Cases in Robotic Soccer

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Or: How to Program Soccer Robots?

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1956: Birth of „Artificial Intelligence“

Proposal:

RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

J. McCarthy, Dartmouth College
M. L. Minsky, Harvard University
N. Rochester, I.B.M. Corporation
C.E. Shannon, Bell Telephone Laboratories

… the conjecture that every aspect of learning or any other feature of **intelligence can in principle be so precisely described that a machine can be made to simulate it.** …

Challenges 1956: Symbols, Search and Logics

Mathematical calculations

Formal logics

Search in complex descriptions

Chess

Language Translation

1997:

Computer Deep Blue wins again human world champion Kasparov

Language Translation in 2006

Who does it better: human or machine?

Machine

- has lexica of hundreds of languages
- but: misses understanding

1956: Birth of „Artificial Intelligence“

Proposal:

RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

J. McCarthy, Dartmouth College
M. L. Minsky, Harvard University
N. Rochester, I.B.M. Corporation
C.E. Shannon, Bell Telephone Laboratories

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of **intelligence can in principle be so precisely described that a machine can be made to simulate it.** An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. …

Translation by Google to German

Wir schlagen, daß ein 2 Monat, die Studie mit 10 Männern der künstlichen Intelligenz während des Sommers von 1956 an der Dartmouth Hochschule in Hanover durchgeführt wird vor, New-Hampshire. Die Studie ist, auf der Grundlage von die Vermutung fortzufahren, die jeder Aspekt der erlernen oder jeder möglichen anderen Eigenschaft der Intelligenz prinzipiell so genau beschrieben werden kann, die eine Maschine gebildet werden kann, um sie zu simulieren. Ein Versuch wird, zu finden gebildet, wie man Maschinen Gebrauchsprache bildet, Abstraktionen und Konzepte bildet, Arten der Probleme löst, die jetzt für Menschen aufgehoben werden und sich verbessert.

Russian

Мы предлагаем 2 месяца 10 человек исследовании искусственного интеллекта осуществляется в течение лета 1956 года в Дартмутский колледж в Ганновере, Нью-Гемпшир. Исследования состоит в том, чтобы действовать на основе догадок о том, что каждый аспект обучения или каких-либо других признаков разведывательных данных в принципе могут быть описаны так точно, что машину можно заставить эмулировать его. Будет сделано все, чтобы найти, как сделать использование языка машин, формы абстракций и понятий, решение иных задач в настоящее время, отведенное для людей, и совершенствование себя. ...

Spanish

Proponemos que 2 meses, el estudio de 10 hombres de la inteligencia artificial esté realizado durante el verano de 1956 en la universidad de Dartmouth en Hannover, de New Hampshire. El estudio es proceder en base de la conjetura que cada aspecto característica que aprende o de la cualquier otra de la poder de la inteligencia en el principio se describa tan exacto que una máquina se puede hacer para simularlo. Una tentativa será hecha de encontrar cómo hacer lengua del uso de las máquinas, formar abstracciones y conceptos, solucionar clases de problemas ahora reservados para los seres humanos, y mejorarse. …

Italian

Proponiamo che i 2 mesi, uno studio dei 10 uomini su intelligenza artificiale sia effettuato durante l'estate di 1956 all'università di Dartmouth a Hannover, del New Hampshire. Lo studio è di continuare in base alla congettura che ogni funzione di caratteristica imparante o qualunque altra di intelligenza può in linea di principio essere descritta così precisamente che una macchina può essere fatta per simularla. Un tentativo sarà fatto di trovare come fare la lingua di uso delle macchine, formare le astrazioni ed i concetti, risolvere i generi di problemi ora riservati agli esseri umani e migliorarsi. …

Arabian

دارتموث في هانوفر نيو هامبشاير. الدراسه هو التصرف على اساس التخمين ان كل جانب من التعلم او اي سمة أخرى الاستخبارات يمكن من حيث المبدأ ان هذا بالضبط ما وصف آلة يمكن محاكاه. ستبذل محاولة ايجاد طريقة لجعل استعمال آلات شكل تجريد اللغة والمفاهيم حل مشاكل انواع ان تحفظ للانسان ، وتحسين انفسهم. ...

Japanese

私達は2か月、人工知能の10人の調査がハノーバー、ニューハンプシャーのダートマスの大学の1956年の夏の間に遂行される提案する。 調査はそれを模倣するために作る機械がことができる主義の知性の缶の学ぶか、または他のどの特徴のもあらゆる面がそう正確に記述されている推量に基づいて 進むことである。 試みは見つける機械使用言語を作り、抽象的概念および概念を形作り、今人間のために確保された種類の問題を解決し彼ら自身を増進する方法をなされる。 …

Chinese

我们建议,2月 男子10人工智能研究进行期间,于1956年夏季在汉诺威达特茅斯学院、 新罕布什尔. 这项研究的基础上进行推测,方方面面学习或任何其他特征 情报原则上是可以这么说,恰恰说明了机器可模拟. 企图将找到如何使用机器语言、形式和抽象的概念, 解决各种问题,现在留给人类、提高自己. ::

Challenges 2006

Agents/Robots

Conversation/Negotiation
Semantic Web

Perception in the real world
Acting in the real world

Cooperation of Humans and Artifacts

Central problem:
Perception and understanding of daily life situations

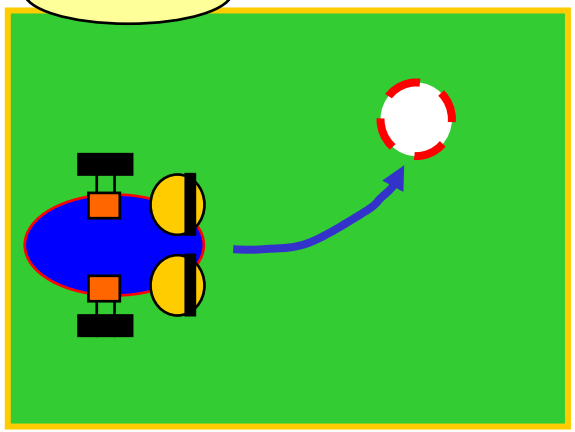
What does the robot see?

What means „intelligent“?

- Fast calculations — *Machines are better than humans*
- Memorize Shakespeare — *Machines can do it*
- Chess — *Machines are better than humans*
- Conversation
- Earn money — *Machines can do it*
- Car driving
- Soccer
- Taking photographs — *Machines can do it*
- ...

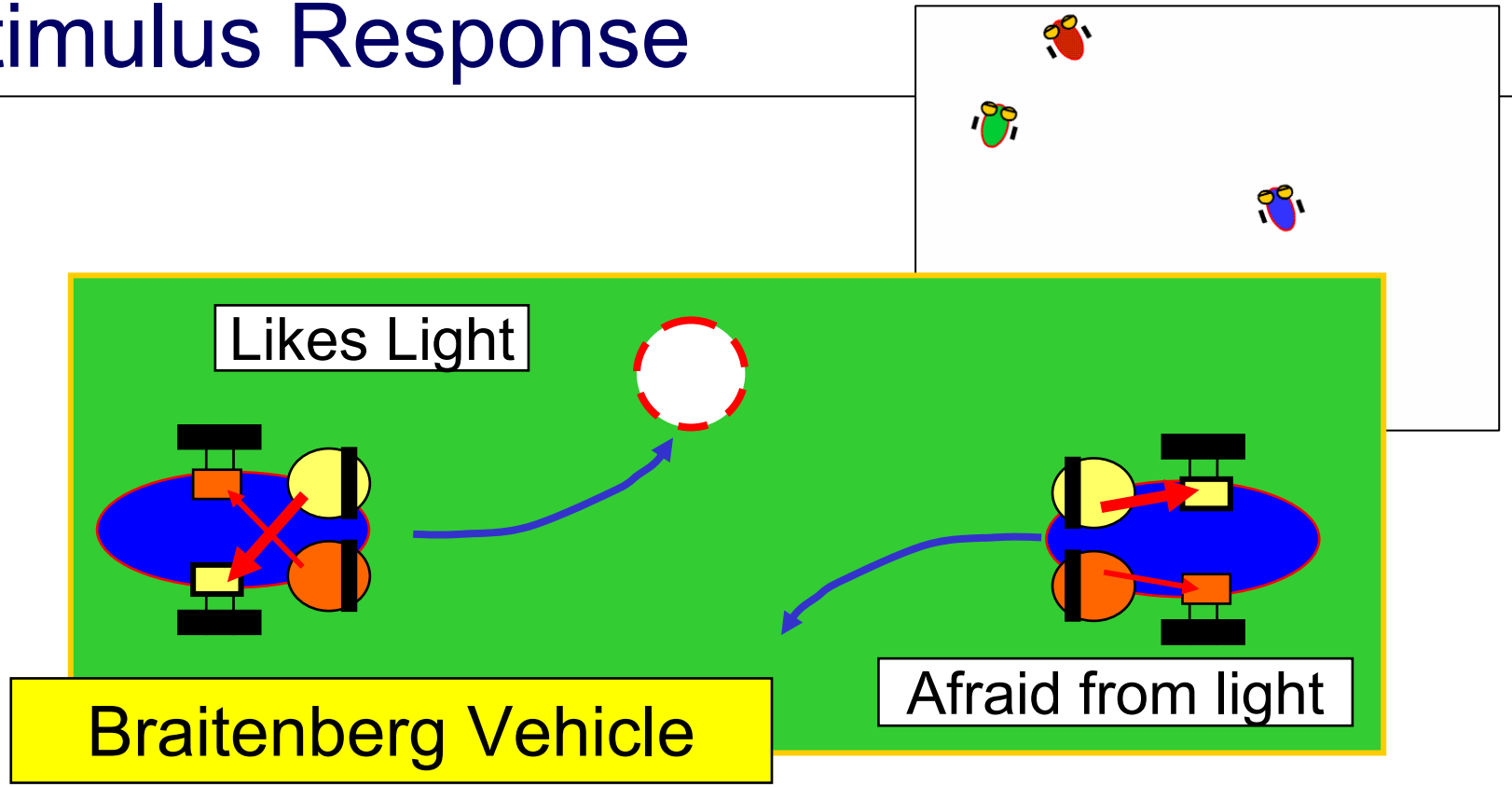
„Conscious“ Acting

I see the light left in front.
I like the light.
I should go to the left.
I have to turn an walk.
My right wheel should move faster than the left one.
etc.



Alternatively:
Stimulus Response →

Stimulus Response



Alternatively: „Conscious“ Acting

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Humboldt University Berlin

Robots

Important aspects (to be implemented):

- Perception
- History of situations
- General knowledge about the world
- Desires, intentions, plans
- Knowledge about own skills
- Social aspects (humans, other robots)

Body-Mind-Problem

Philosophical question:

- Mind without body?

Technical question:

- Artificial Intelligence without an experiencing body?

3 Aspects of Artificial Intelligence

Understand human intelligence (try to implement intelligent behavior)

Build useful machines (not necessarily like humans, but understandable by humans)

Cooperation of humans, agents and robots

AI at Humboldt University

Acting by experience: Case Based Reasoning

Knowledge Management

Agent Oriented Techniques

Cognitive Robotics

Social Intelligence: Socionics

AI in Medicine

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Humboldt University Berlin

Challenges for Intelligence

Play chess
Recite Hamlet
Earn money
Ride bicycle
Play soccer

Chess:
- Static
- 3 Minutes per move
- Single action
- Single player
- Information:
  - reliable
  - complete

Soccer:
- Dynamic
- Milliseconds
- Sequences of actions
- Team
- Information:
  - unreliable
  - incomplete

Soccer as test bed: RoboCup

- International initiative to foster AI and Robotics

- Organized by **RoboCup Federation**
  - RoboCup Soccer Games
  - RoboCup-Rescue
  - RoboCup@Home
  - RoboCup Junior
  - Conferences

Soccer Playing Robots

Challenge:

Human Dimensions

- Body
- Autonomy

Challenge: Humanoid Robots

- Not a fast moving car
- Not 6 legs for kicking
- Not a knight with arms
- No gun
- No wings
- No remote control
- …

But …

Challenge: Humanoid Robots

But:

- Fully autonomous
- Human like shape: Arms, legs, …, soft skin
- Run, jump, grasp, carry
- Understanding of the world
- Rational behavior
- communication und cooperation

…

A robot which plays and understands soccer could accompany you in the metro.

RoboCup: Recent Situation

- Total Autonomy
  - Perception
  - Decision

No human interaction allowed!

- Body: Different classes:
  - Middle Size (50 cm Diameter)
  - Small Size (18 cm Diameter)
  - Four Legged Robots (Aibo, finishing)
  - Simulation (2D, 3D)
  - Humanoids

RoboCup

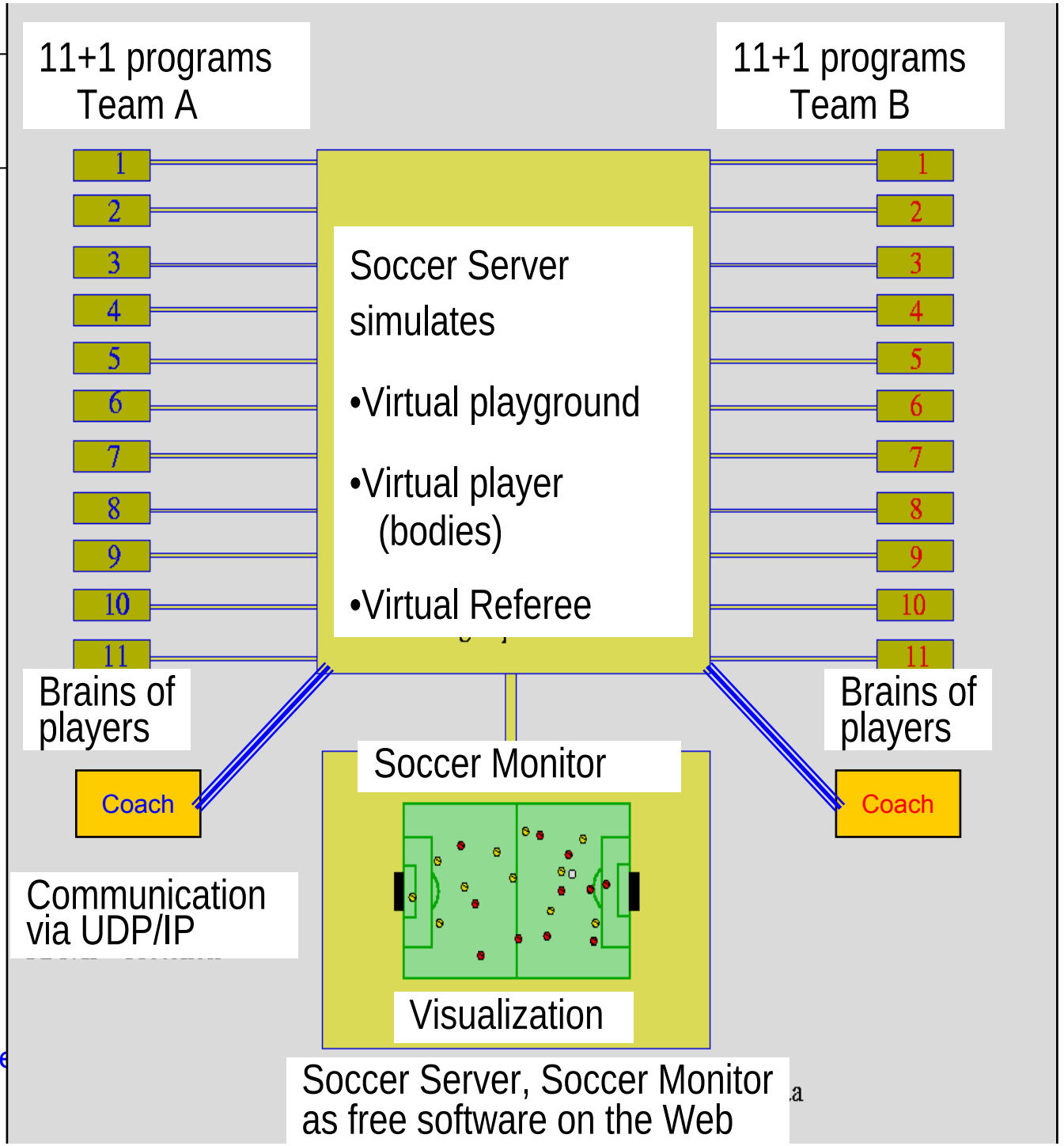
Simulation 2D

Actions

kick,dash,turn,
turn-neck, catch,
say, ..

Sensors

see, sense-body,
hear, ...



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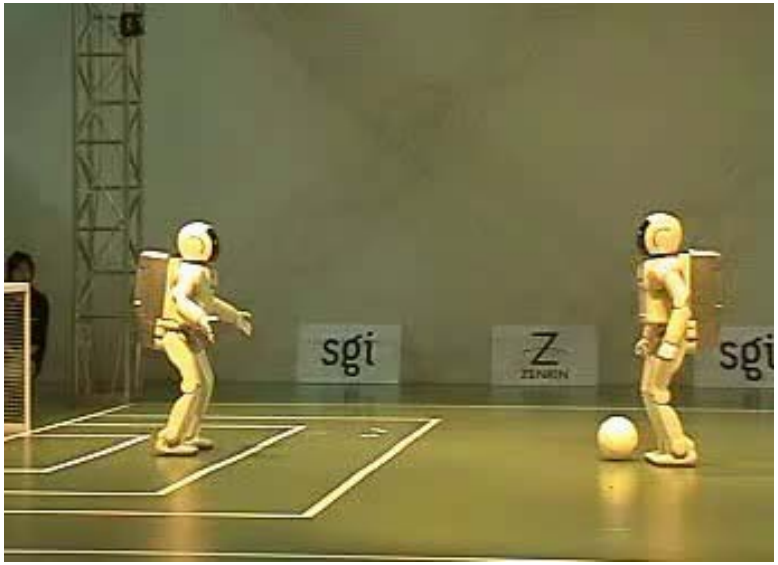
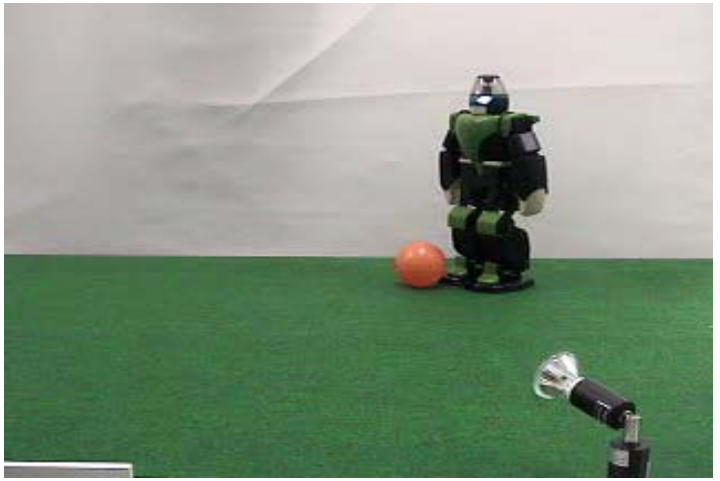
Humanoid Robots in RoboCup



Asimo (Honda)
2002



Vision (Osaka)
2004

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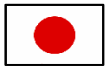
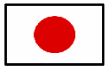
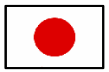
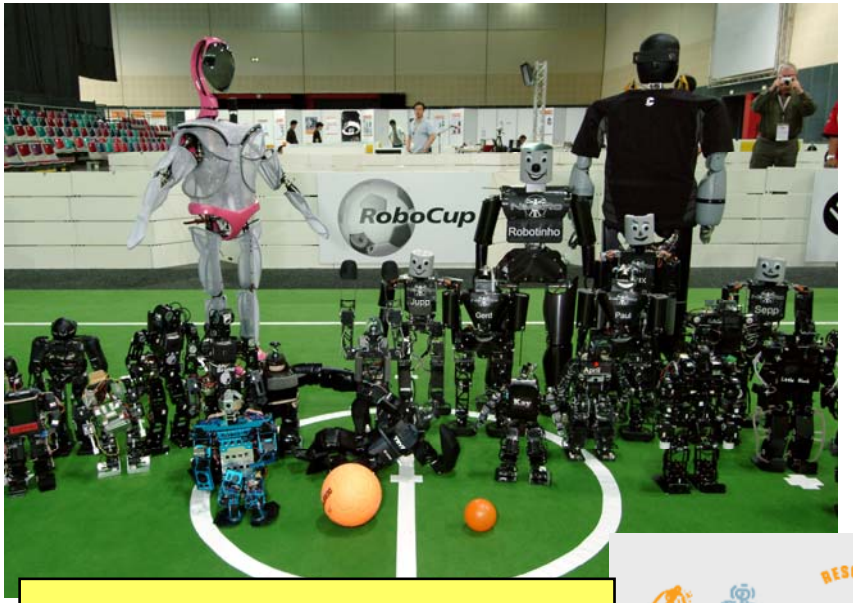
RoboCup World Championships

