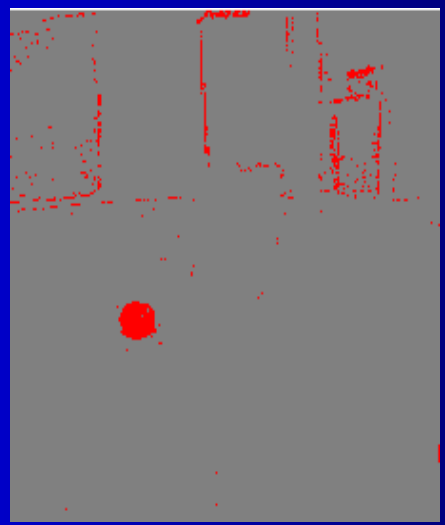


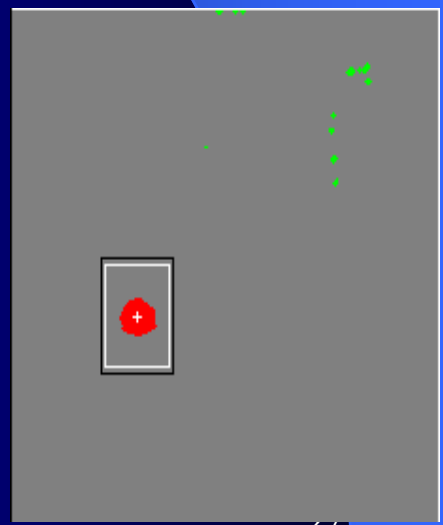
- Real-time and robust
- Effective calibration
- Colored blobs identified as objects
- Confidence computed



Robot Perception

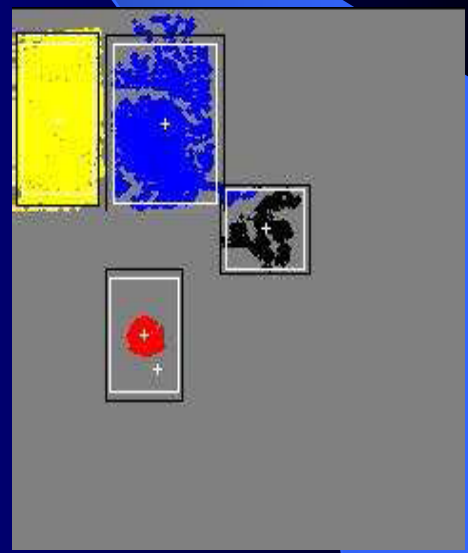
Example of image processing and features extraction of the ball: Acquire, segmentation, blob detection, and Ball extraction.



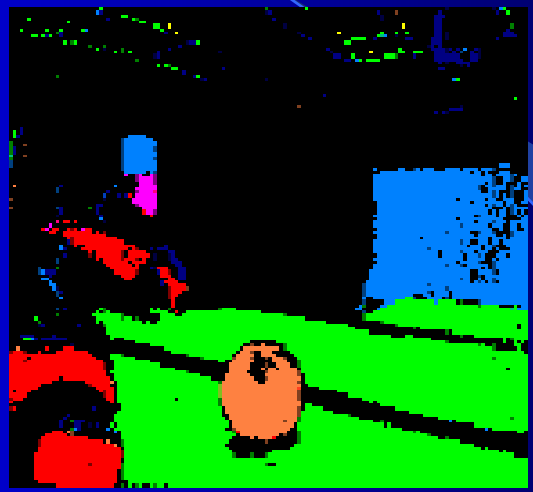


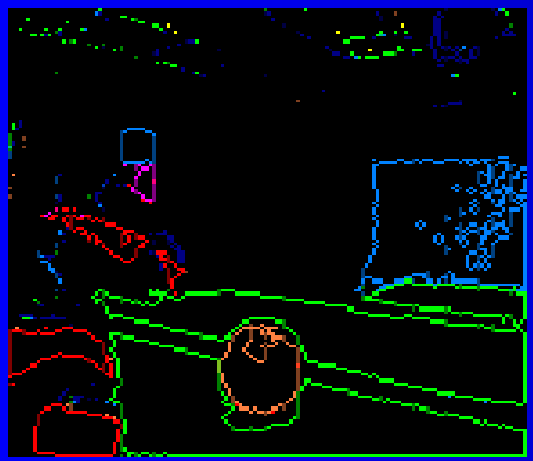
The Problem of Perception

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.

