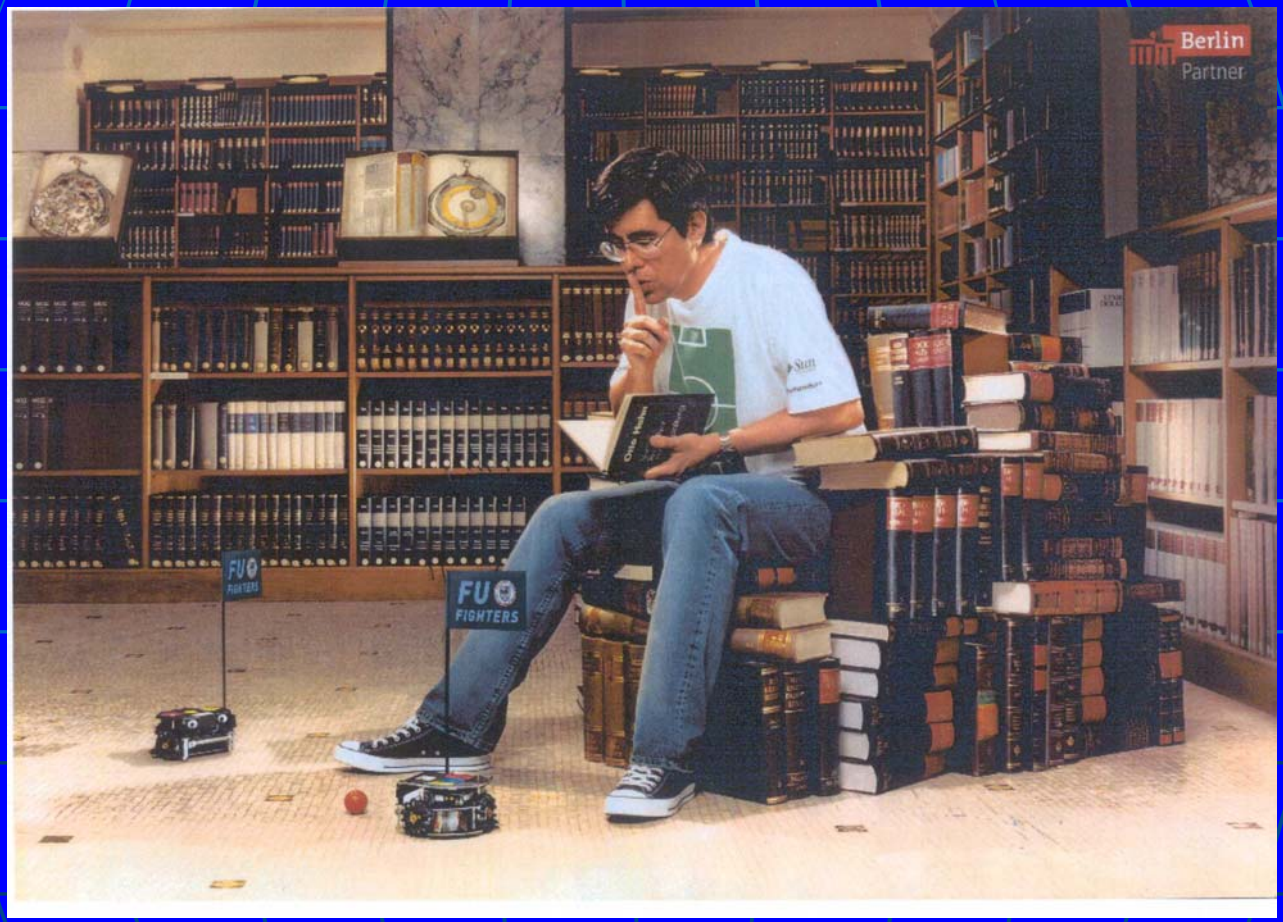
Computer Vision and Control for Autonomous Robots



Prof. Dr. Raul Rojas
FU Berlin

Embodied Intelligence: A new Paradigm for AI

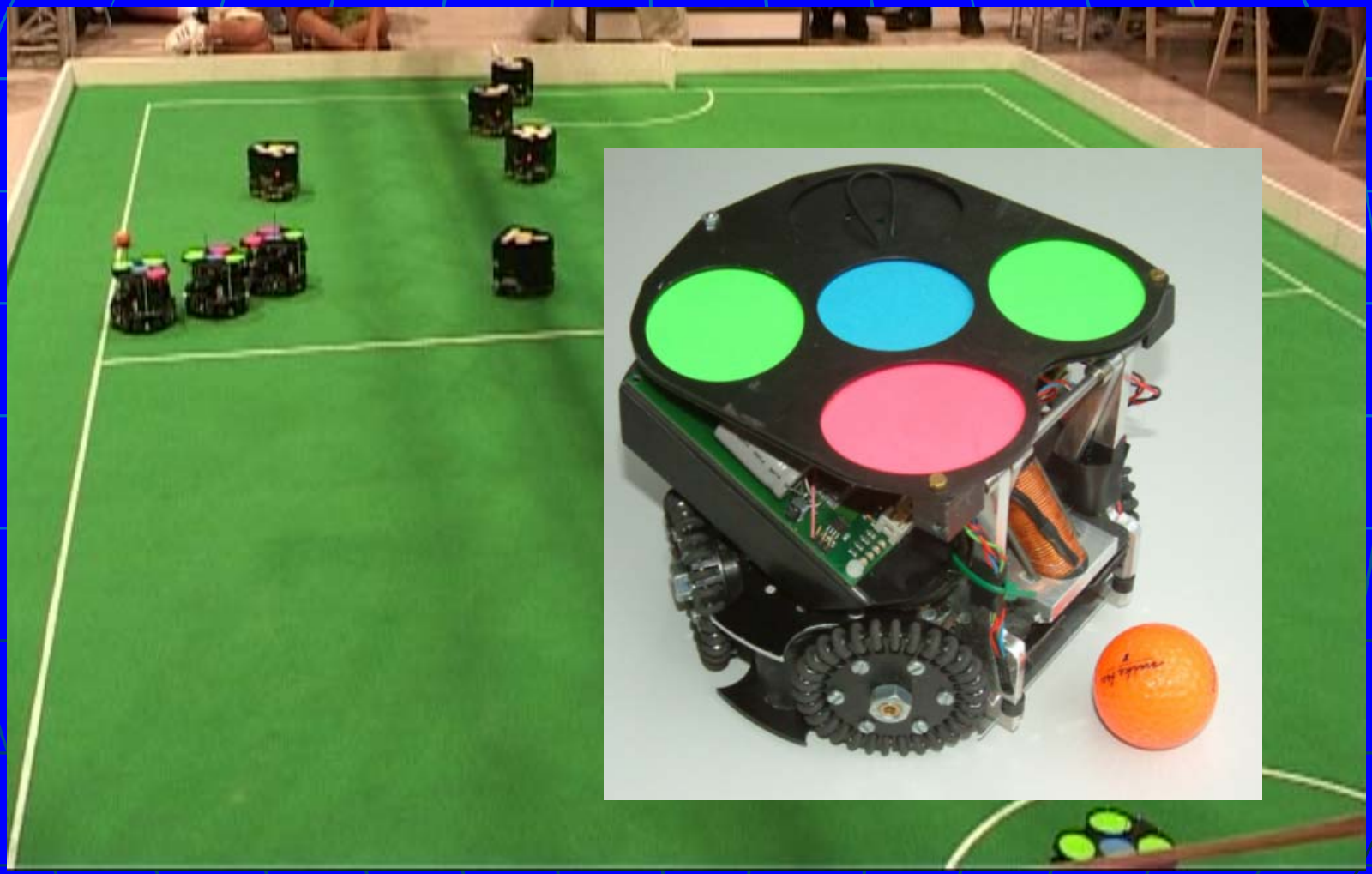
- Intelligence needs a body: mechanics
- Computer vision in real time
- Energy management
- Local control
- Communication between agents
- Coordination and team behavior
- Adaptation and learning