	1997	Nagoya
	1998	Paris
	1999	Stockholm
	2000	Melbourne
	2001	Seattle
	2002	Fukuoka
	2003	Padua
	2004	Lisbon
	2005	Osaka
	2006	Bremen
	2007	Atlanta
	2008	Suzhou
	2009	Graz



RoboCup Bremen 2006
444 Teams
from 36 Countries
2500 Participants

RoboCup at Humboldt University Berlin

AT Humboldt (Simulation League)

- World Champion Nagoya 1997
- Vice Champion Paris 1998
- Vice Champion (3D) Lisbon 2004

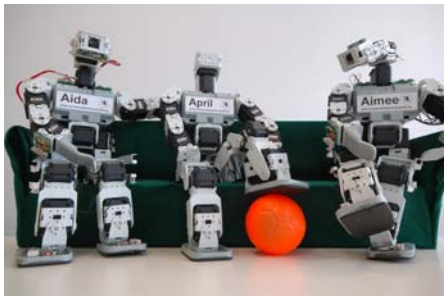
Aibo-Team Humboldt (Sony Four Legged League)

- Winner German Open Paderborn 2001, 2004
- 2nd Place German Open Paderborn 2002, 2003, 2005

German Team (Sony Four Legged League)
(Berlin, Bremen, Darmstadt, Dortmund)

- Winner „Technical Challenge“ Padova 2003
- World Champion Lisbon 2004, Osaka 2005

Since 2006: Humanoid Team Humboldt



Research and Championships

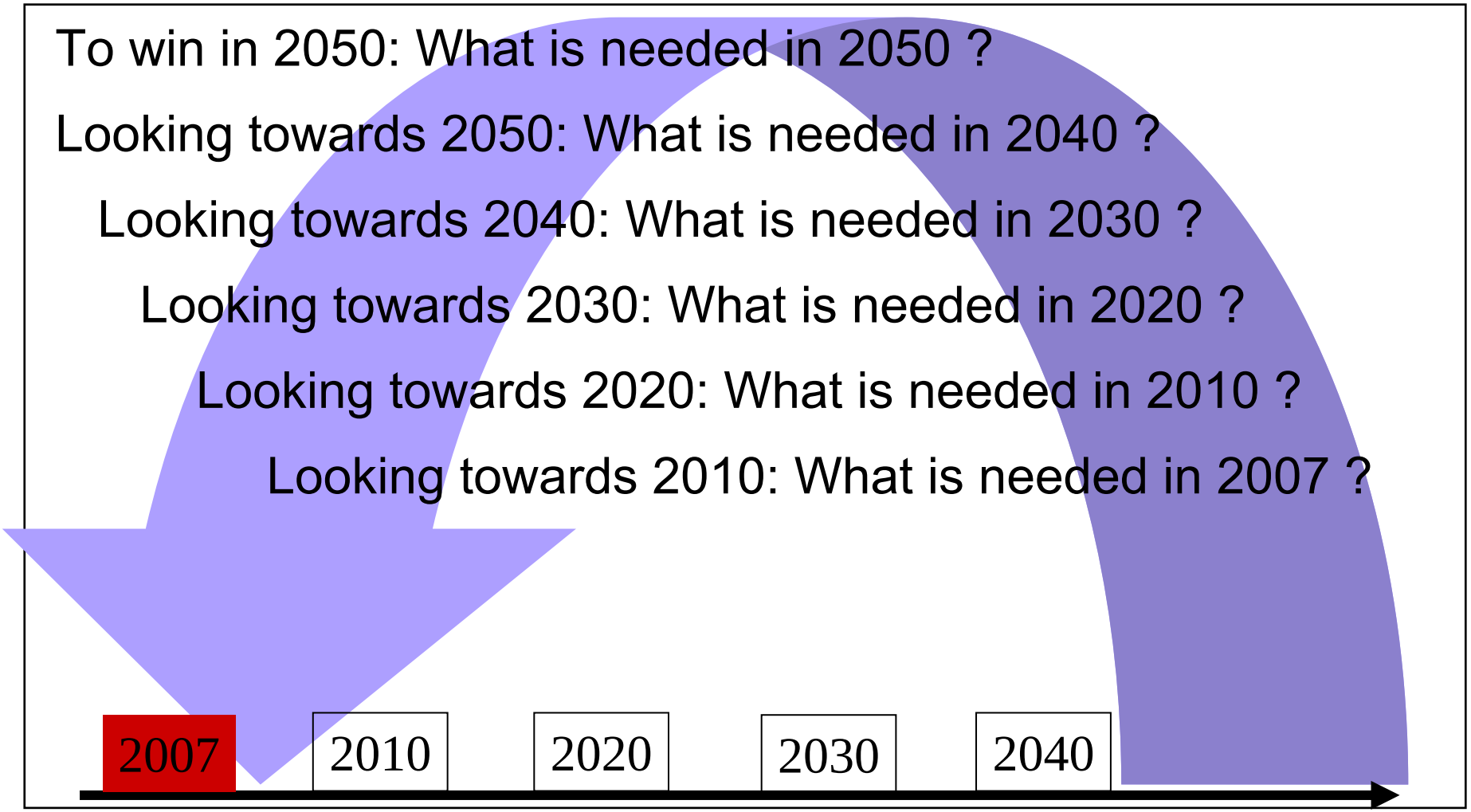
The RoboCup Challenge:

To play and win with a team of humanoid robots

against the human world champion in 2050

- Energy
- Materials
- Sensors
- Perception
- Control
- Actors

Research and Championships



Research and Championships

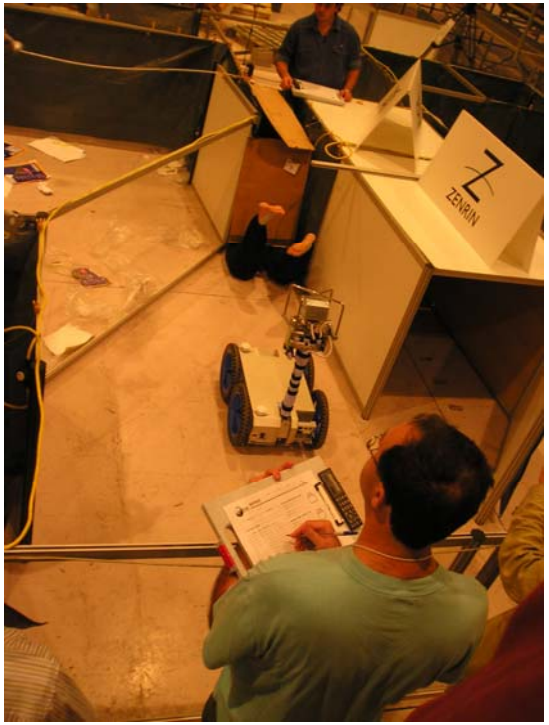
10 years of RoboCup: 1997 - 2006

Melbourne 2000

Bremen 2006

RoboCup Rescue

- Simulation
- Robots in Test Arena



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RoboCup@Home

Robots in Daily Environments

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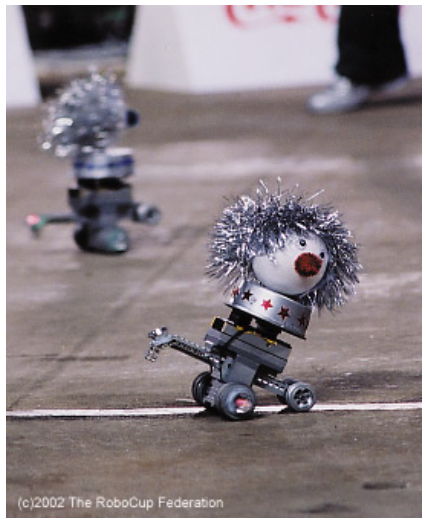
RoboCup Junior

- Soccer
- Dance
- Rescue



German Initiative „RoboCupJunior“
at „Year if Infomatics 2006“
administrated by Humboldt University
250 Junior Teams in Germany

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,
ICCBR 2007

INFOR MATIK JAHR
Wissenschaftsjahr 2006

Robots

Important aspects (to be implemented):

- Perception
- History of situations
- General knowledge about the world
- Desires, intentions, plans
- Knowledge about own skills
- Social aspects (humans, other robots)

Perception

Sensors to perceive

- the environment
- own status (proprioception)

-Camera
-Microphon
-Range finders (laser, sonar, …)
-Force sensors
-Battery status
-Angles of joints

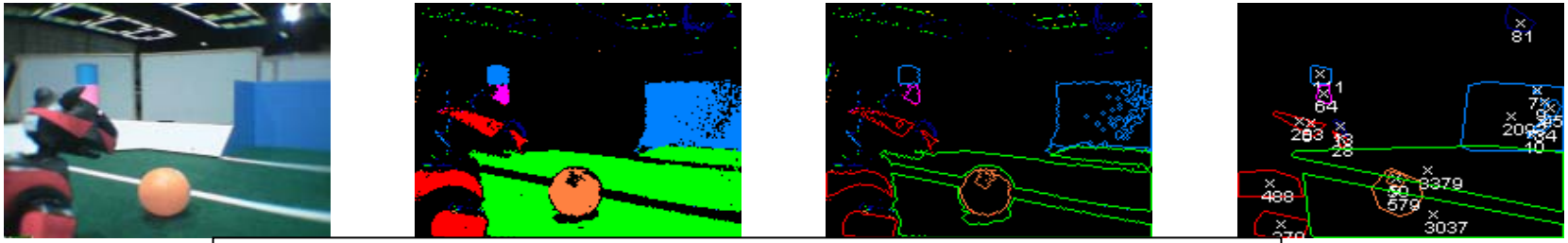
Perception

What does the robot see?

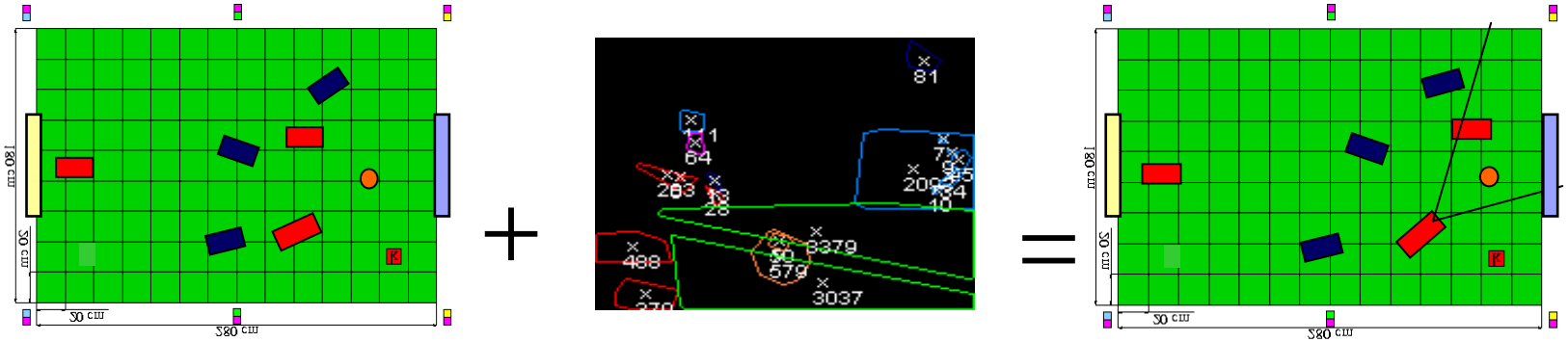
How to identify the ball?

The ball is orange.
The ball is circular.
The ball is not dangling from above.
The ball moves straight on.

Image Processing



Perception := sense(SensoryData);



Belief_new := update (Perception, Belief_old);

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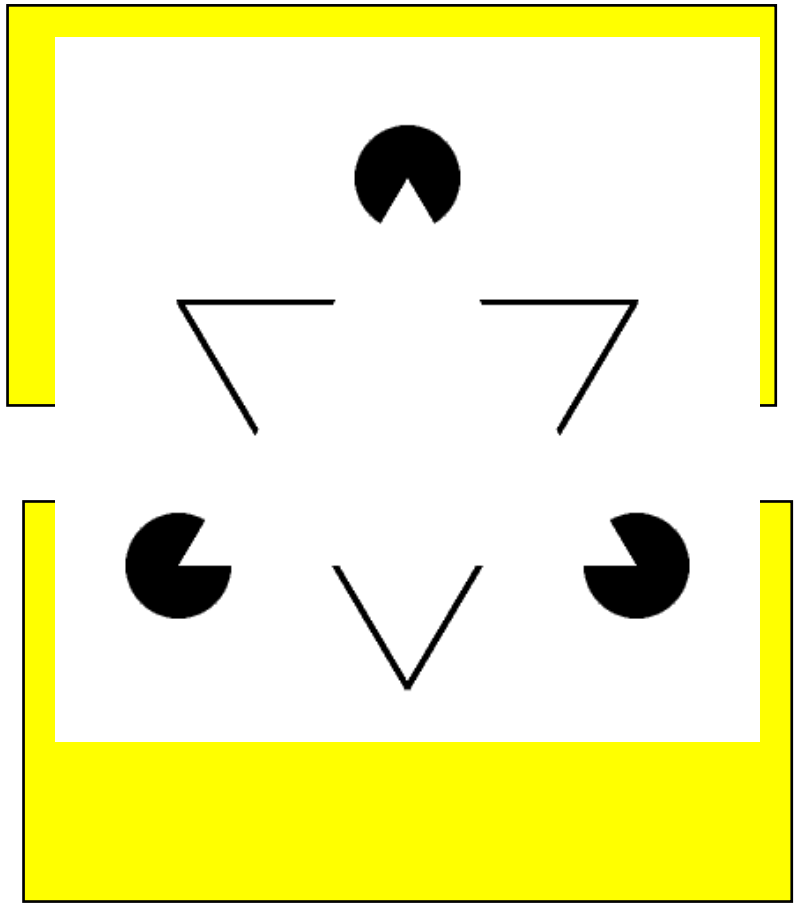
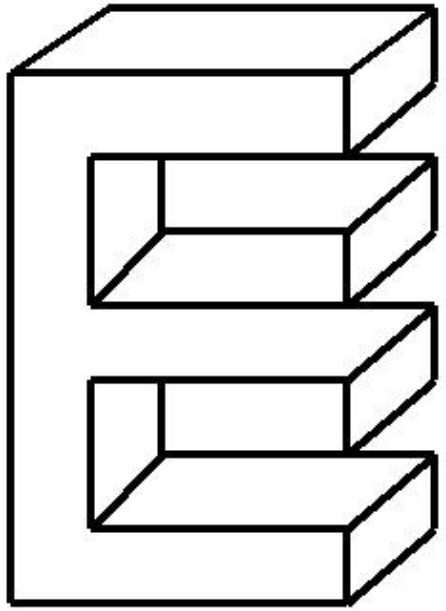
Perception by Humans (Integration)



Perception by Humans (Interpretation)

Visual system of humans is very complex.

No comparable artificial system.



Perception: How to Understand the World

Interpretation by integration of

- Old perceptions
- Data from different sensors
- Objects identified from recent percepts
- Knowledge about the world

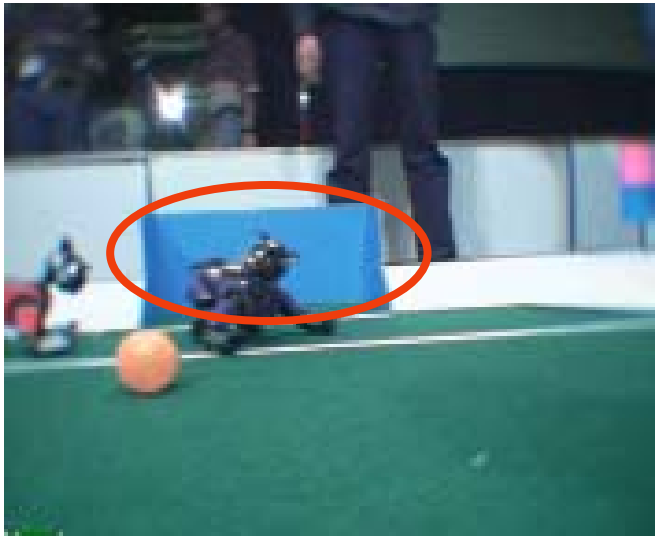
All information is incomplete and unreliable.

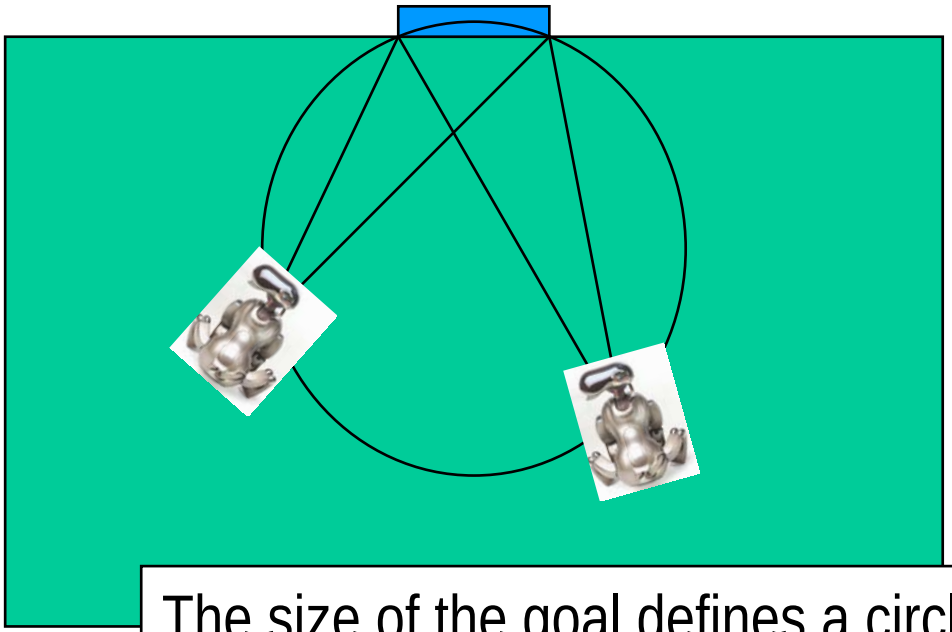
But: Many redundancies can be exploited using methods from statistics and constraint satisfaction.

Exploiting Redundancy

Where am I ?
Where is the ball ?