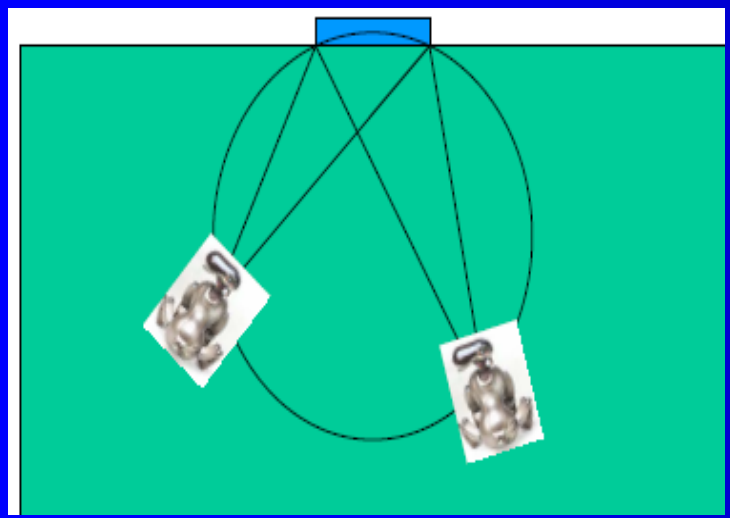
But: Many redundancies can be exploited using methods from statistics and constraint satisfaction.

Exploiting Redundancy

Where am I ?

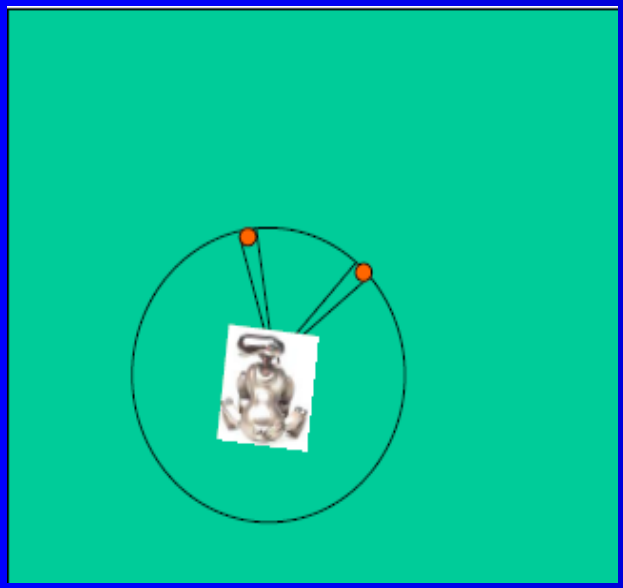
Where is the ball ?