„Artificial Intelligence is the art and science of the subconscious“

Robotic Soccer as AI Benchmark

- RoboCup started with IJCAI 1997
- I - Simulation league
- II – Small size league
- III- Mid-size league
- IV- Legged league
- V – Humanoid league

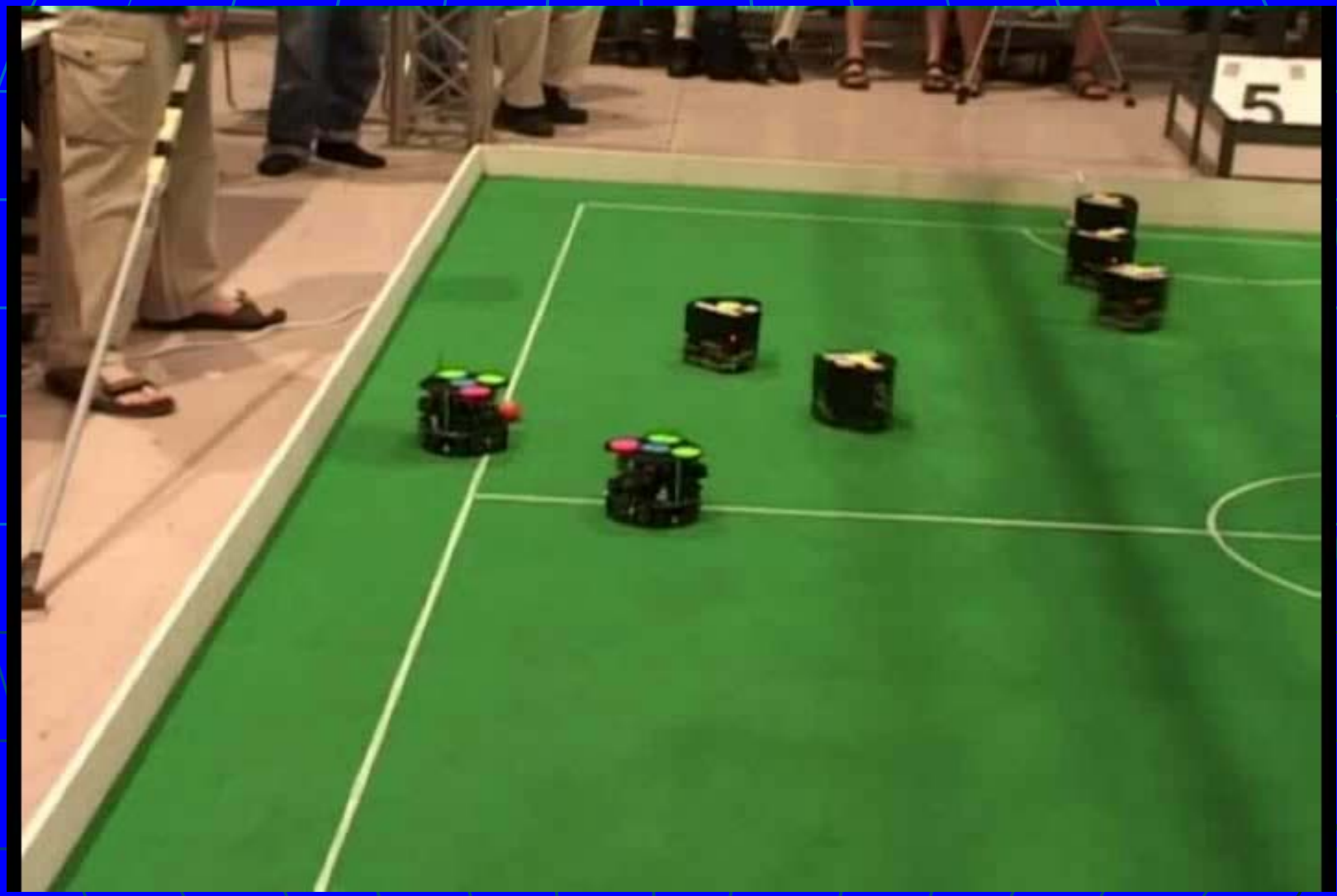
Small-Size Liga



4.5 by 5 meter field

Five vs five

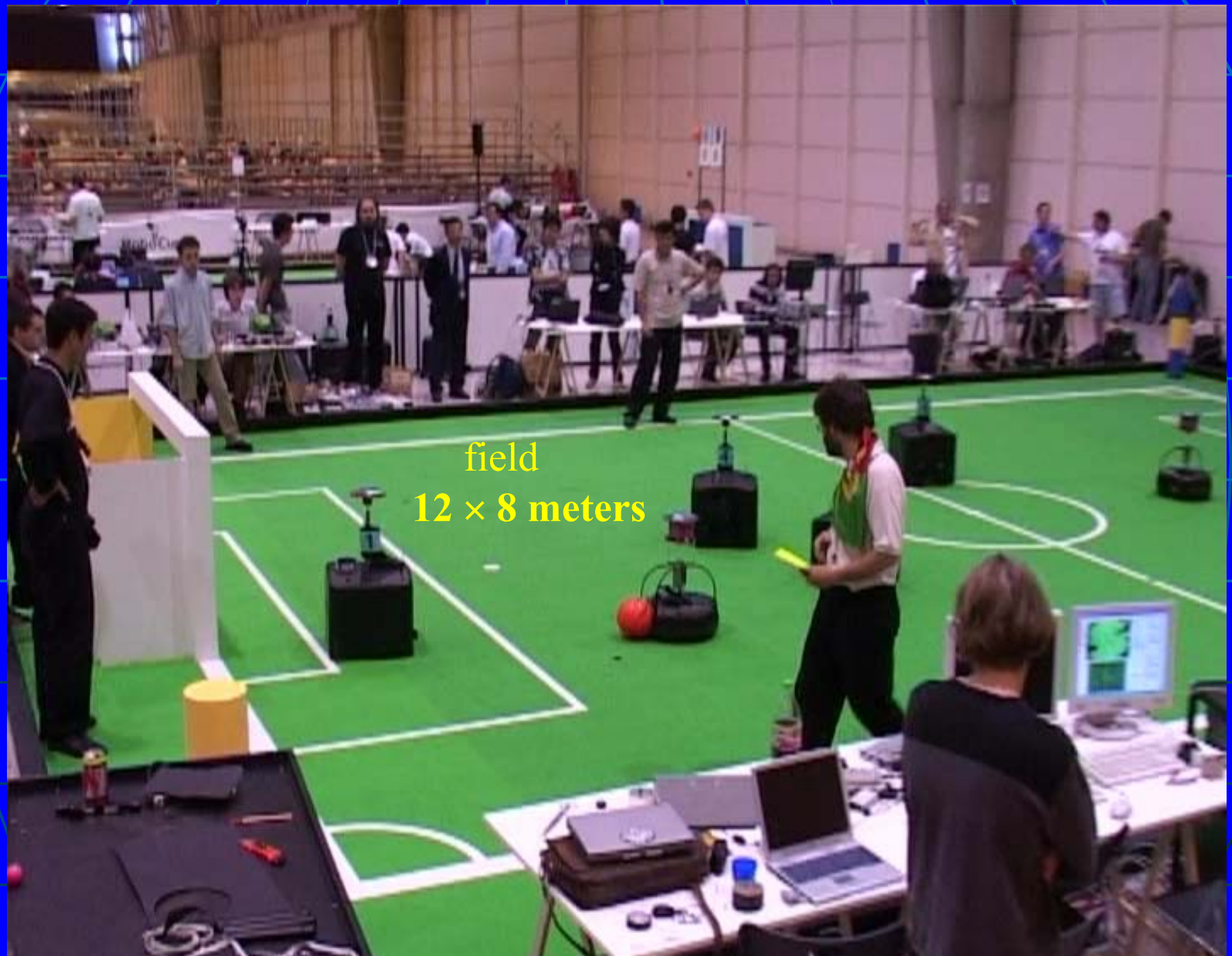
Lisbon 2004



Kicking the distance

Mid-size league

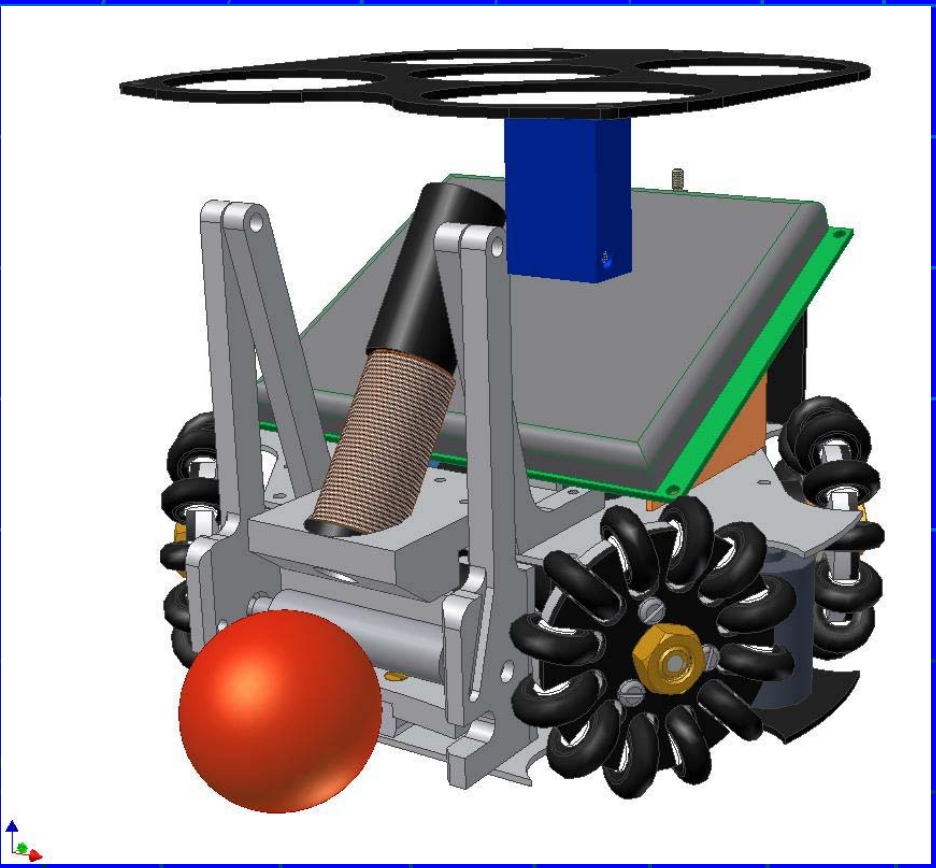
four
on
four