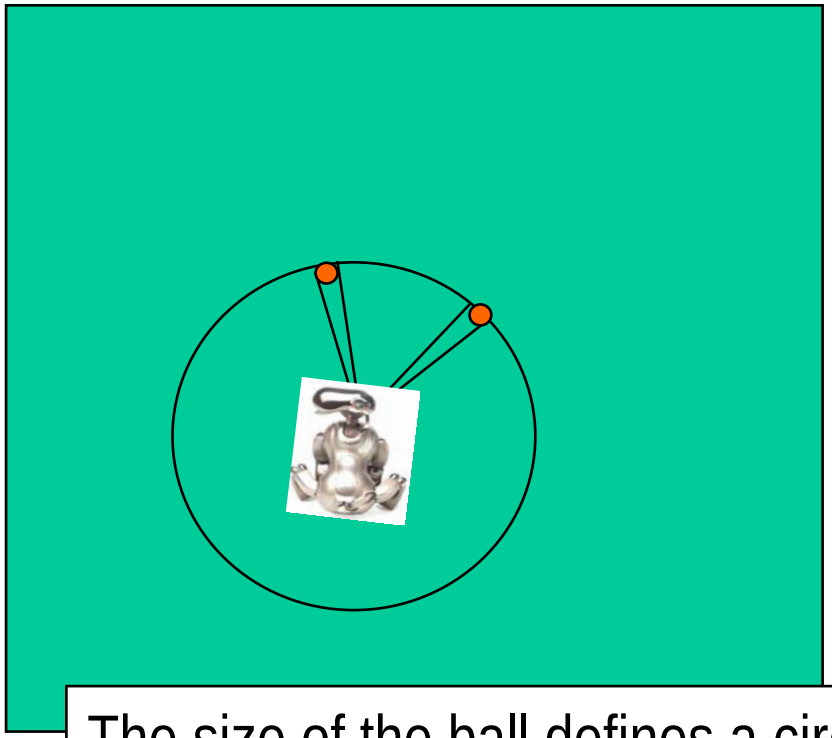
Exploiting Redundancy





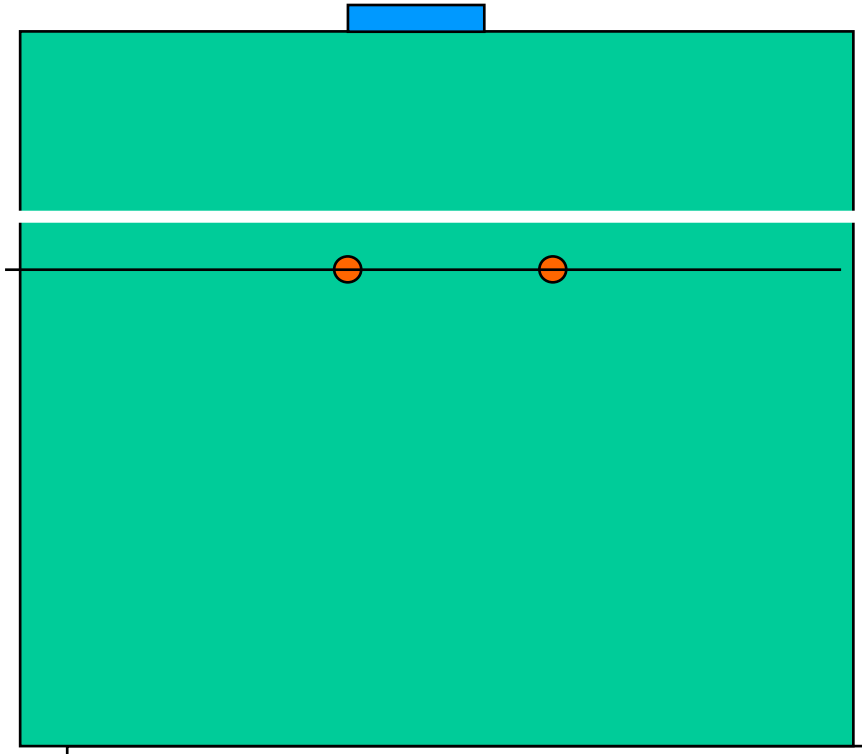
The size of the goal defines a circle of possible positions of the observer

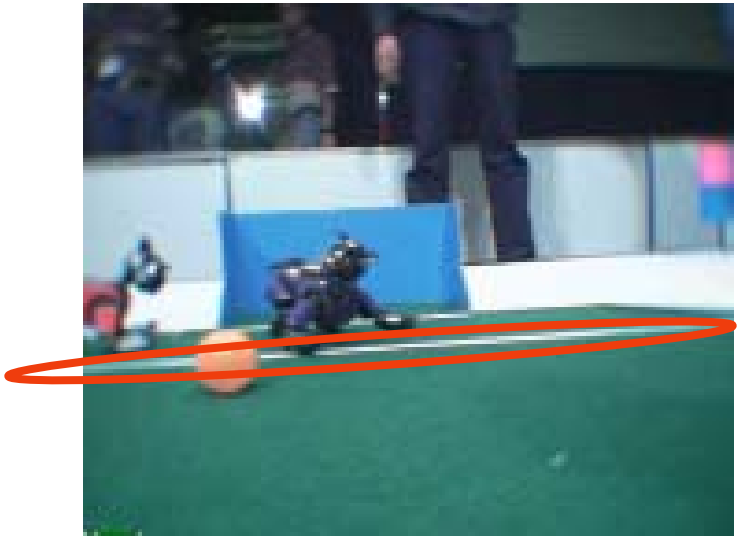
Exploiting Redundancy



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

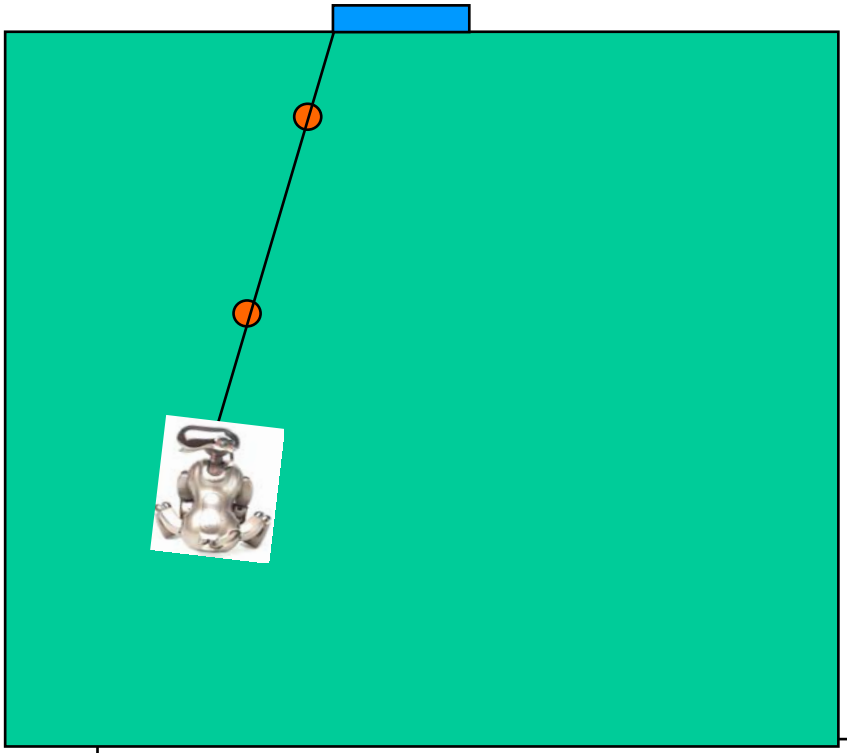
Exploiting Redundancy





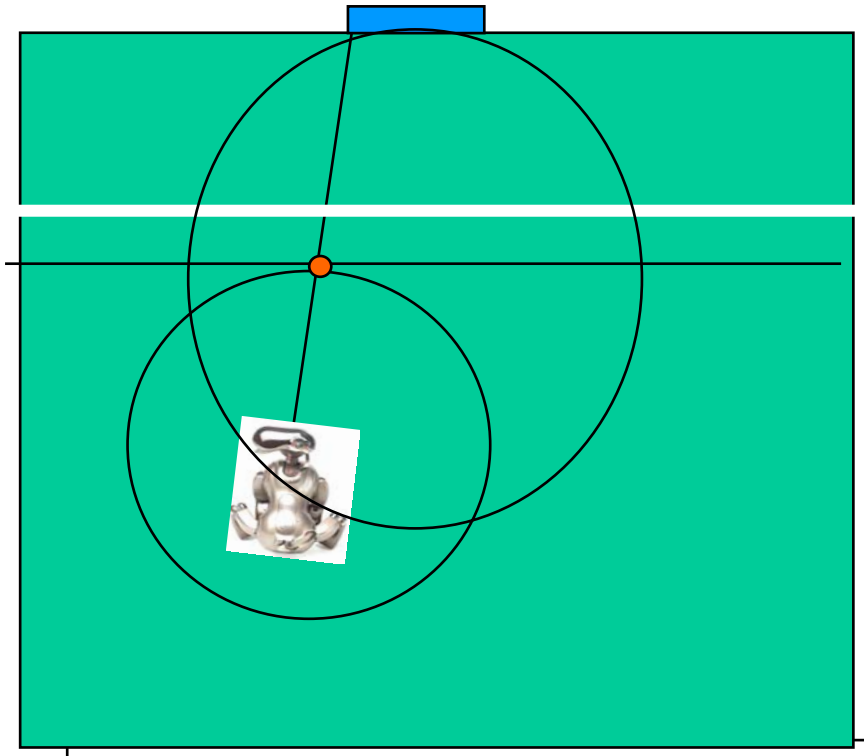
The ball lies on a line before the penalty border line

Exploiting Redundancy



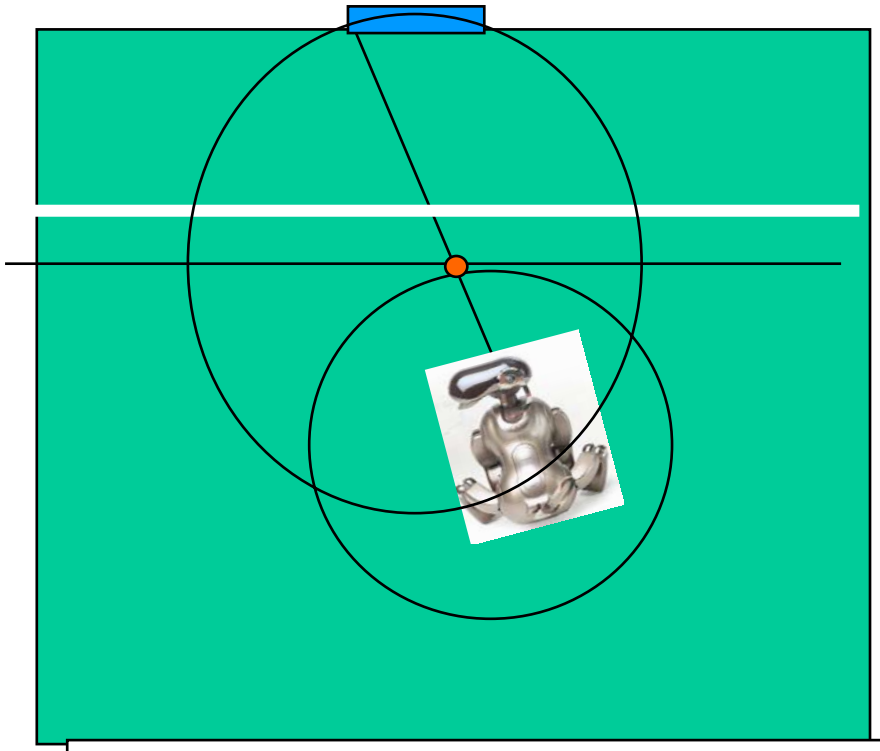
The ball lies on a line between goal post and observer

Exploiting Redundancy



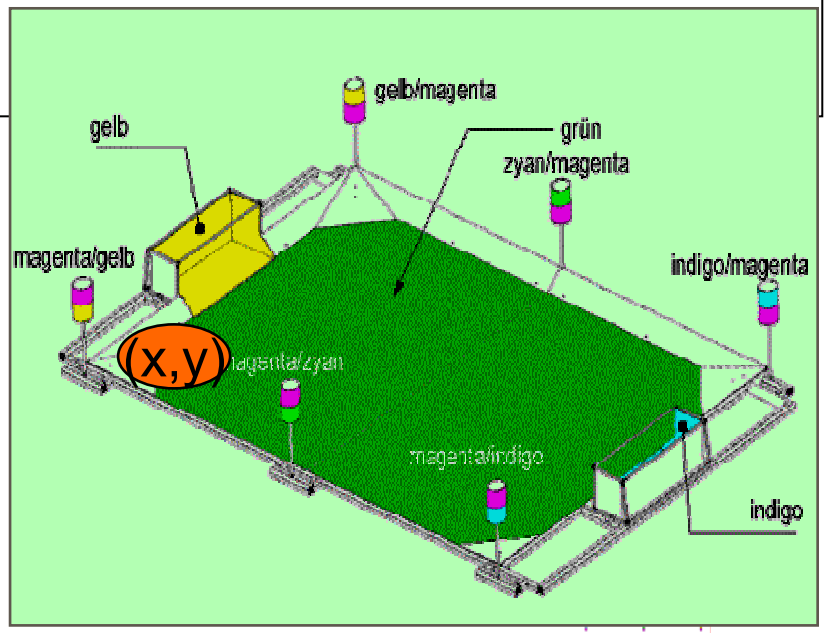
Combination yields 2 possible positions

Exploiting Redundancy



Combination yields 2 possible positions

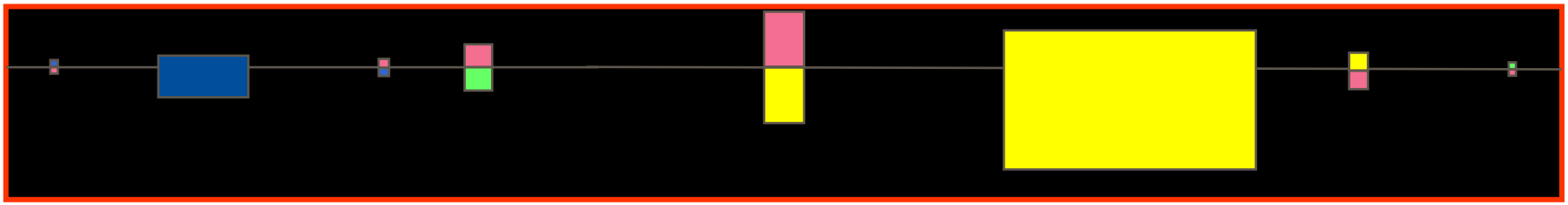
Navigation using CBR



Cases

Problem part:

Omnidirectional Image



Solution part: Own Position Coordinates (x,y)

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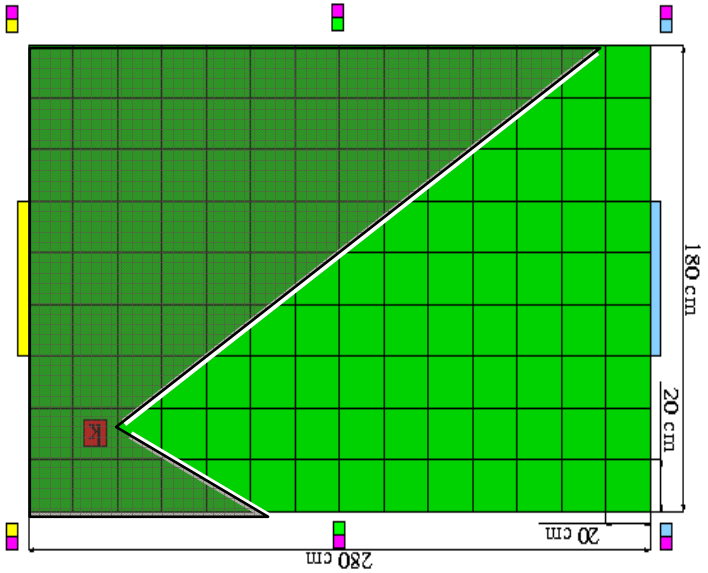
Navigation using CBR

Retrieval of similar cases

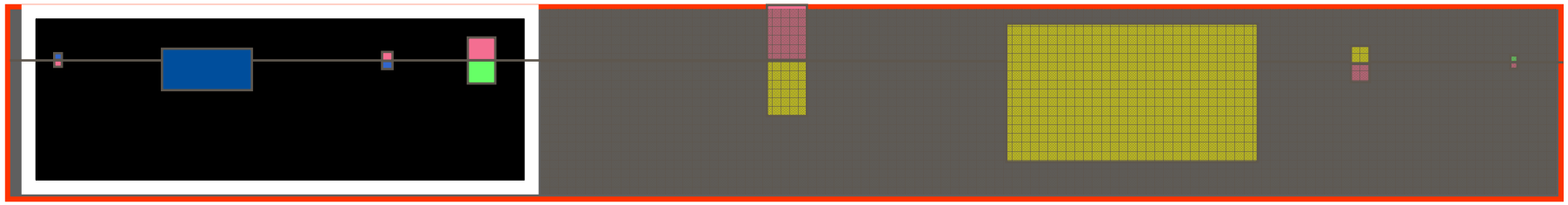


Query: preprocessed image

– **partiell**

(limited view angle)

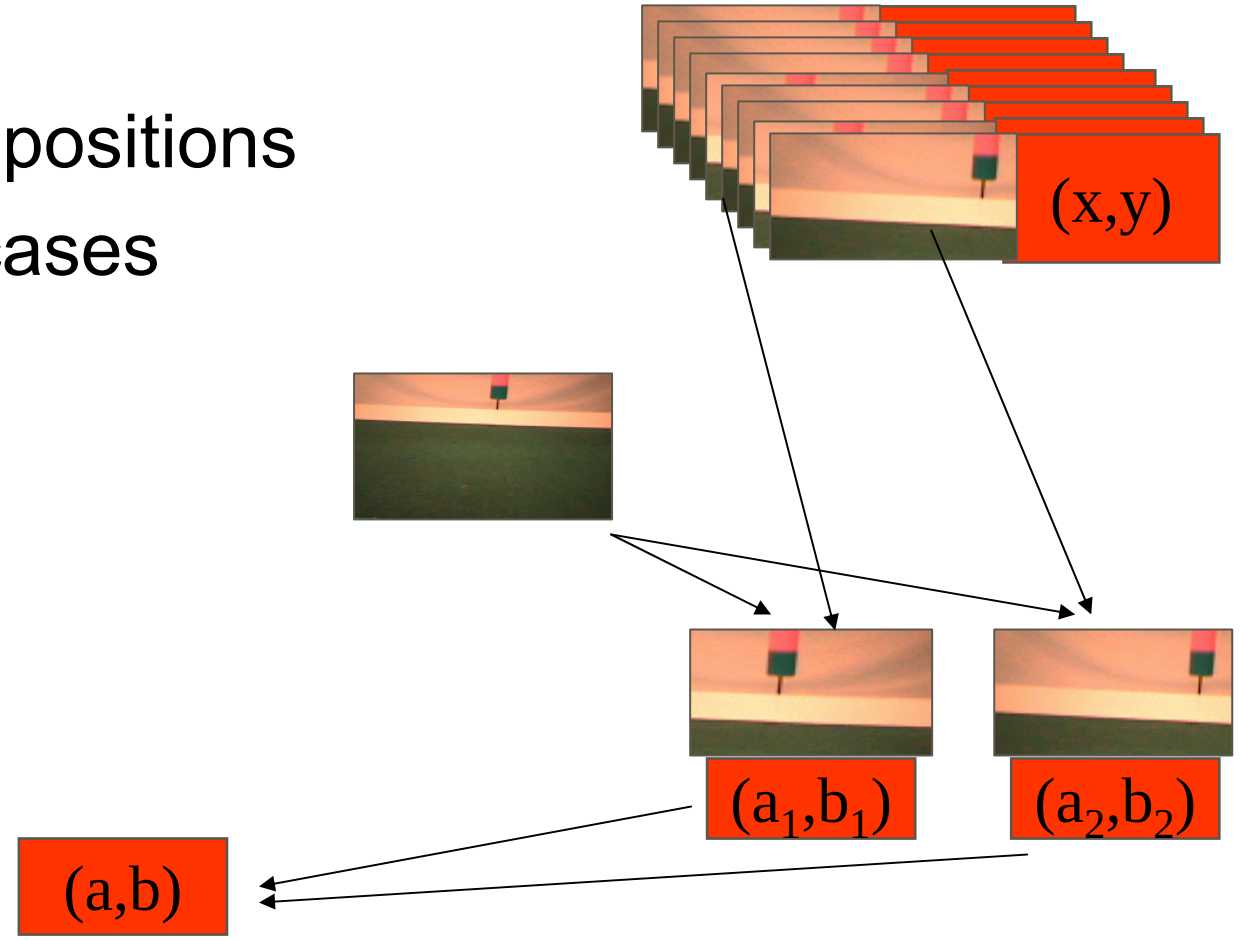
– **noisy**



Navigation using CBR

Adaptation

Interpolating positions of retrieved cases



Similarity in Navigation

Confidence measure for own position:

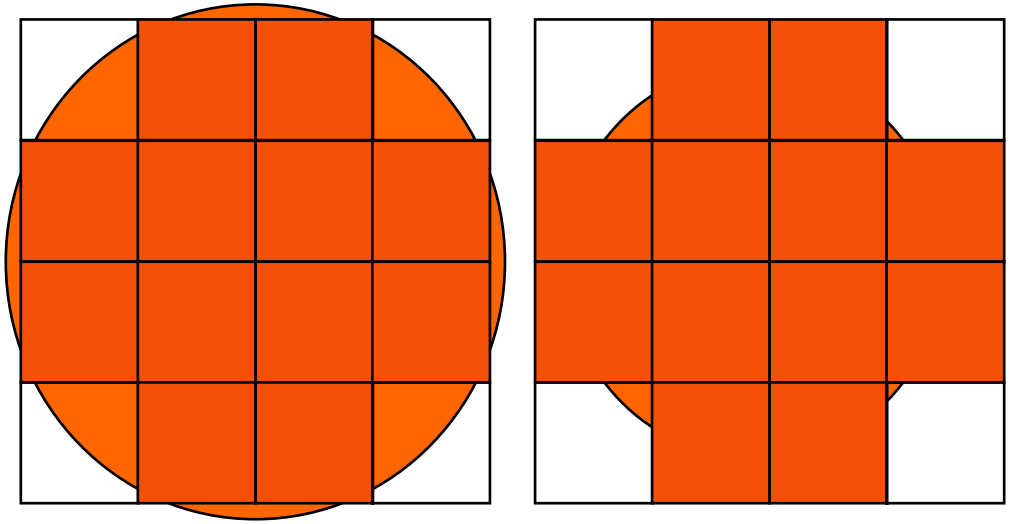
Similarity between

- actual perception
- expected perception

Bayesian methods: Particle Filter, Kalmanfilter

Similarity in Navigation

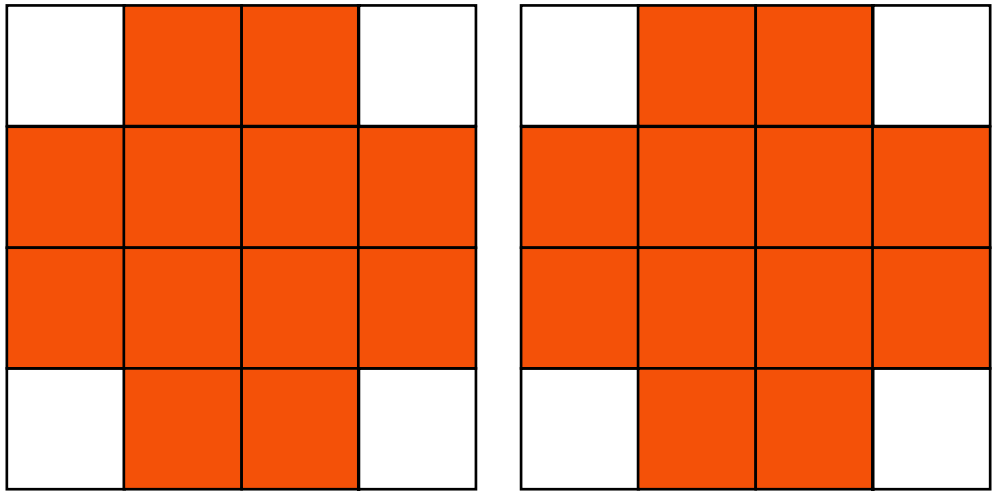
Problems with quantization



Balls of different size

Similarity in Navigation

Problems with quantization



Balls of different size
- may have same appearance in the image

Similarity in Navigation

Quantization and noise:

Similarity may be not continuous

Perception: Opponent modeling

Online: Coach program

Offline: Analysis of logfiles

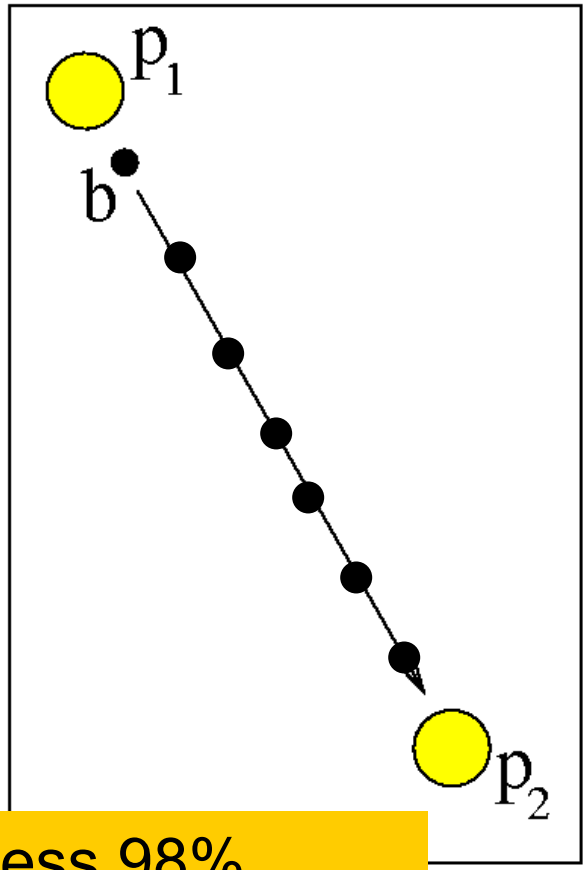
Tons of data available in Simulation League:

- logfiles of championships in the web
- designed cases

Casebase: Analysis of logfiles

Example: Pattern for Pass

- $ballControl_2(p_1,t_0,t_1)$
- $ballFree(t_2, t_{n-2})$
- $ballControl_1(p_2, t_{n-1}, t_n)$
- $ballFastDeparting(p_1,t_2, speed)$
- $teammateInKickRegion(p_1,t_2)$
- $sameTeam(p_1,p_2)$
- $notSame(p_1,p_2)$
- …



Evaluation: Correctness 98%
(similar to classification by humans)

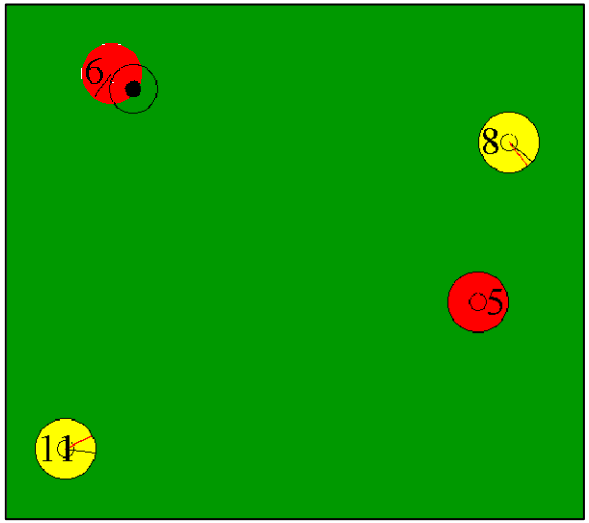
Behavior prediction (classification)

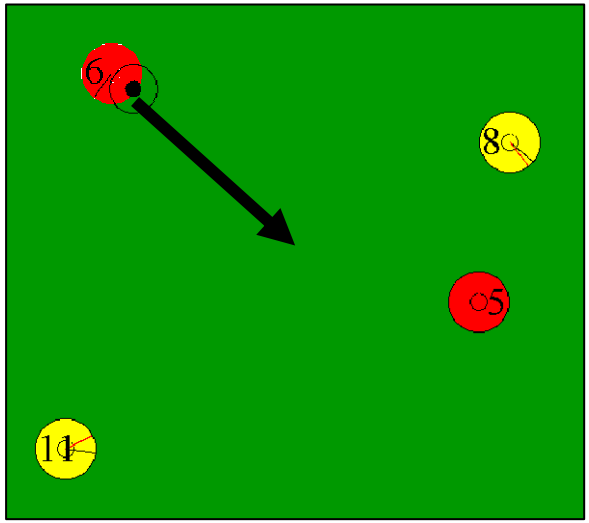
PhD Thesis
Jan Wendler

Trigger + Behavior

Trigger:
Important part of situation
- Positions of near players
- Position/Speed of Ball

Behavior:
Interpreted sequence of actions
e.g. „Pass to …“





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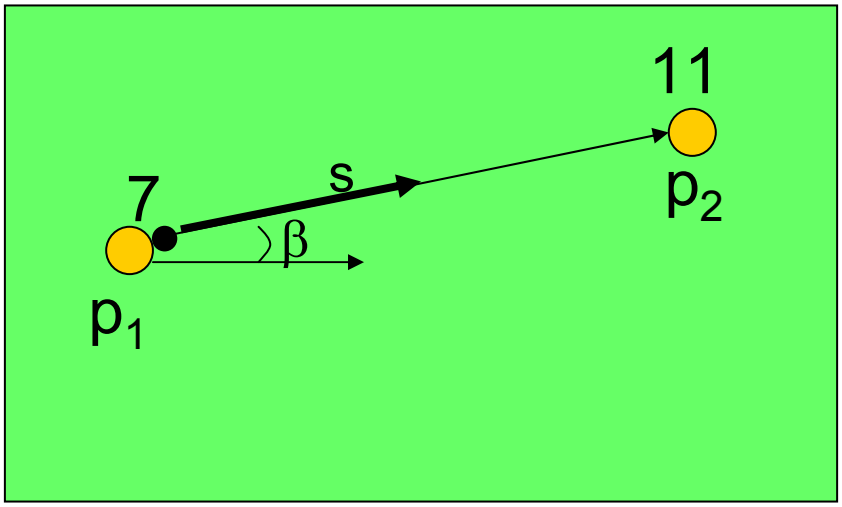
,
ICCBR 2007

Behavior

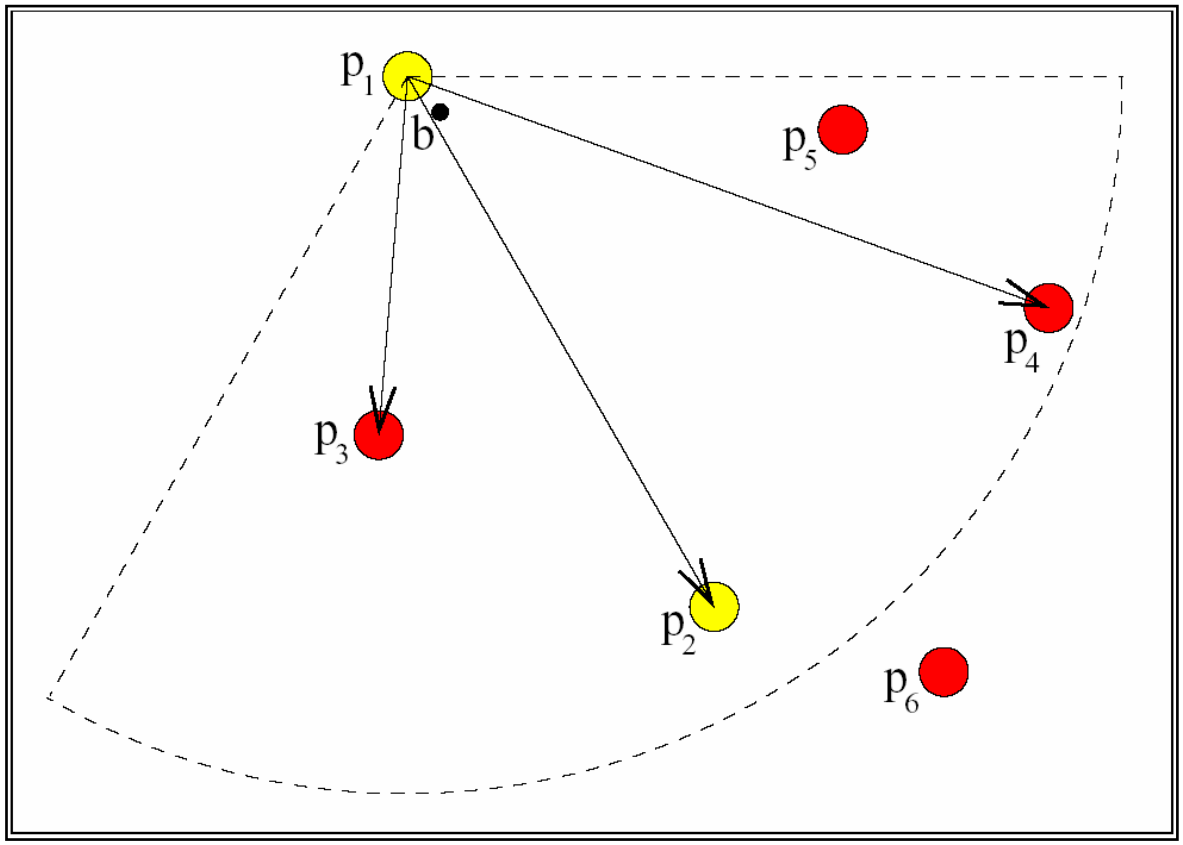
Pass by player 7 at position p_1

to player 11 at Position p_2

with angle β and speed s



Situation (Trigger)



Primary Attributes

- Position p_1
- $\overrightarrow{p_1p_2}$
- $\measuredangle(\overrightarrow{p_1p_3}, \overrightarrow{p_1p_2})$
- $\overrightarrow{p_1p_3}.length$
- $\measuredangle(\overrightarrow{p_1p_4}, \overrightarrow{p_1p_2})$
- $\overrightarrow{p_1p_4}.length$

Secondary Attributes

- *Player numbers*
- *Time*
- *Team*
- *...*

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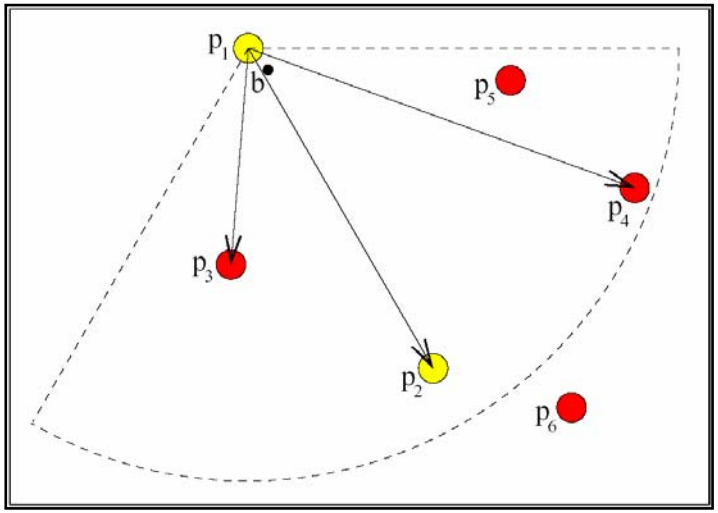
Similarity for Trigger

Weighted sum of local similarities



Primary Attributes

Position p_1

$\overrightarrow{p_1p_2}$

$\measuredangle(\overrightarrow{p_1p_3}, \overrightarrow{p_1p_2})$

$\overrightarrow{p_1p_3}.length$

$\measuredangle(\overrightarrow{p_1p_4}, \overrightarrow{p_1p_2})$

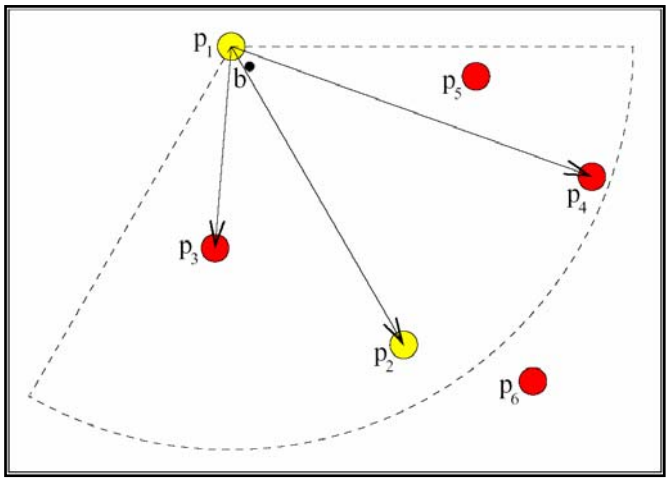
$\overrightarrow{p_1p_4}.length$

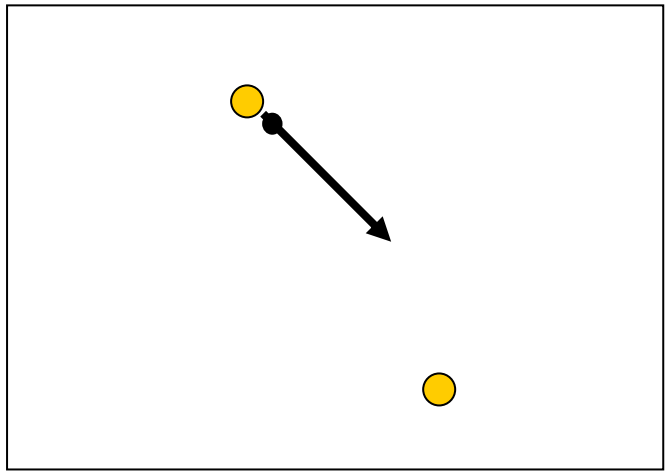
$situation\_sim(s^1,s^2) = \sum_{i=1,...n} w_i * attribut_i\_sim(a^1_i, a^1_i)$

Weights w_i defined by experiments

Cases

Case: [Trigger, Behavior]





Parameter of Situation

Parameter of Behavior

Behavior prediction for opponents:
Similar trigger leads to similar behavior

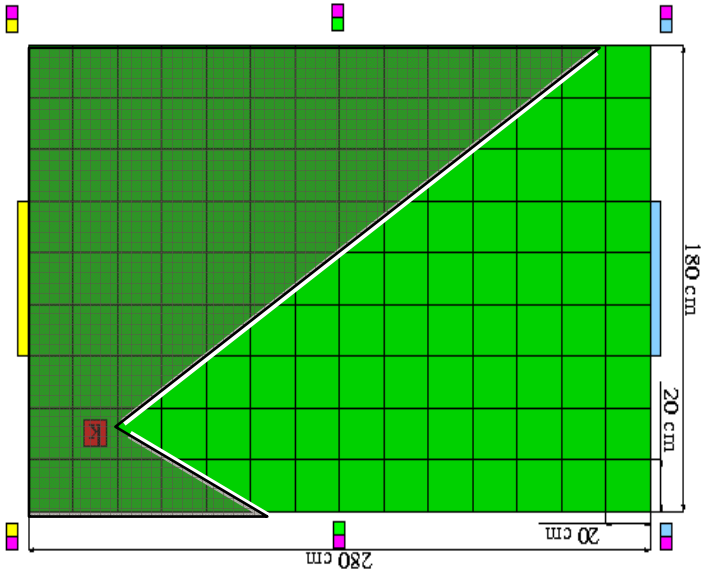
Accuracy of behavior prediction only < 50%

Why?

- Decision of opponent depends not on single situation:

  Deliberative Behavior (worldmodel, goals/plans)

- Opponent has limited belief about situation



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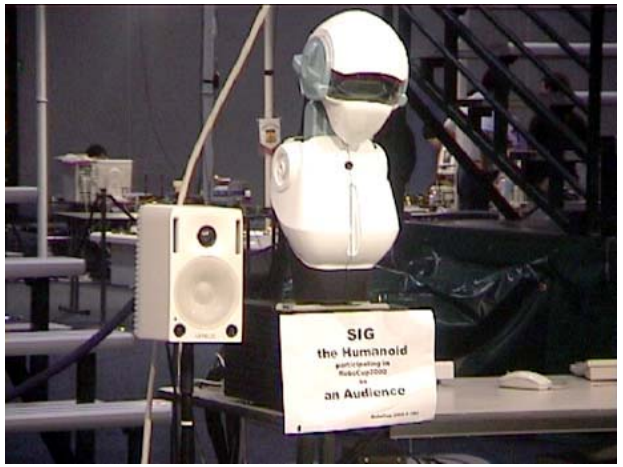
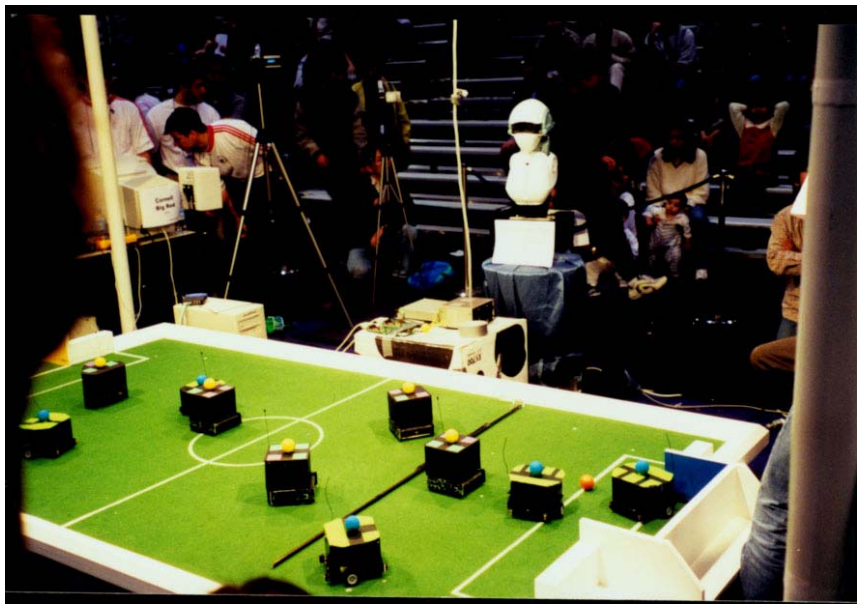
Further applications of analysis

Commentator programs





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How to “Understand Myself”

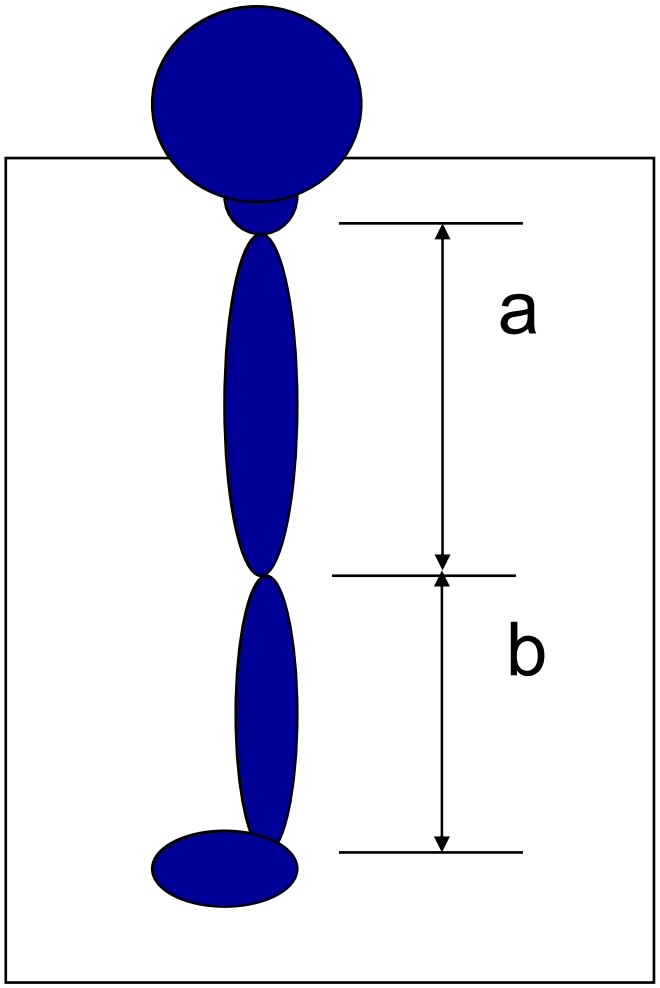
How to use the body?