Exploiting Redundancy



The size of the goal defines a circle of possible positions of the observer

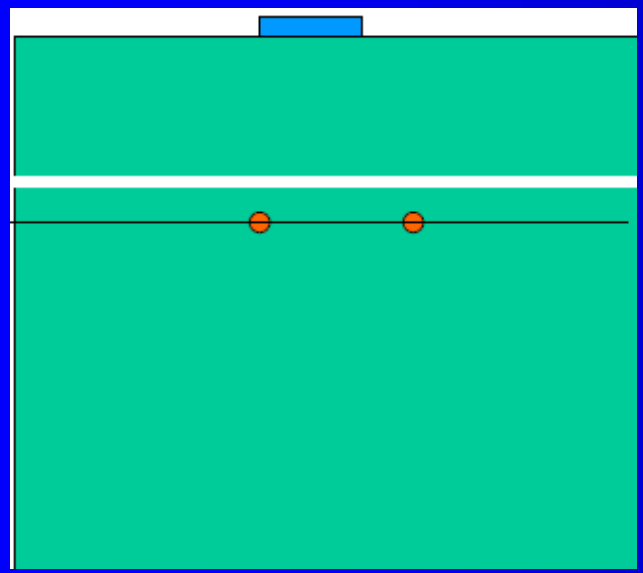
Exploiting Redundancy



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

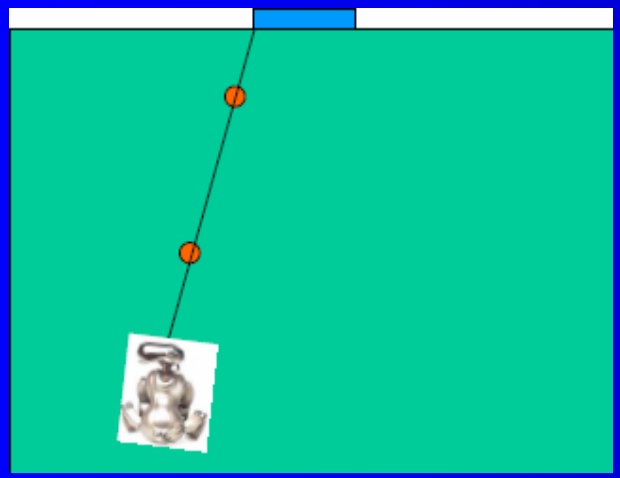
Exploiting Redundancy

The ball lies on a line before the penalty border line



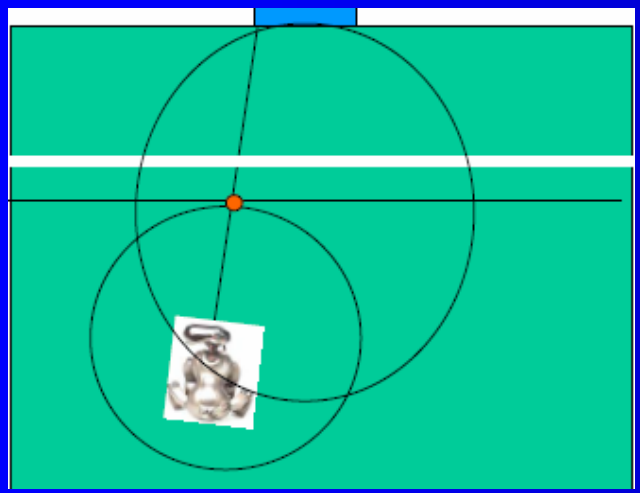
Exploiting Redundancy

The ball lies on a line between goal post and observer



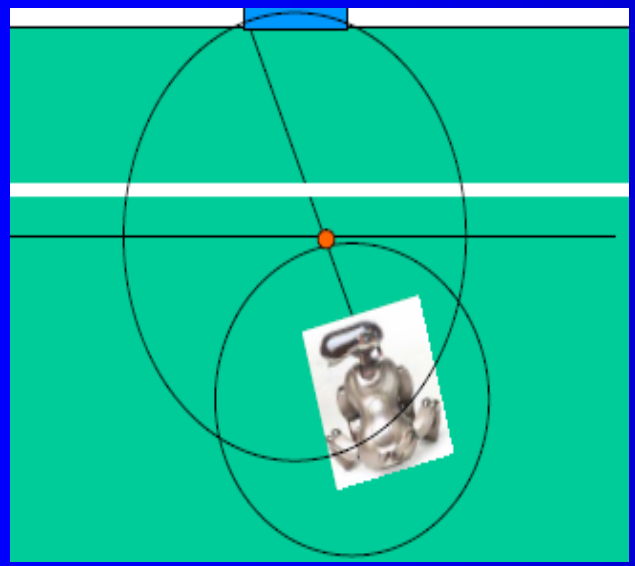
Exploiting Redundancy

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 w
- Desires: What are my wishes
- Intention: Which desires will I re
- Plans: How can I realize my inte