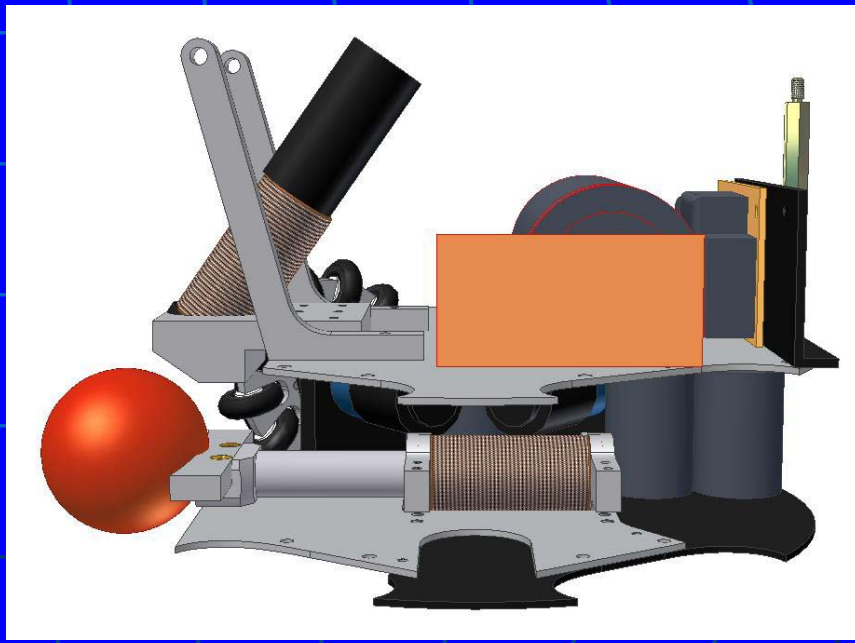


Lisbon 2004

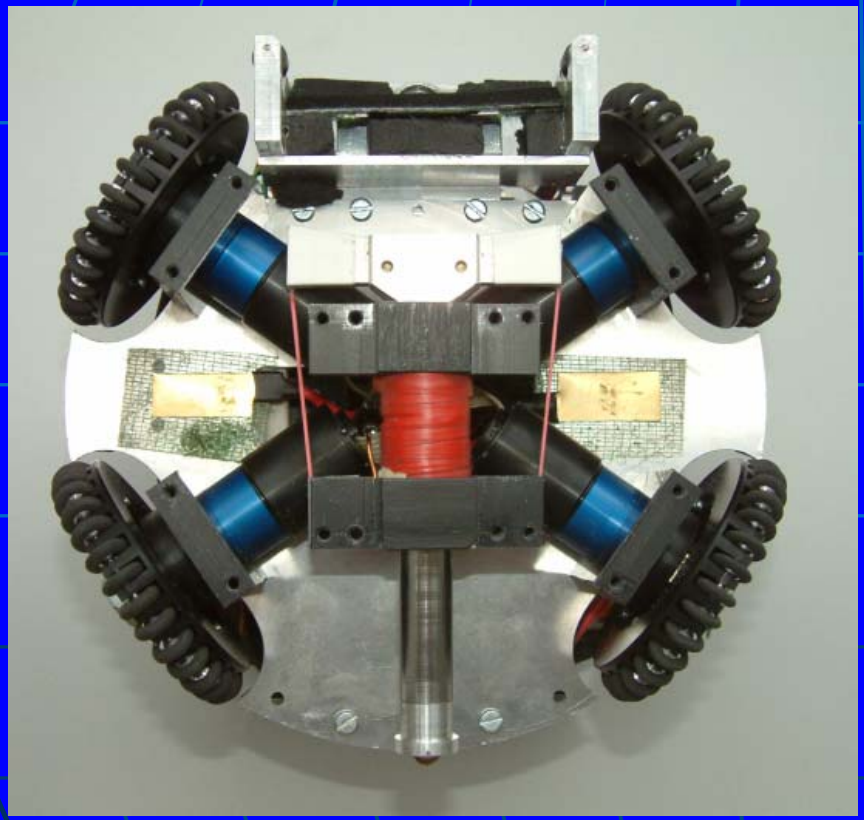
Pressuring the goalie

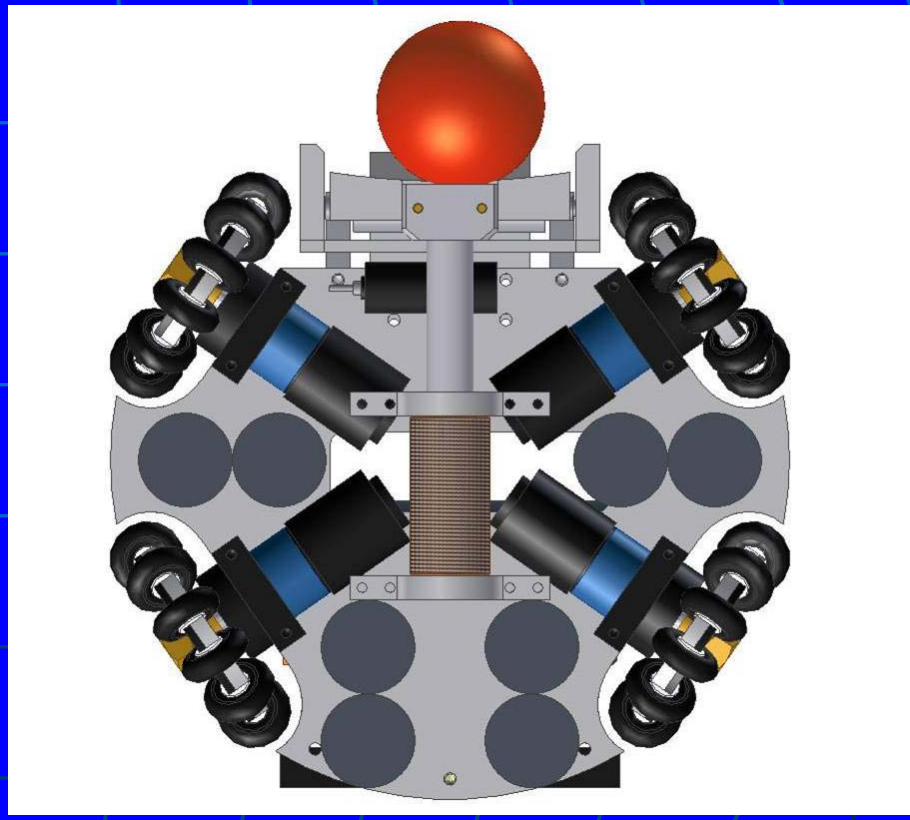
Our small-size robots



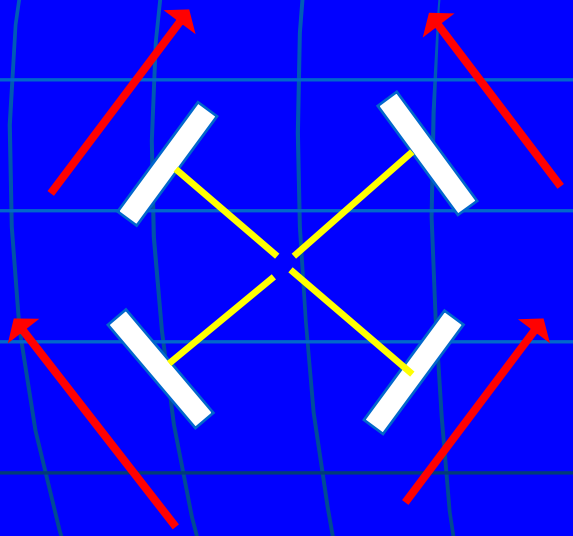


Omnidirectional Design