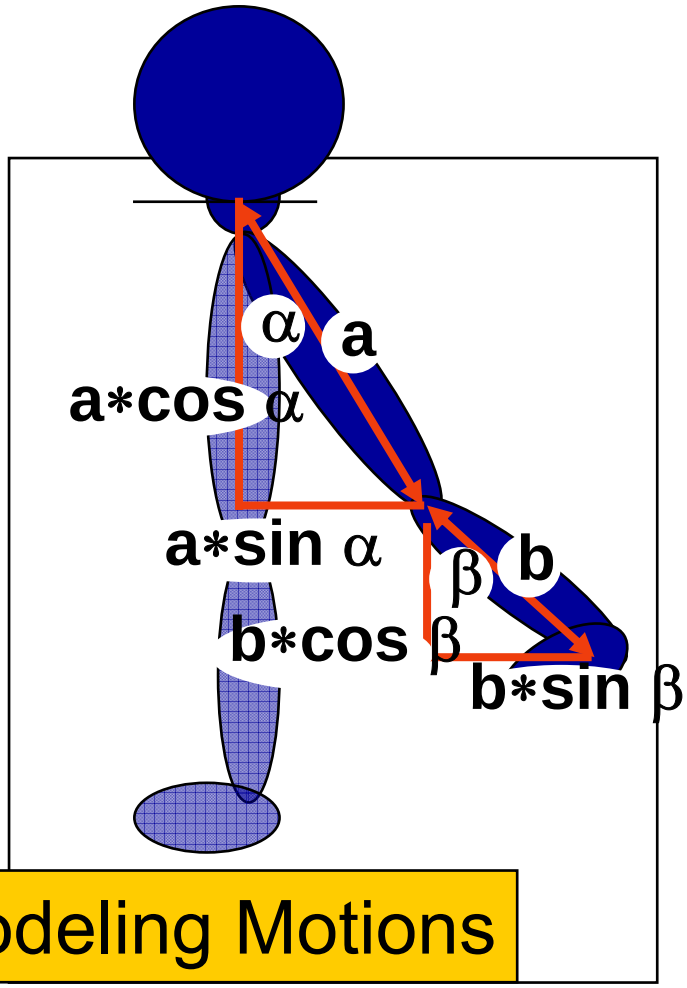
How to walk, jump and run?

How to kick and dribble?

How to stand up?

The Problem of Body Movements





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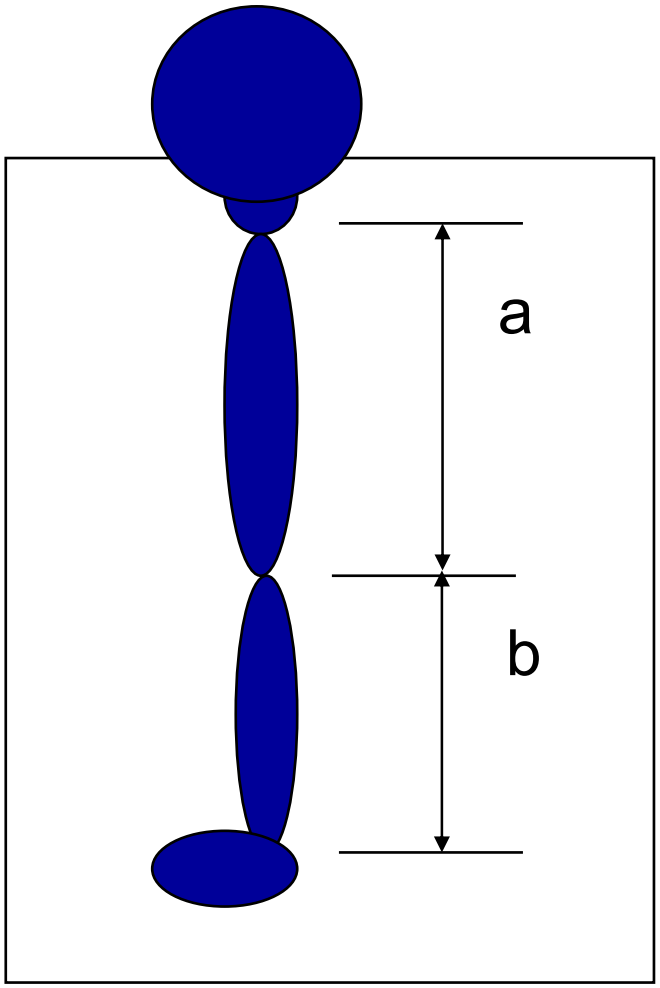
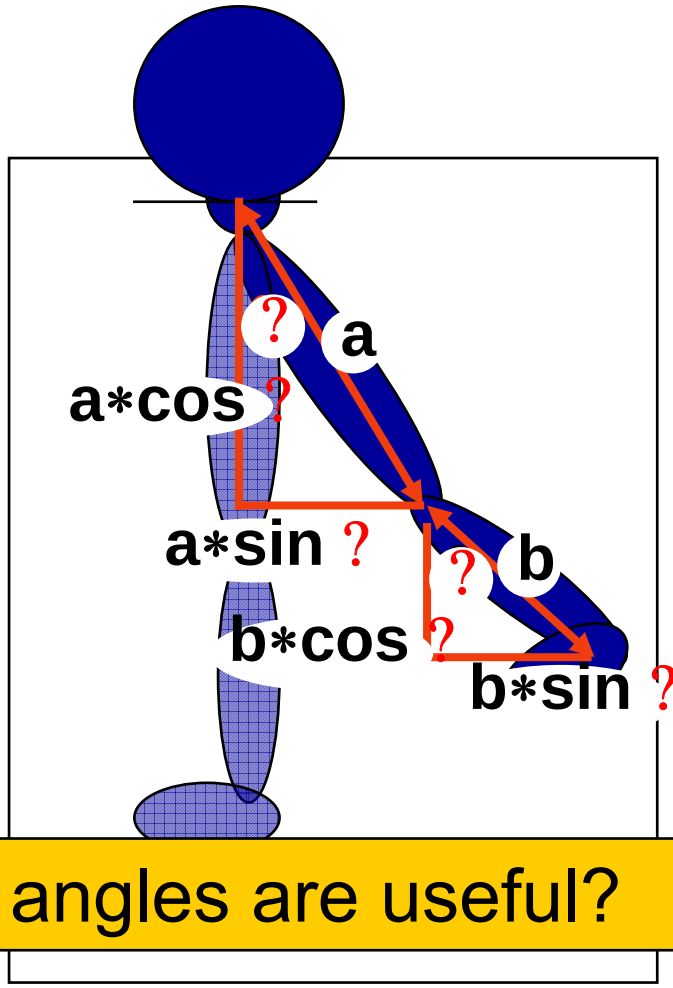
The Problem of Body Movements





Which angles are useful?

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Complex Calculations

$$px_3 = px(\Theta_1, \Theta_2, \Theta_3)$$

$$px_0 = 0$$

$$py_0 = 0$$

$$px_1 = \cos(\Theta_1) * a_1$$

… but humans walk without knowing physics and calculations

$$py_3 = py_2 + \sin(\Theta_1 + \Theta_2 + \Theta_3) * a_3$$

$$px_3 = \cos(\Theta_1) * a_1 + \cos(\Theta_1 + \Theta_2) * a_2 + \cos(\Theta_1 + \Theta_2 + \Theta_3) * a_3$$

$$py_3 = \sin(\Theta_1) * a_1 + \sin(\Theta_1 + \Theta_2) * a_2 + \sin(\Theta_1 + \Theta_2 + \Theta_3) * a_3$$

$$\frac{\Delta py(\Theta)}{\Delta \Theta_2} = \cos(\Theta_1 + \Theta_2) * a_2 + \cos(\Theta_1 + \Theta_2 + \Theta_3) * a_3 = px_3 - px_1$$

$$\frac{\Delta py(\Theta)}{\Delta \Theta_3} = \cos(\Theta_1 + \Theta_2 + \Theta_3) * a_3 = px_3 - px_2$$

Machine Learning

- Evolutionary Algorithms
- Reinforcement Learning
- Case Based Reasoning
- Neural Networks
- …

On different levels from basic skills up to complex multi agent behavior

Keyframe Techniques

Keyframe: Positions of joints

Motion:

Sequence of keyframes

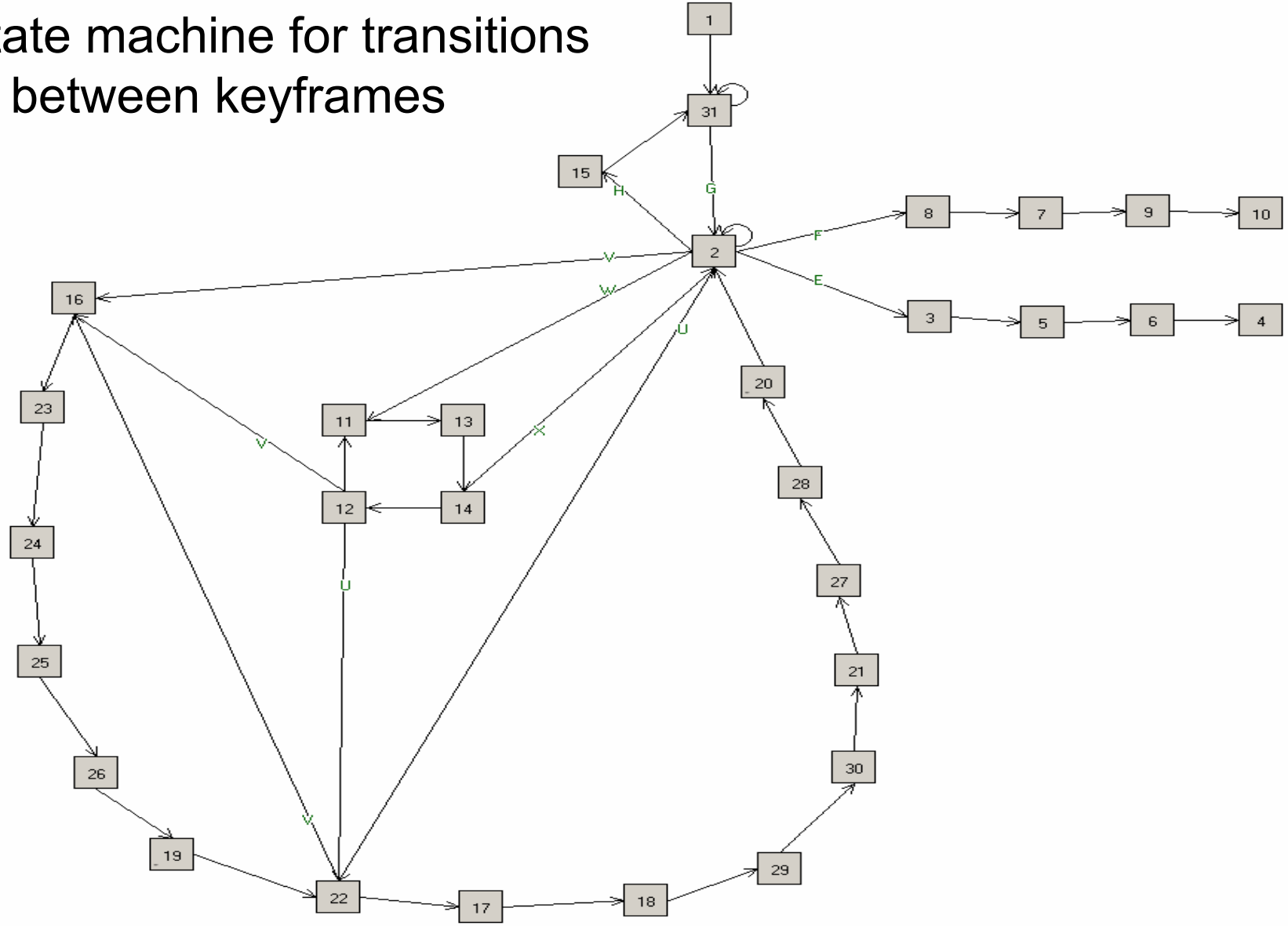
Teaching:

Record keyframes during motion

VStone 2004

Motion Net

State machine for transitions between keyframes



Ha
Hu

Project: CBR for Keyframe Techniques

Keyframe (sequences) are cases.

- Classification of useful behaviors for a task

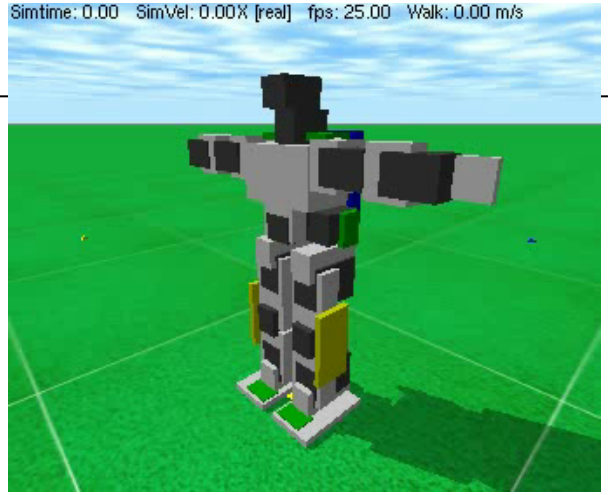
- Adaptation needed according to
  - task parameters
  - environment (e.g. floor)

Needs sensory feed back

Learning in Simulation

Evolutionary approach with

simple recurrent Neural Networks



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

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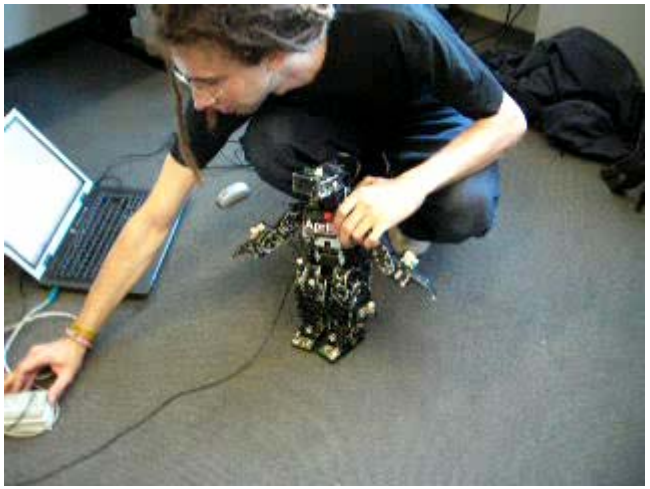
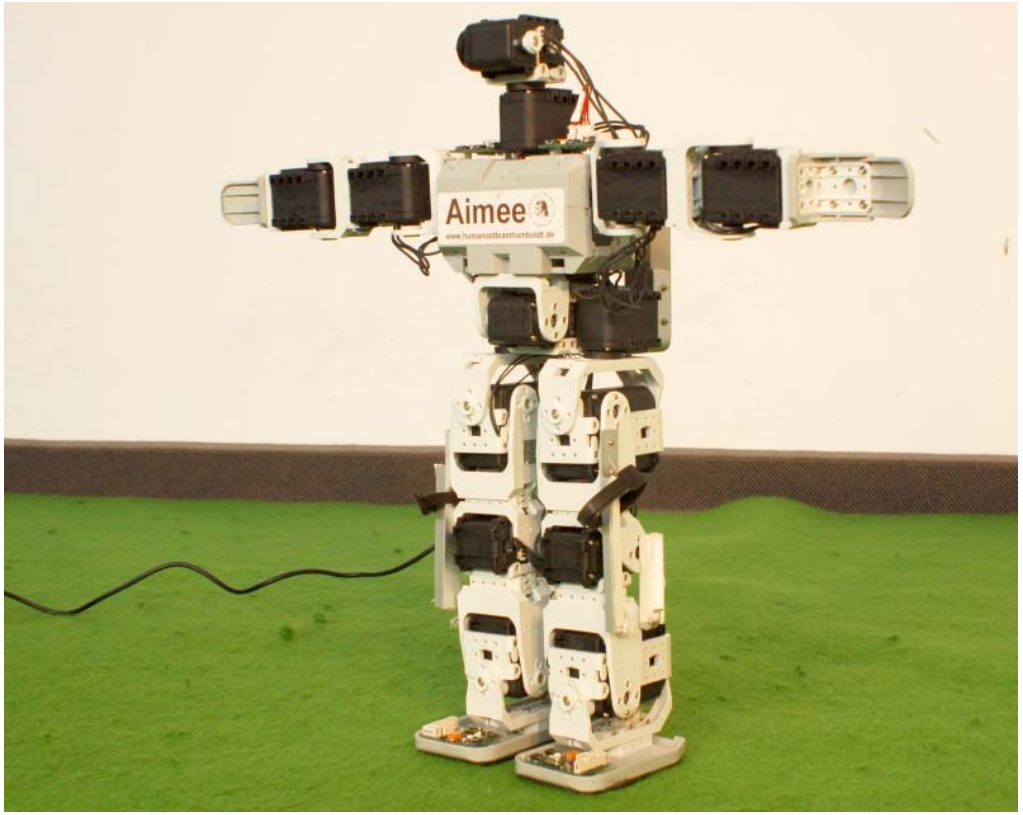
Proprioception: Feeling the own Body





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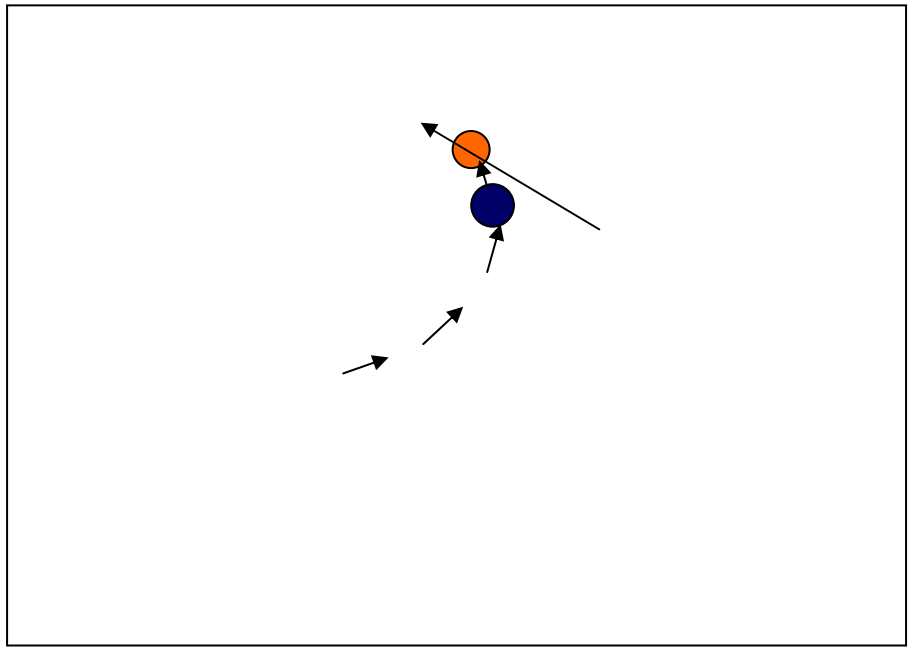
How to Play

- Where am I?
- Where is the ball?
- Where are the others?
- What are they doing?

- What shall I do?