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

Program structure for agents/robots

Models of partners/opponents in the program

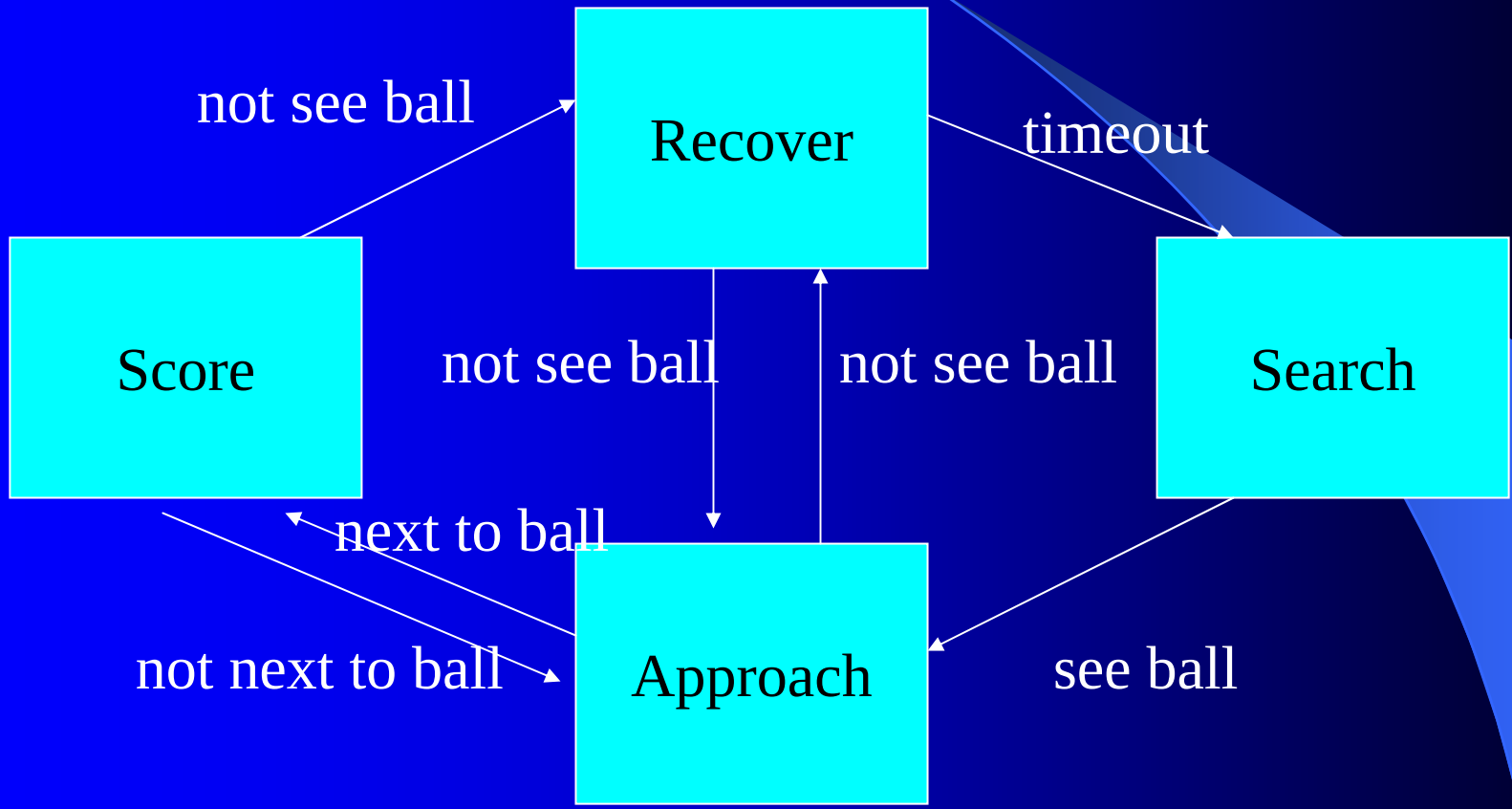
Models of others:

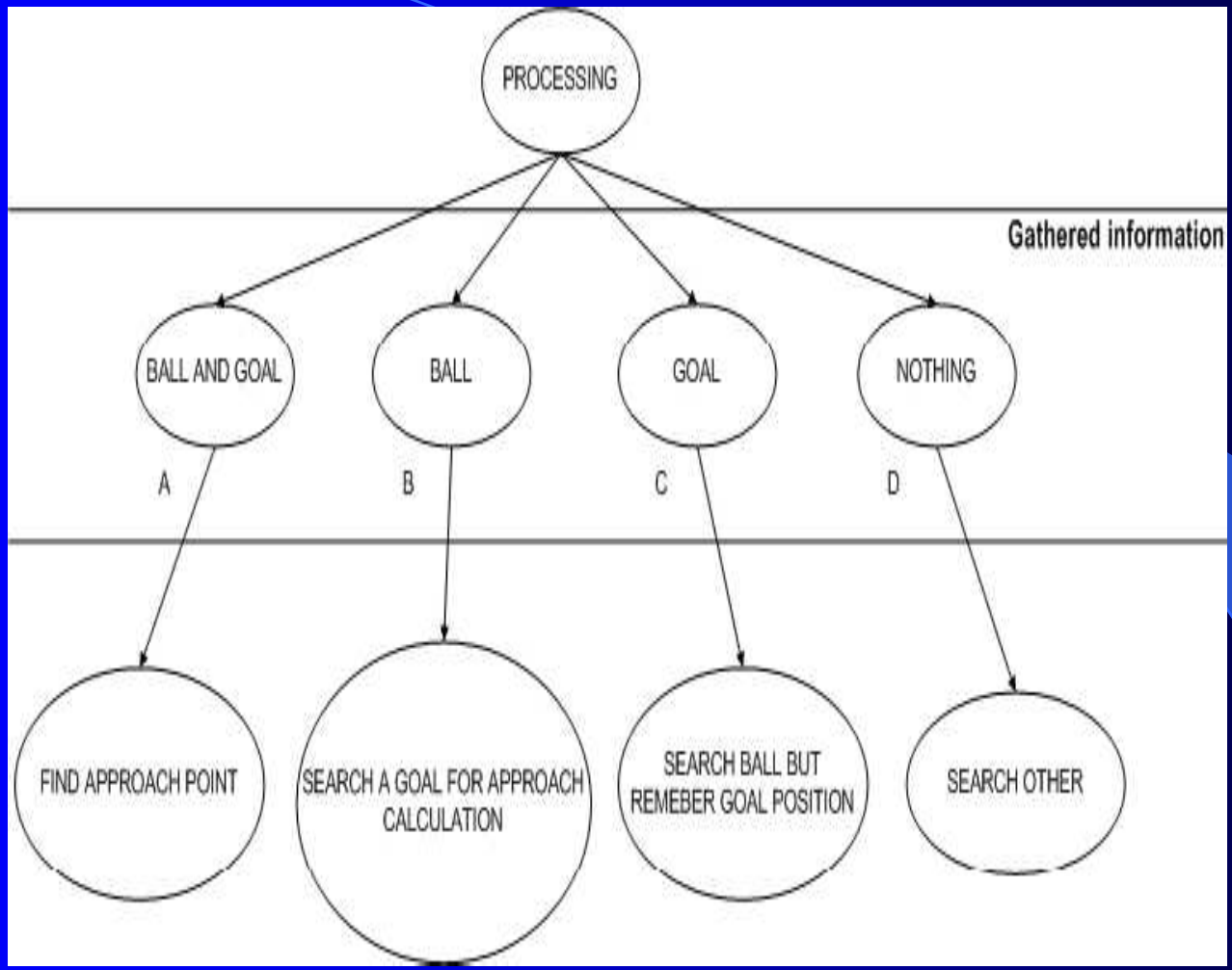
What are their beliefs/desires/intentions/plans