Omnidirectional Control

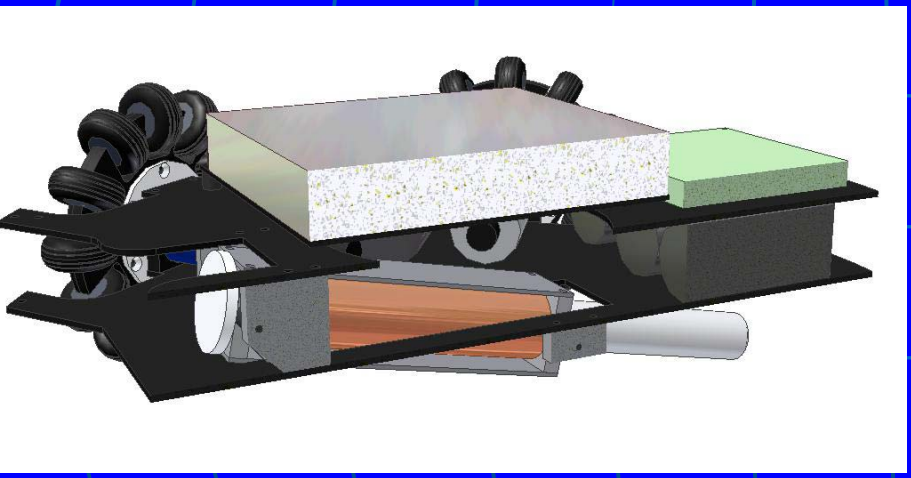


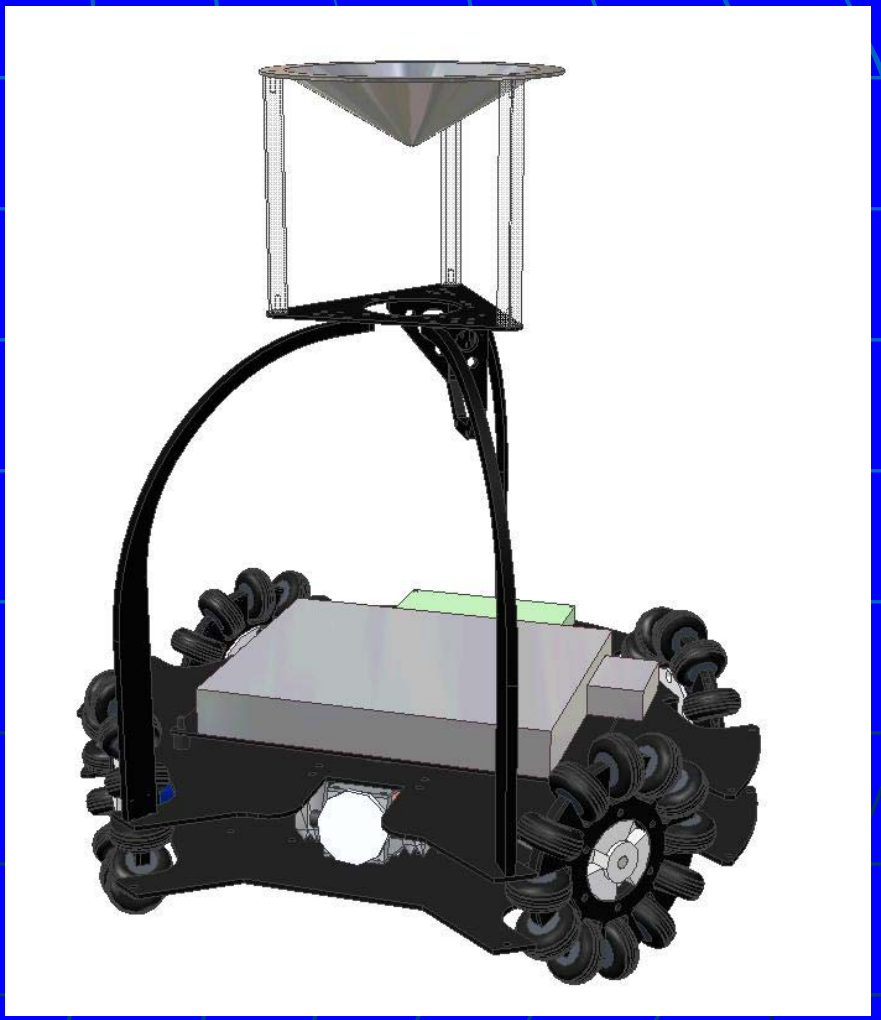
Our mid-size robots

Omnidirectional vision

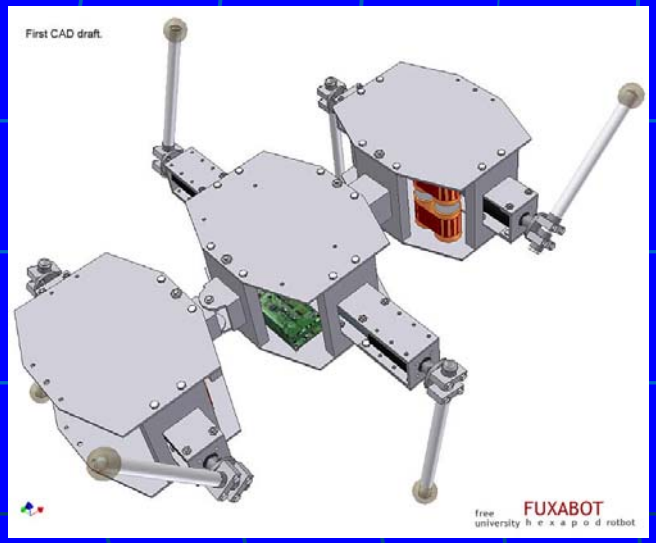
- **Laptop for control**
- **Firewire video camera**