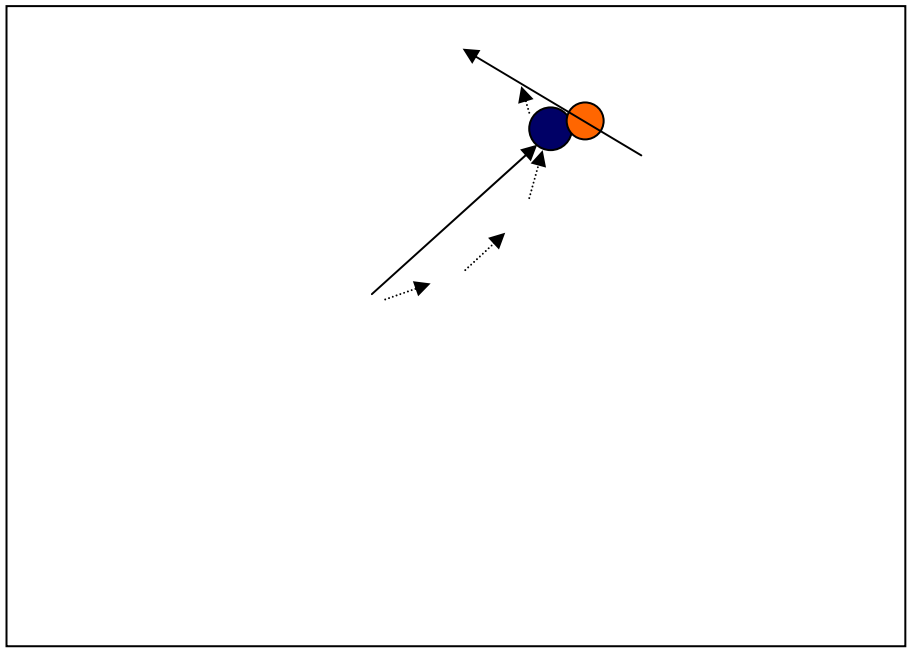
Stimulus-Response

Run for the ball



Goal directed behavior

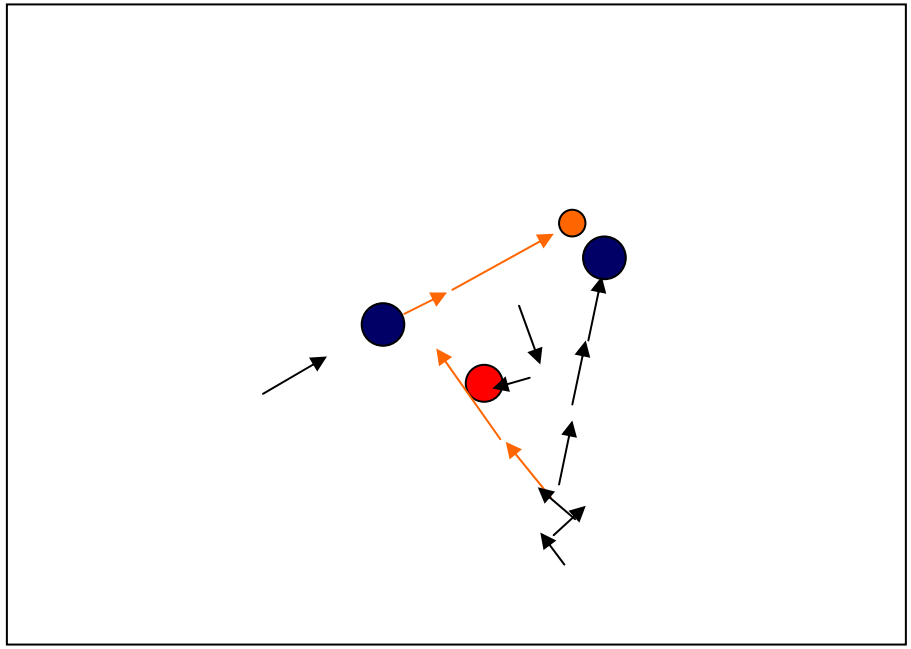
– Acting according to predefined goal



Cooperation

Cooperation

Joint intention *(Double pass)*



How to program a double pass (wall pass)?

1. Trial („Chess-like“):

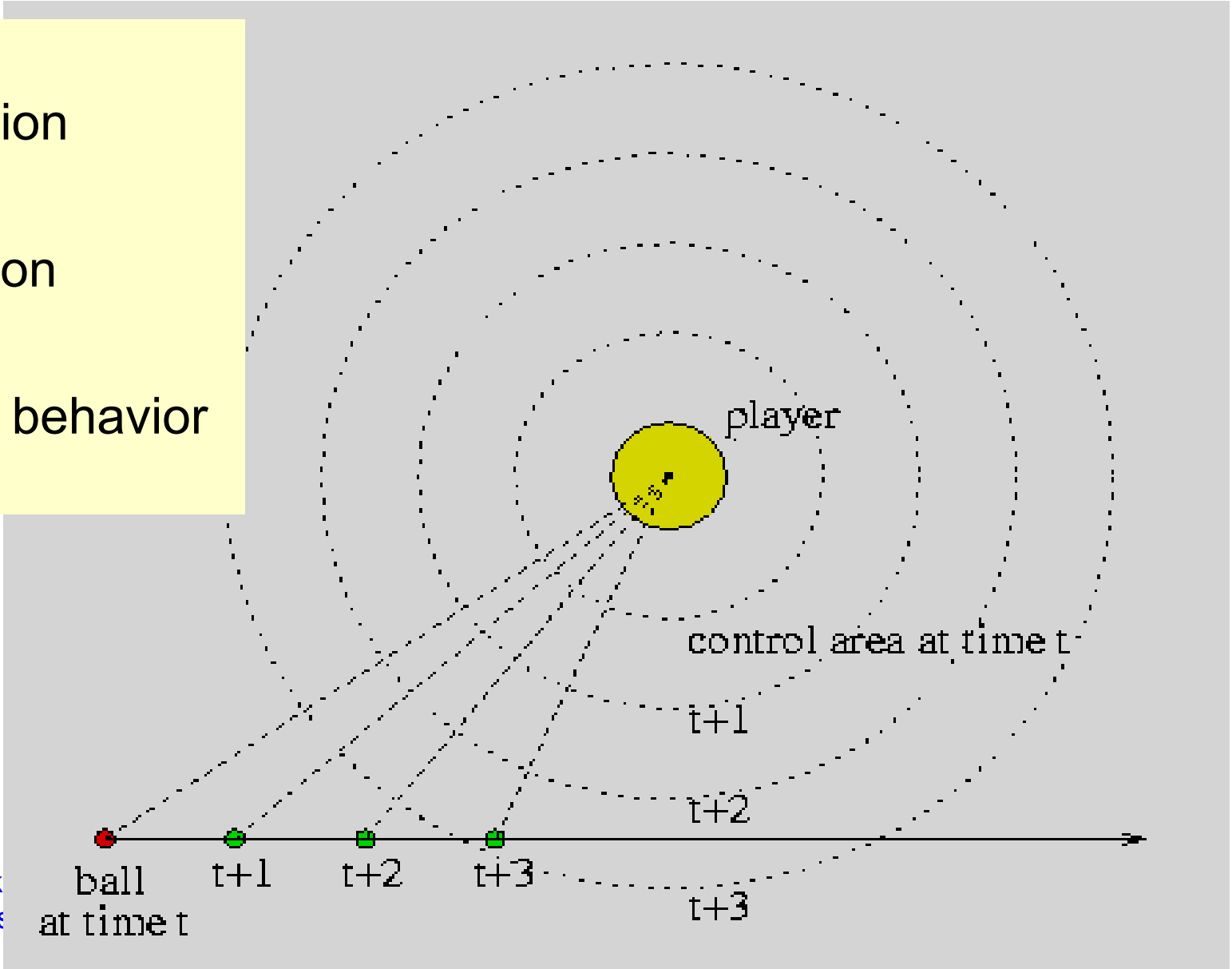
- Foresight simulation
- Choice of best alternative

Where to intercept the ball?

By calculation

By simulation

By learned behavior



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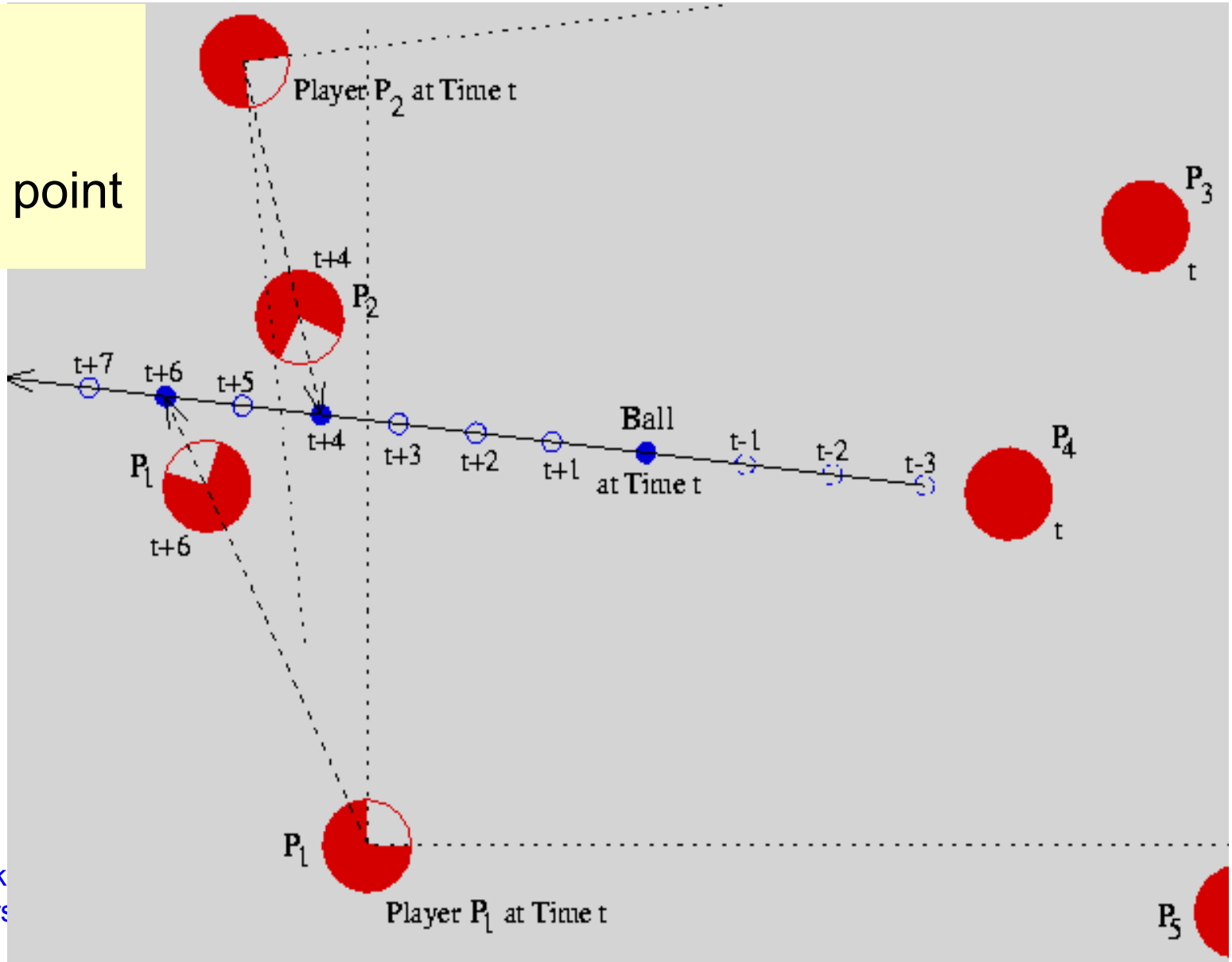
Which player can intercept first?

Based on
calculation
of intercept point



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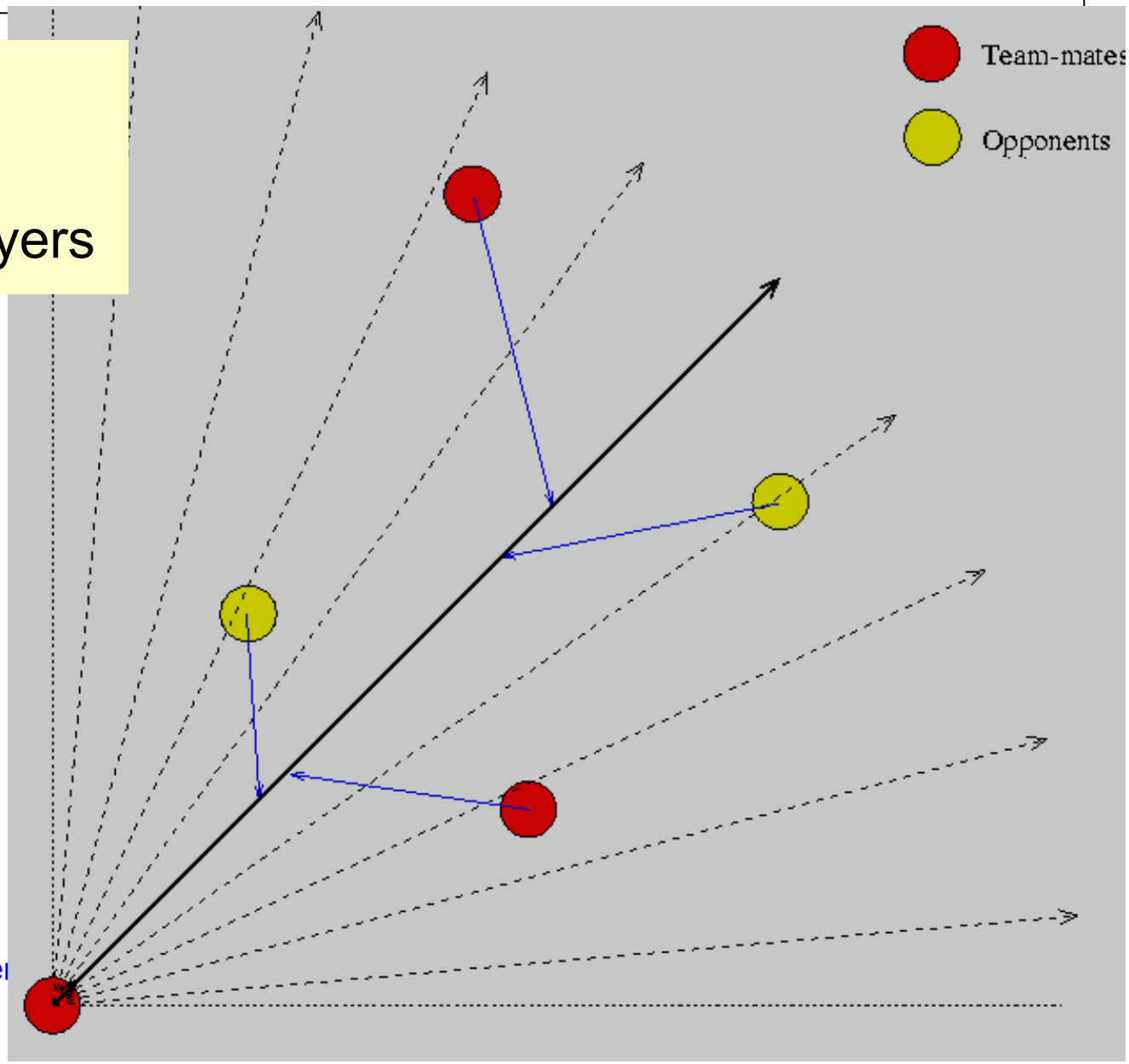
Pass to which team mate?

Based on
calculations
of intercepting players



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How to program a double pass?

1. Trial („Chess-like“):

- Foresight simulation
- Choice of best alternative

Result:
Useful only for short term decisions

How to program a double pass?

2. Trial („Emergence“):

If every player behaves in an optimal way,

then a double pass emerges without planning.

Result:

double pass emerges from time to time

How to program a double pass?

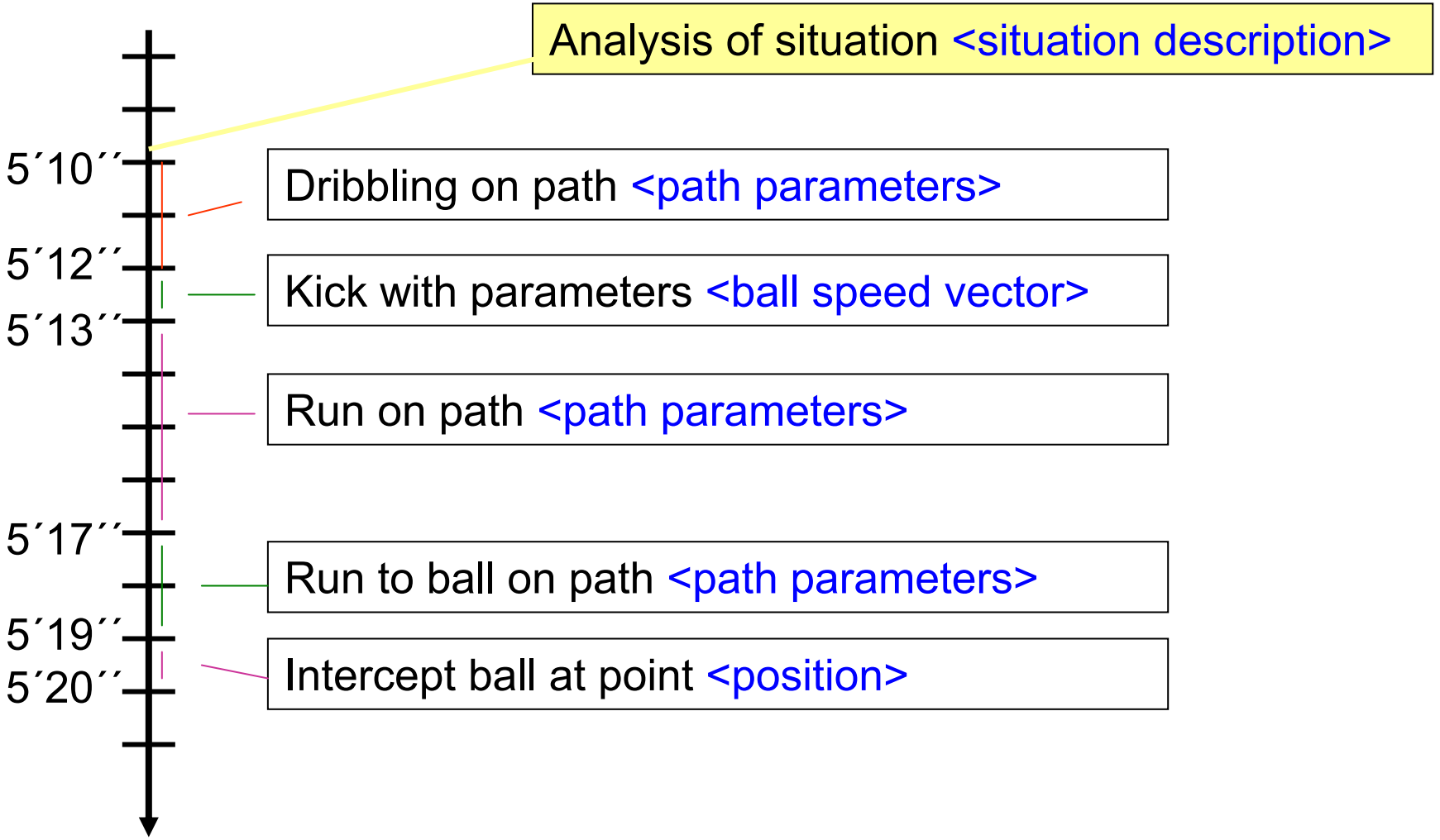
3. Trial:

Use Bratman´s concepts for „bounded rationality“

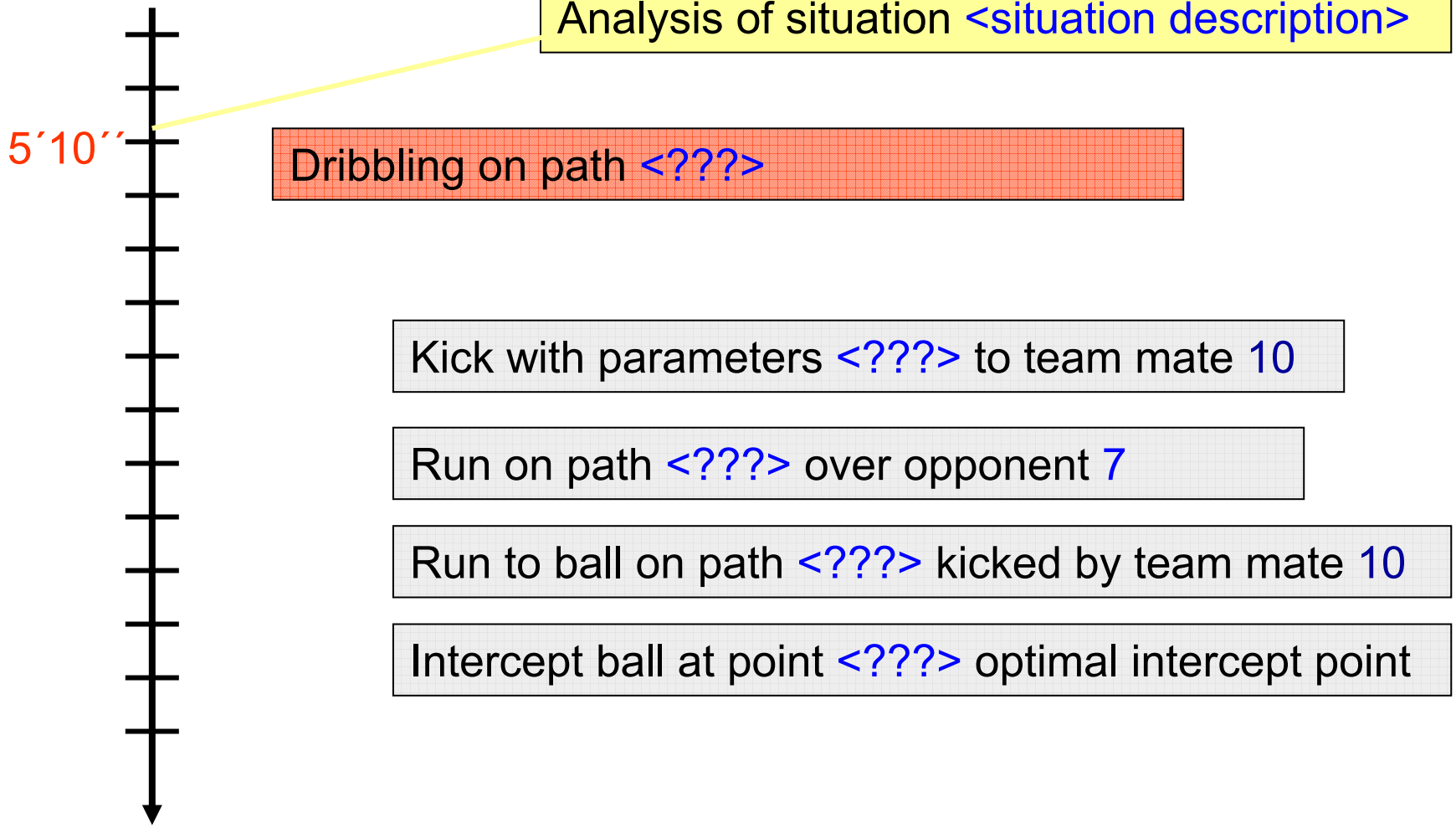
Belief-Desire-Intention-Architecture (BDI)

Still under work …

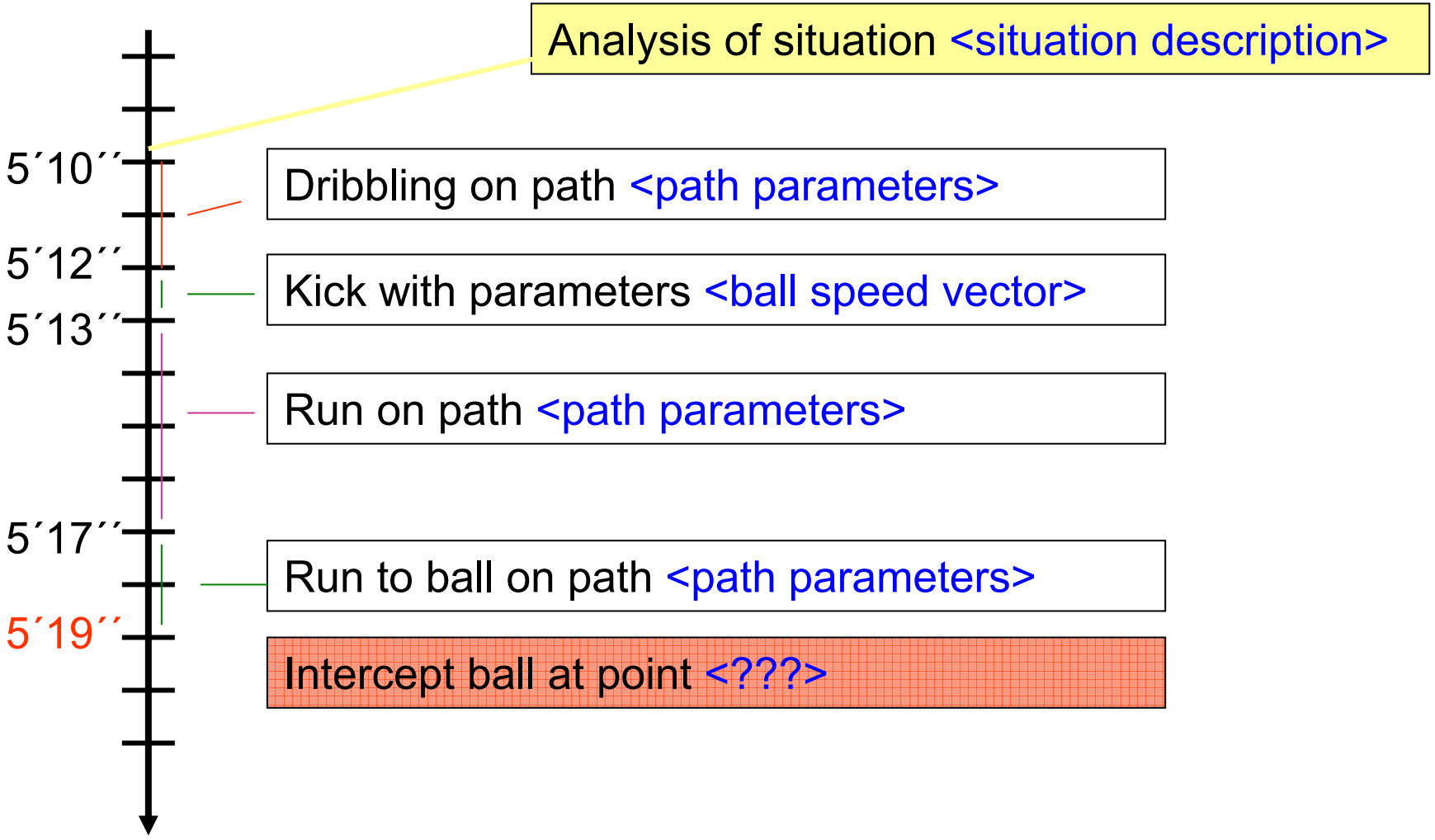
Only partial plan in the beginning



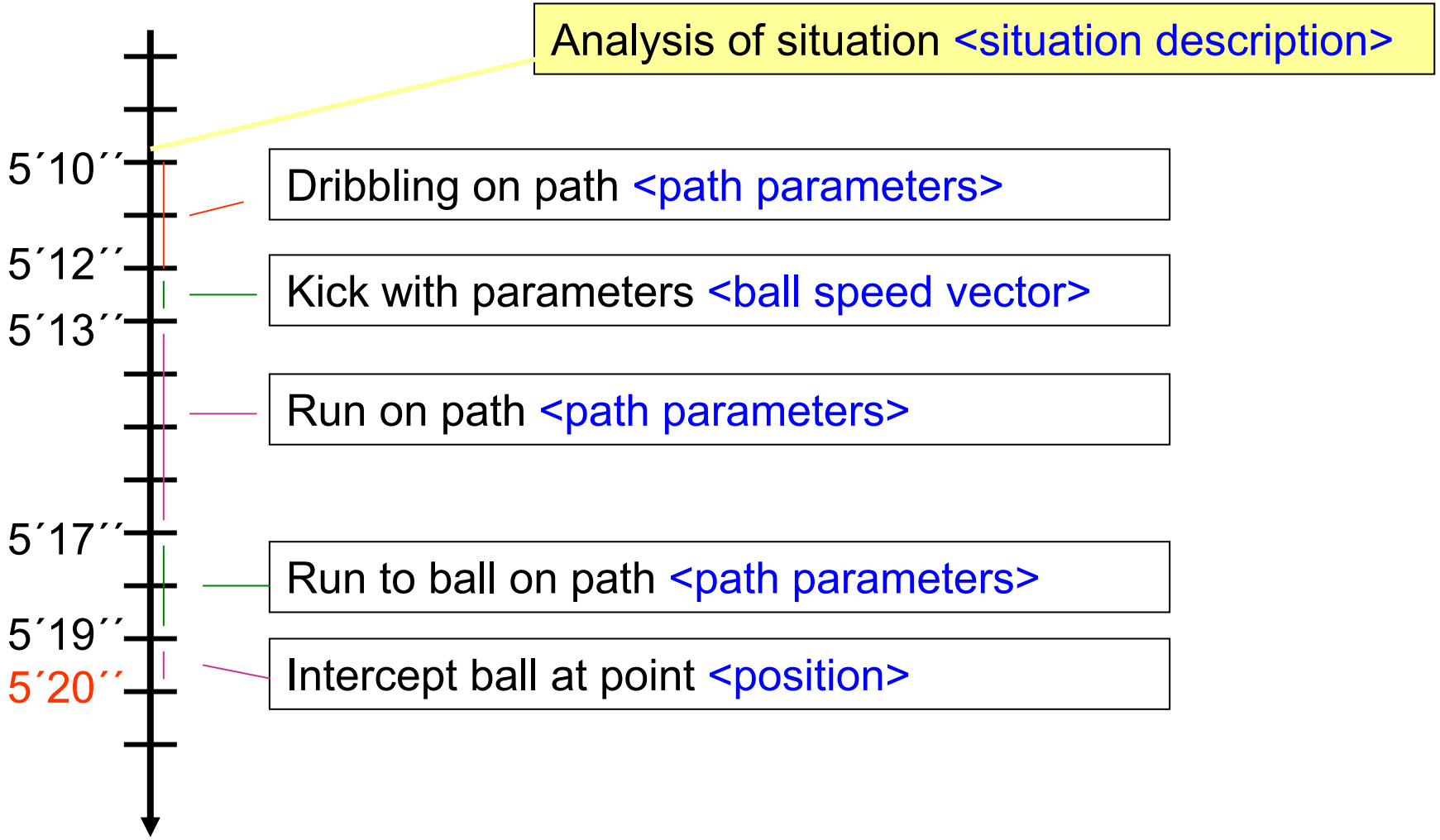
Time 5´10´´


Analysis of situation <situation description>
5´10´´
Dribbling on path <???>
Kick with parameters <???> to team mate 10
Run on path <???> over opponent 7
Run to ball on path <???> kicked by team mate 10
Intercept ball at point <???> optimal intercept point

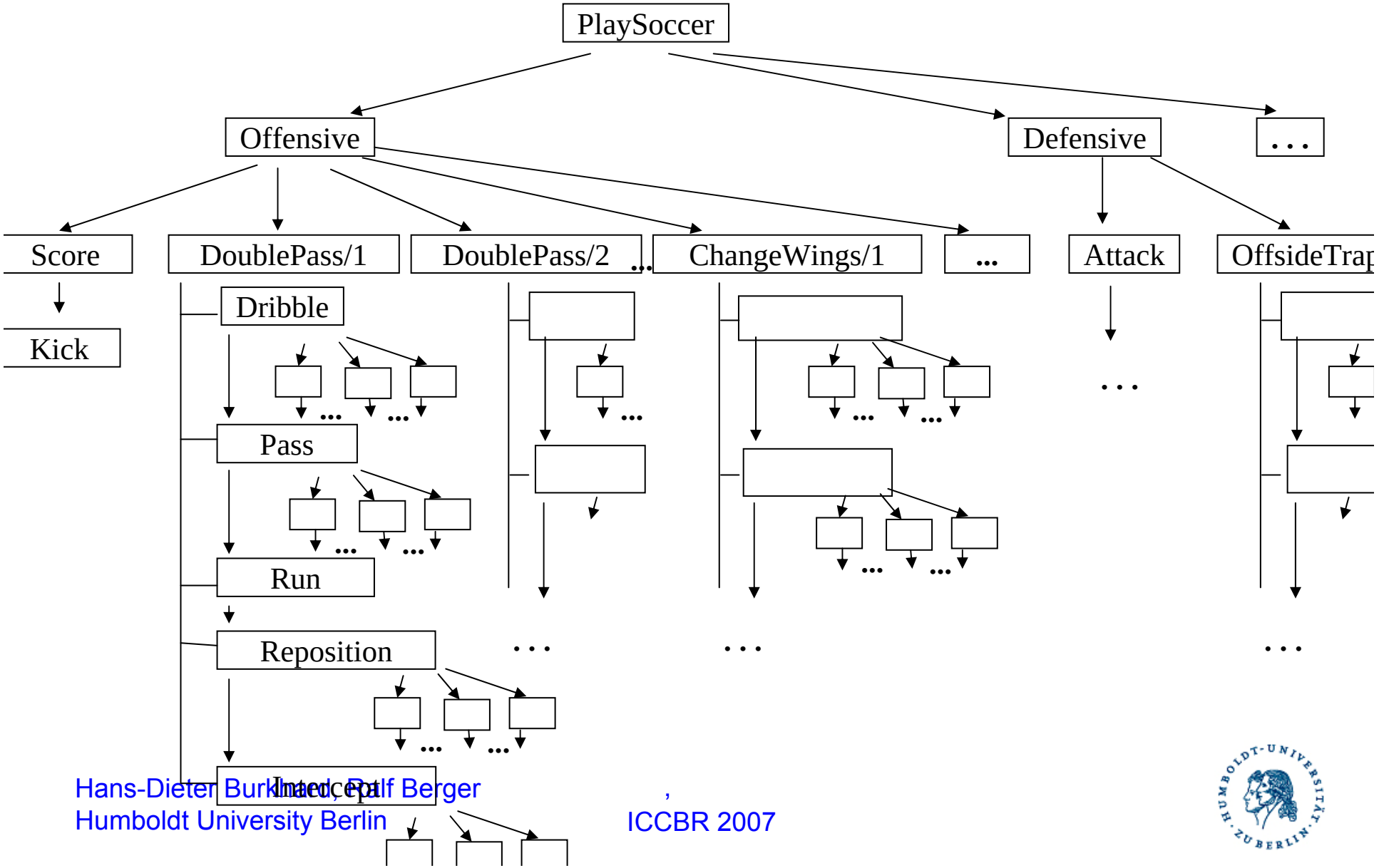
Time 5´19´´

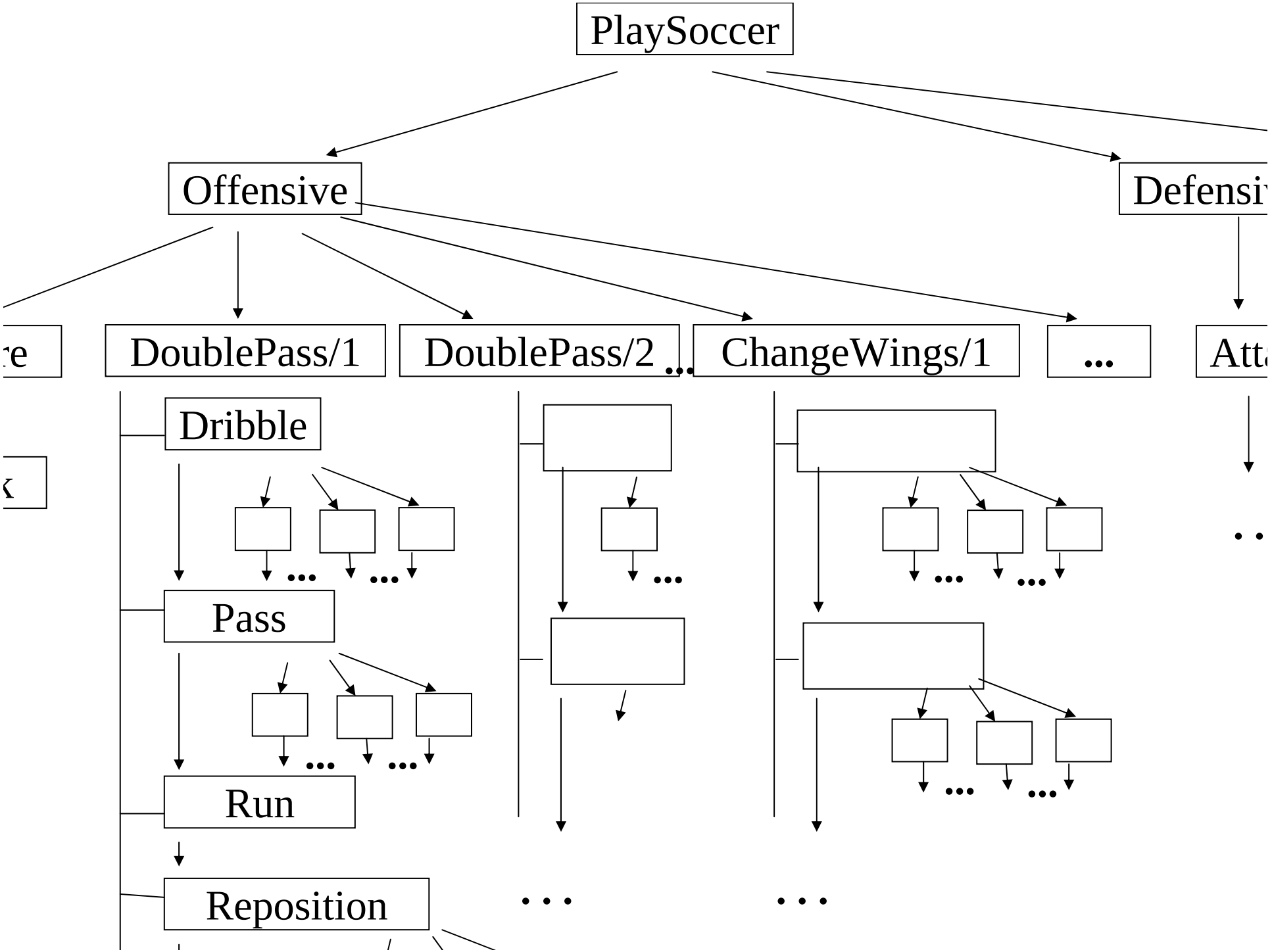

Analysis of situation <situation description>
5´10´´
Dribbling on path <path parameters>
5´12´´
Kick with parameters <ball speed vector>
5´13´´
Run on path <path parameters>
5´17´´
Run to ball on path <path parameters>
5´19´´
Intercept ball at point <???>

Time 5´20´´

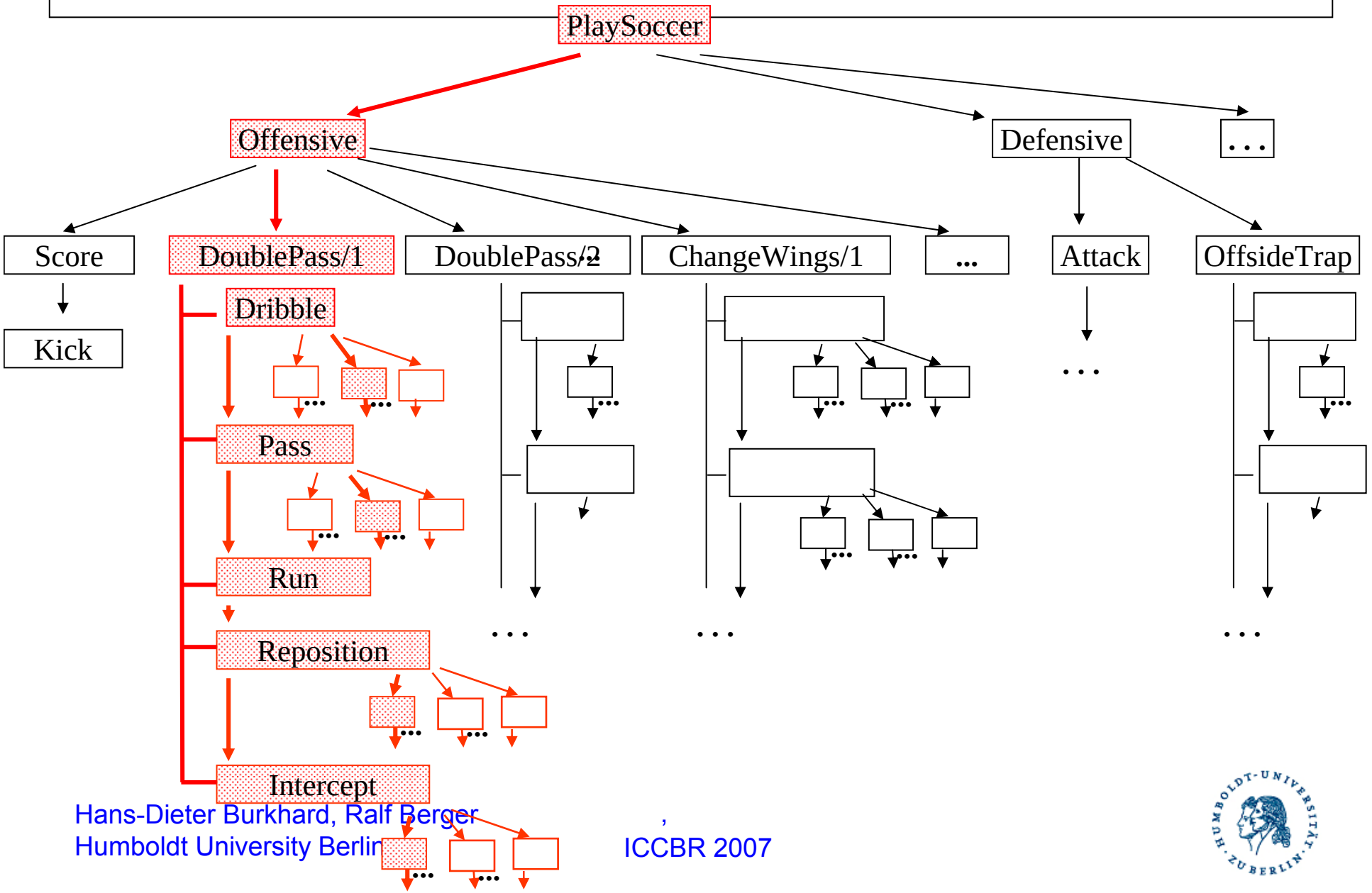

Analysis of situation <situation description>
5´10´´
Dribbling on path <path parameters>
5´12´´
Kick with parameters <ball speed vector>
5´13´´
Run on path <path parameters>
5´17´´
Run to ball on path <path parameters>
5´19´´
5´20´´
Intercept ball at point <position>