Three different situations at RoboCup (2006):

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

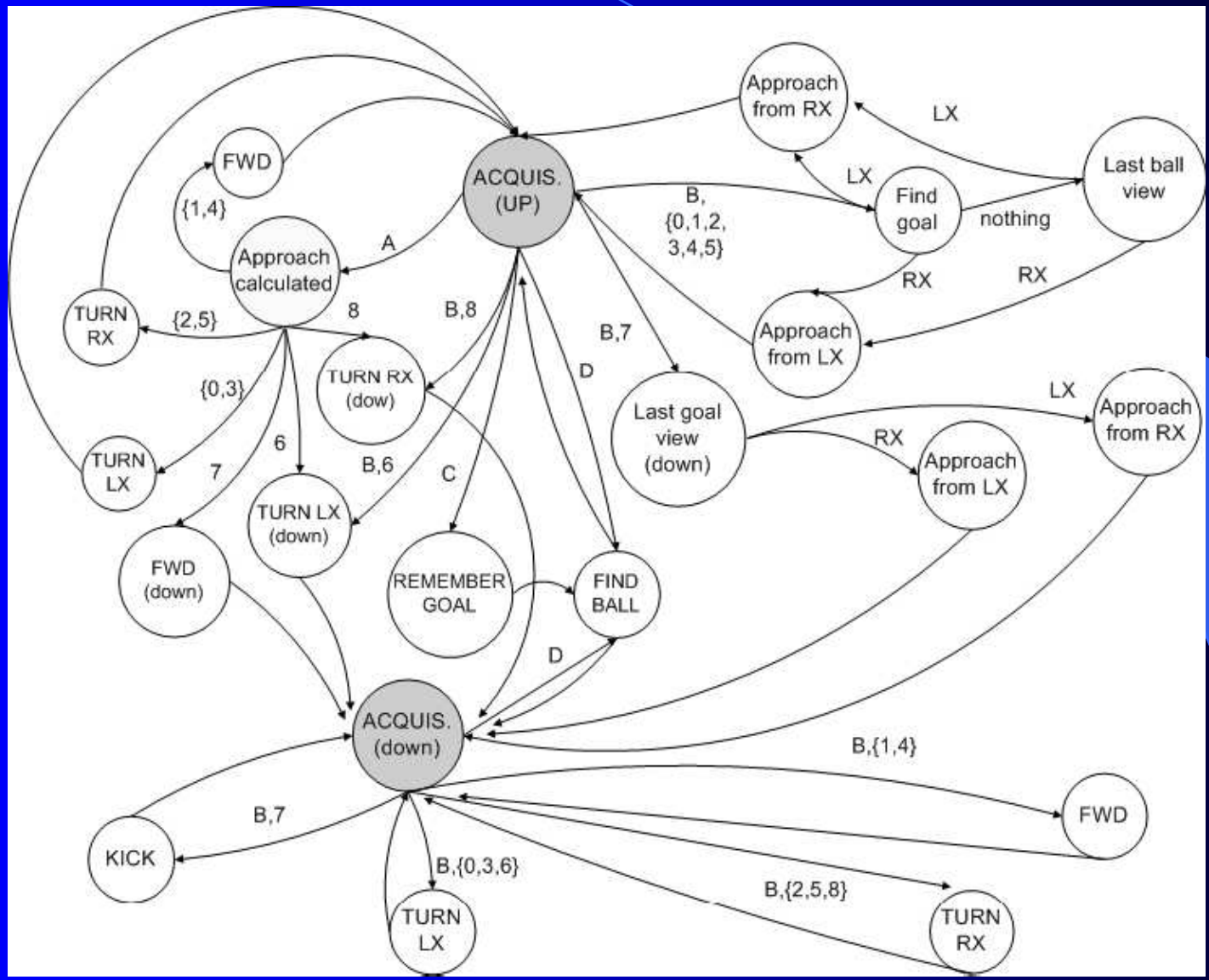
Behaviors


Recover
not see ball
timeout
Score
not see ball
not see ball
Search
next to ball
not next to ball
Approach
see ball



Arbiter in context environment.