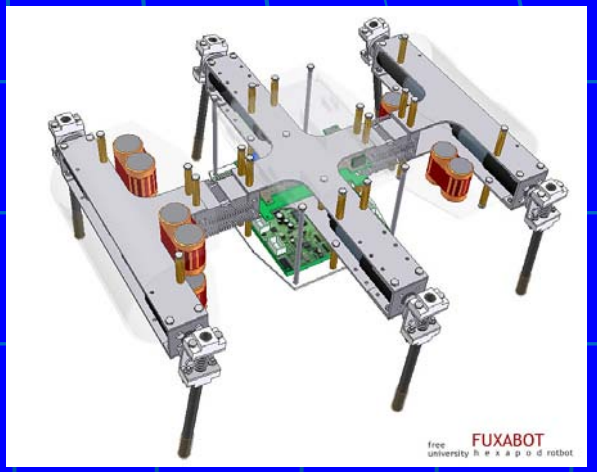
CAD Design

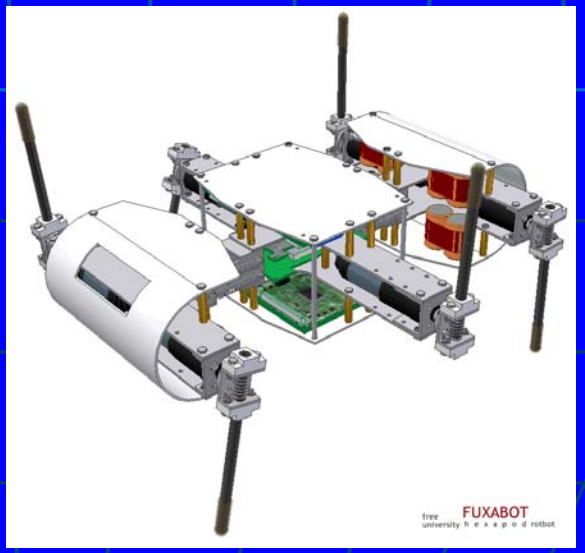




FUXABOT: The Hexapod

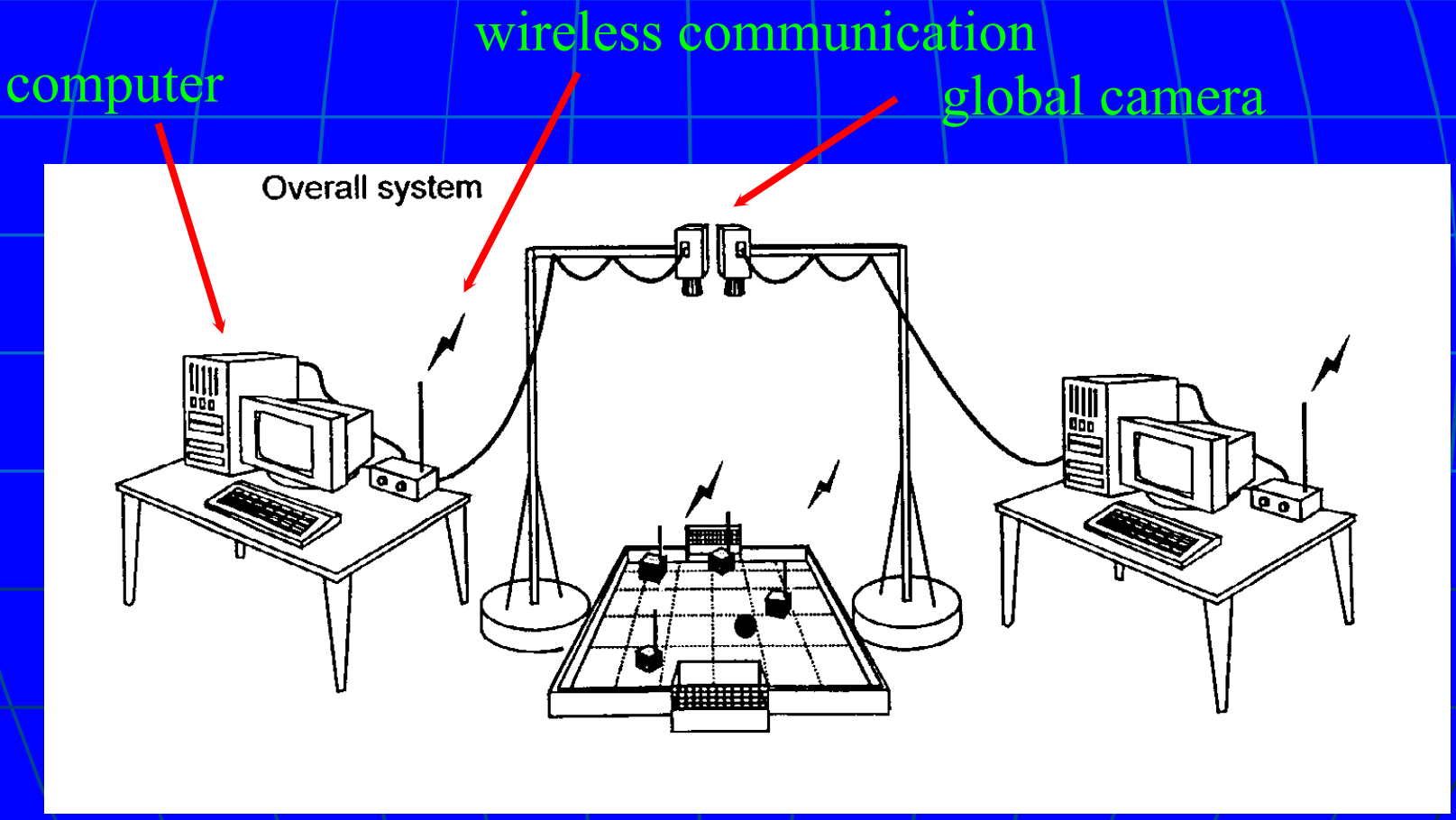






I Global vision