Hierarchy of Options

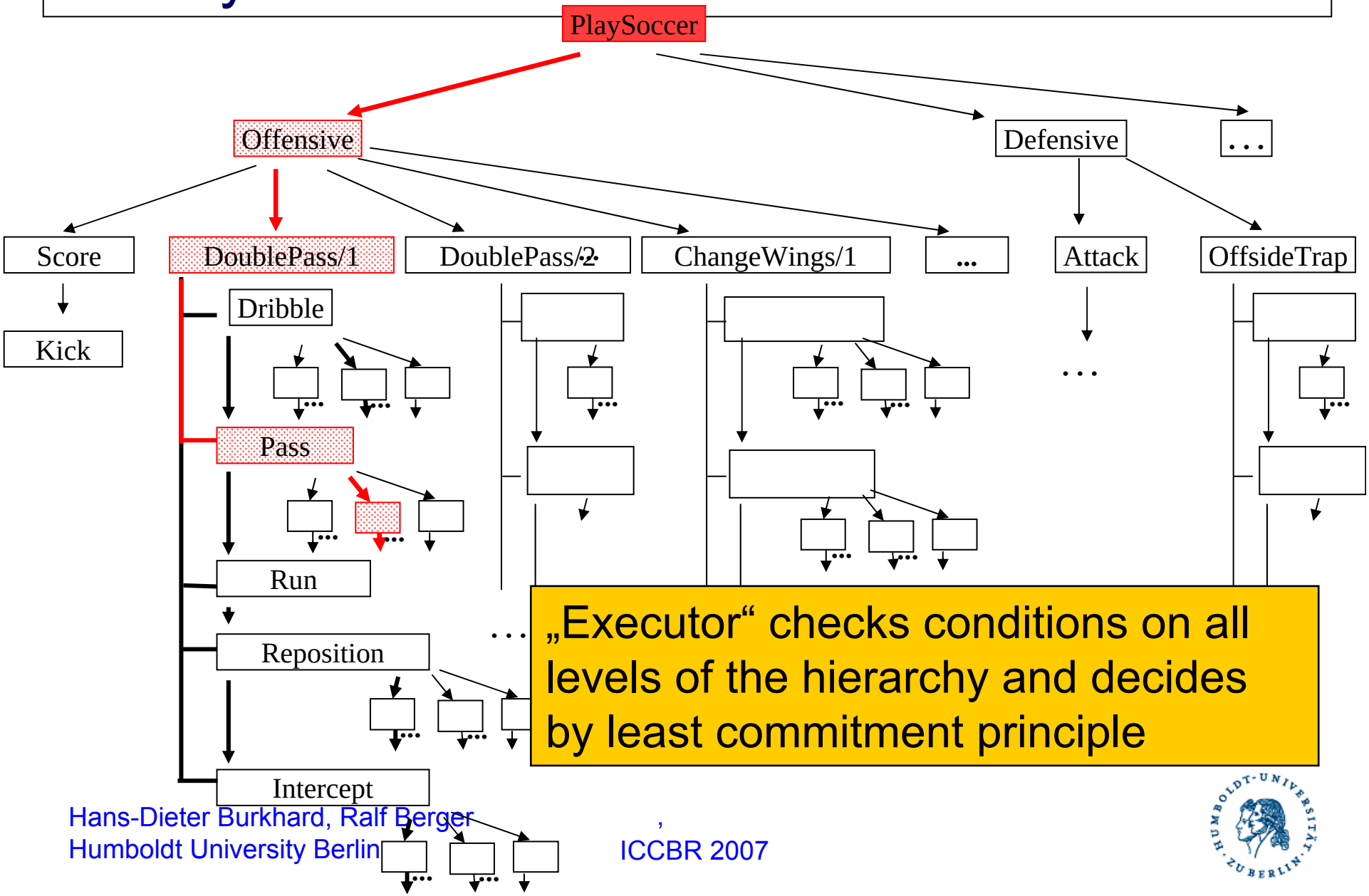



PlaySoccer
Offensive
Defensi
re
DoublePass/1
DoublePass/2
ChangeWings/1
...
Att
Dribble
Pass
Run
Reposition

Result of “Deliberator“: Intention Subtree



Activity Path: Present state of an Intention



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Double-Pass Architecture

- Predefined Option Hierarchy
- Deliberator
- Executor

„Doubled“ 1-Pass-Architecture:

- 1. Pass: Deliberator (goal-oriented: Intention Subtree)
- 2. Pass: Executor (stimulus-response: activity path)

- on all levels -

Differences to “classical” Programming

- Control flow by Deliberation (“Agent- oriented”)
- Runtime organisation by 2 Passes through all levels

When to make a double pass?

- Depends on situation: Classification task

Case: Problem part: Situation

Solution part: Action/plan

Classification using CBR, e.g. for:

- Game play
- Positioning
- Goalie behavior
- Kick selection
- Player types (power, accuracy, …)

Ongoing decisions …

Observations, decisions, actions during double pass:

- Observe opponent
- Search for team mate
- Dribble
- Pass to team mate
- Run over opponent
- Run forward
- Intercept
- ….

Many situations (problems) and decsions (solutions)

Would need many different rule type cases

AT Humboldt Project

Consider the whole episode with all decisions and subgoals/subbehaviors as a single case

- Using Case Retrieval Nets (CRN) for case completion
- Using Double Pass Architecture (DPA) for structuring (following the BDI-approach)

Case completion

Problem solving as a process of

- collecting information entities in reality
- guided by CBR.

Constraint type cases:

no distinction between problem and solution.

Case completion

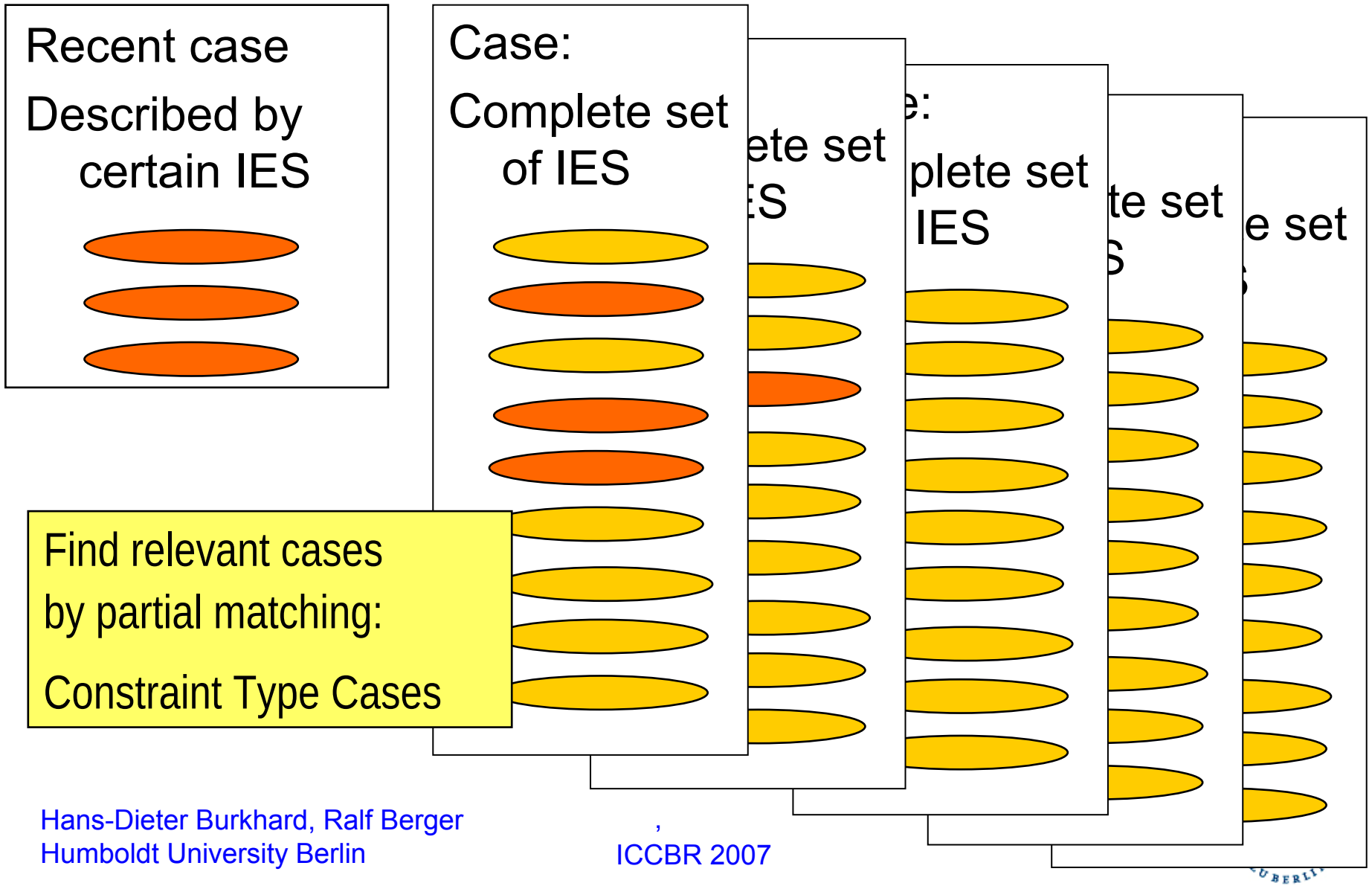
- Observe opponent
- Serch for team mate
- Dribble
- Pass to team mate
- Run over opponent
- Run forward
- Intercept

Consider whole episode
as a single case.

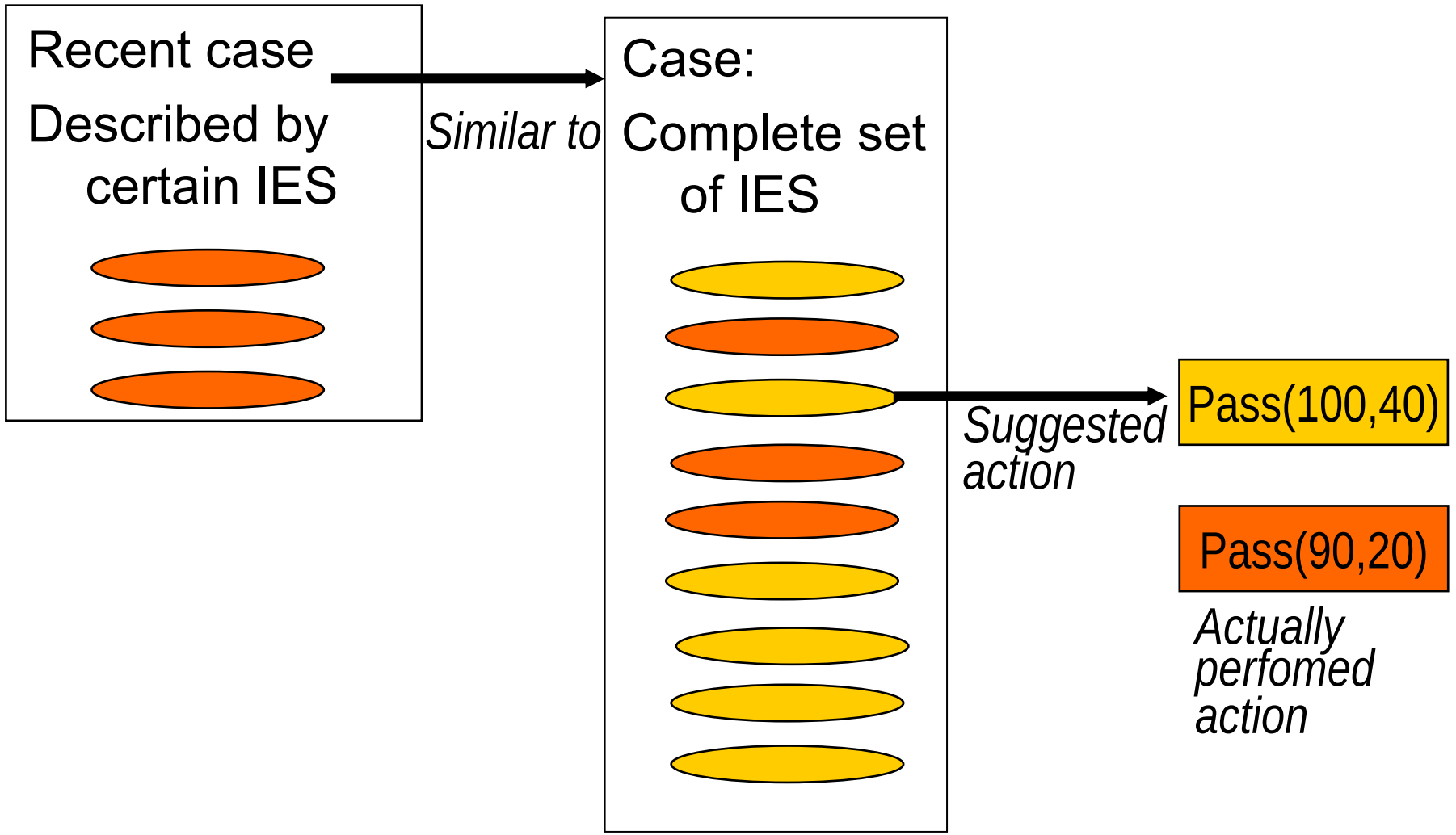
Information entities (IEs)
Describe observations and decisions.

While performing the double pass:
Old cases for useful hints
Collect new IEs while acting

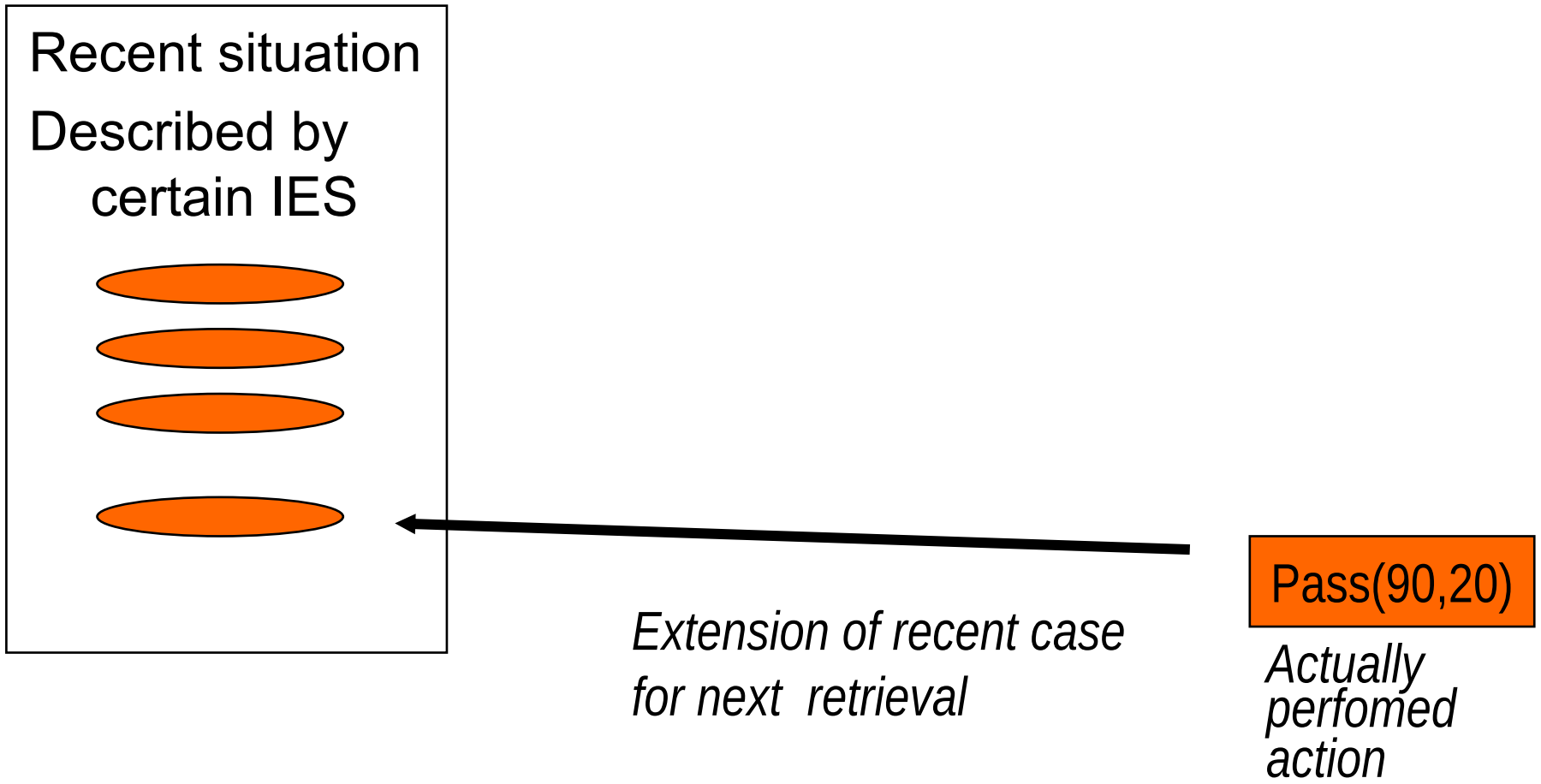
Case Completion



Case Completion



Case Completion



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 ...

Hans-Dieter Burkhard, Ralf Berger
Humboldt University Berlin

Thanks to

RoboCup Federation

RoboCup Teams all over the world

Deutsche Forschungsgemeinschaft (DFG)

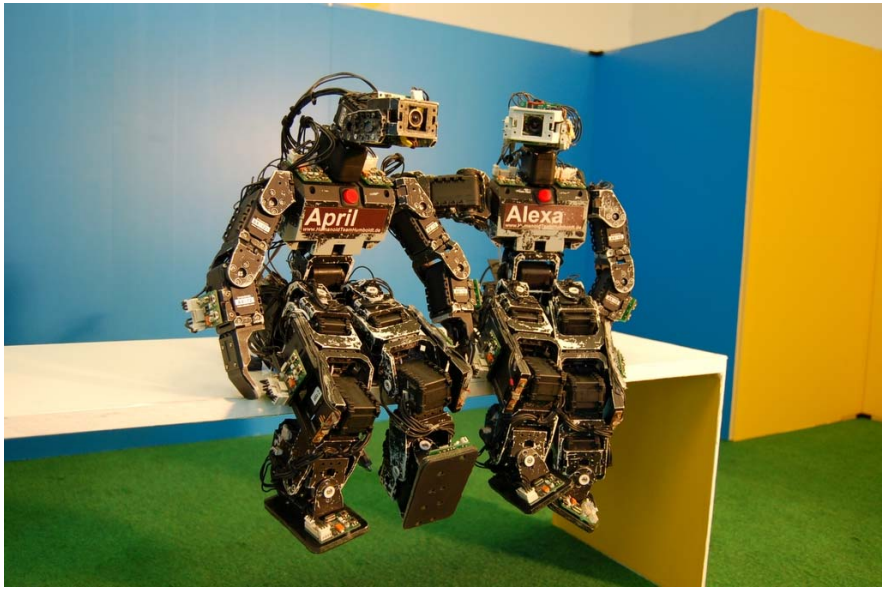
Bundesministerium für Bildung und Forschung (BMBF)

Teams of the AI-Lab at Humboldt University

Sponsors Sony, Empolis, DaimlerChrysler, PSI,WISTA

RoboCup is an Integration Project

… for humans all over the world.



See you in Suzhou July 2008

- or at GermanOpen April 2008 at Hannover Fair