The finite state machine implemented in RobotCore controlling the behavior of the soccer robot.



Programming Soccer Robots

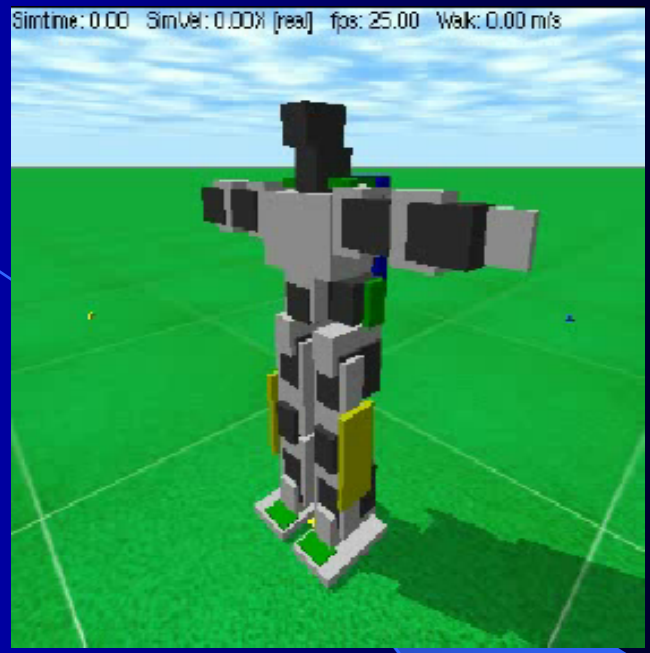
What can we learn?

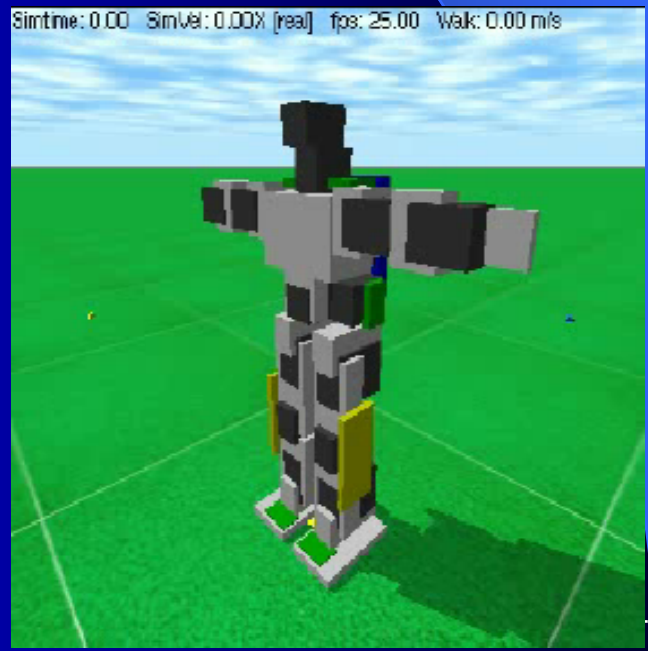
How to understand the world.
How to realize rational behavior in the daily world.

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





http://www.robocup.de/AT-Humboldt/simloid-evo.shtml?de

Proprioception:
Feeling the own Body

AUTONOMOUS ROBOTICS

Syllabus

- **Actuator and control**
- **Motion and Kinematics**
- **Sensing and vision**
- **Intelligent Behaviors**
- **Bahvior 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

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• “A light software architecture for a Humanoid Soccer Robot”, A. Maggi et al., IAS-Lab, Dep. of Information Engineering, University of Padua, Italy