Global vision

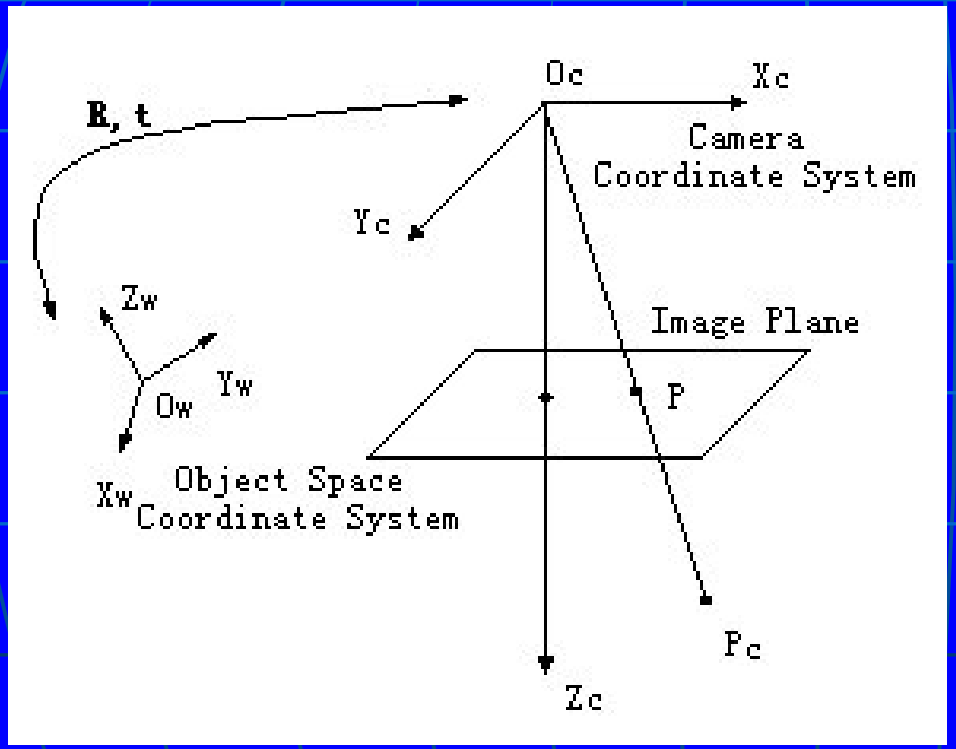


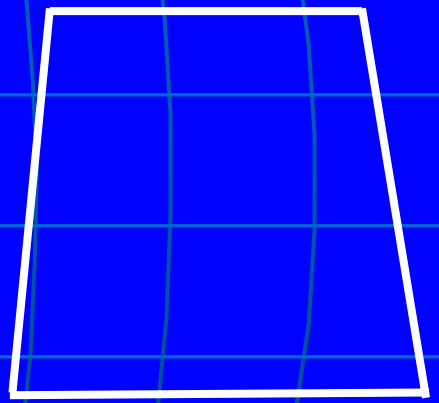
The world is colored

Team color

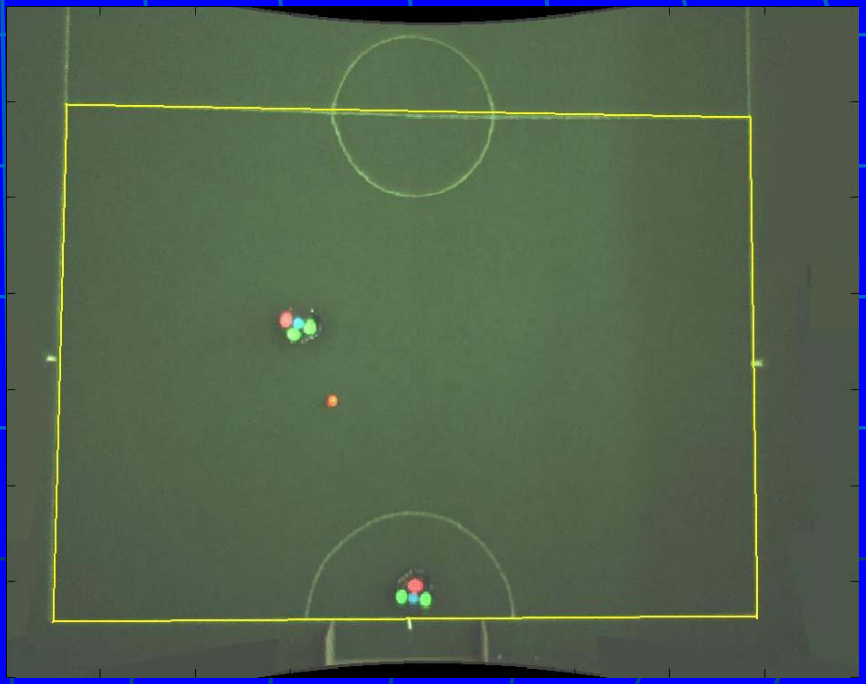
ball

Projective Transformation





Automatic camera calibration



Illumination artifacts

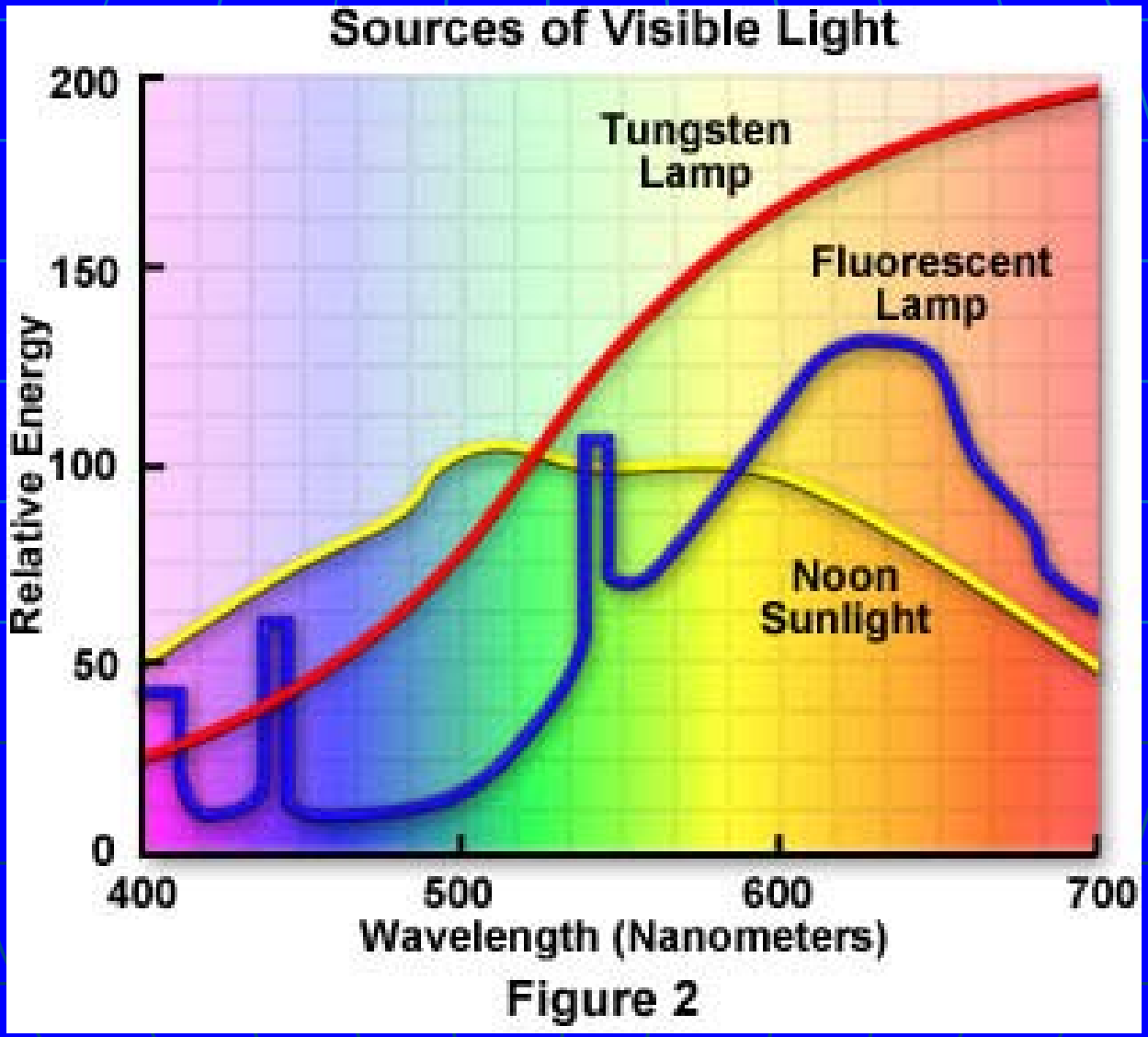
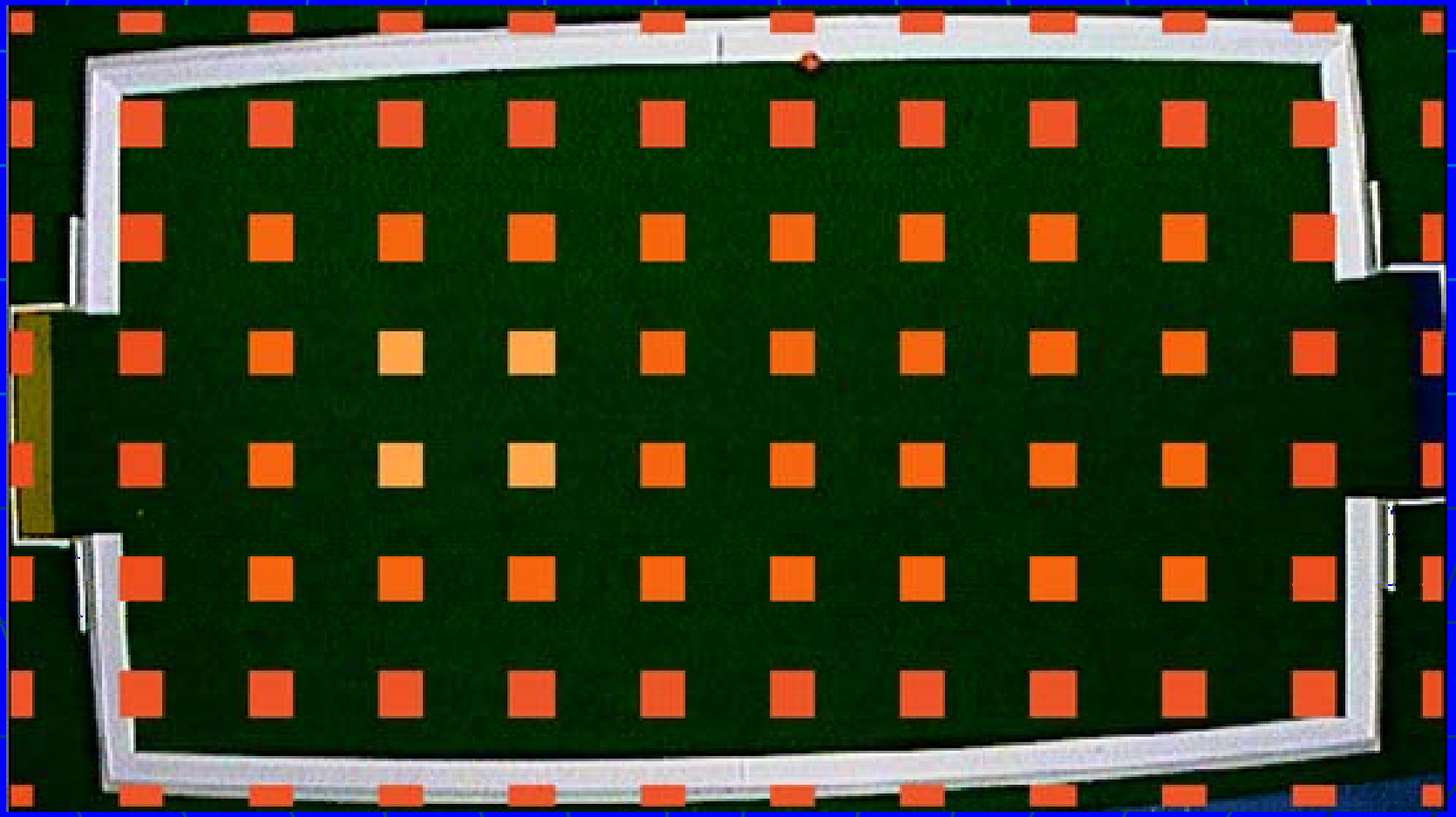


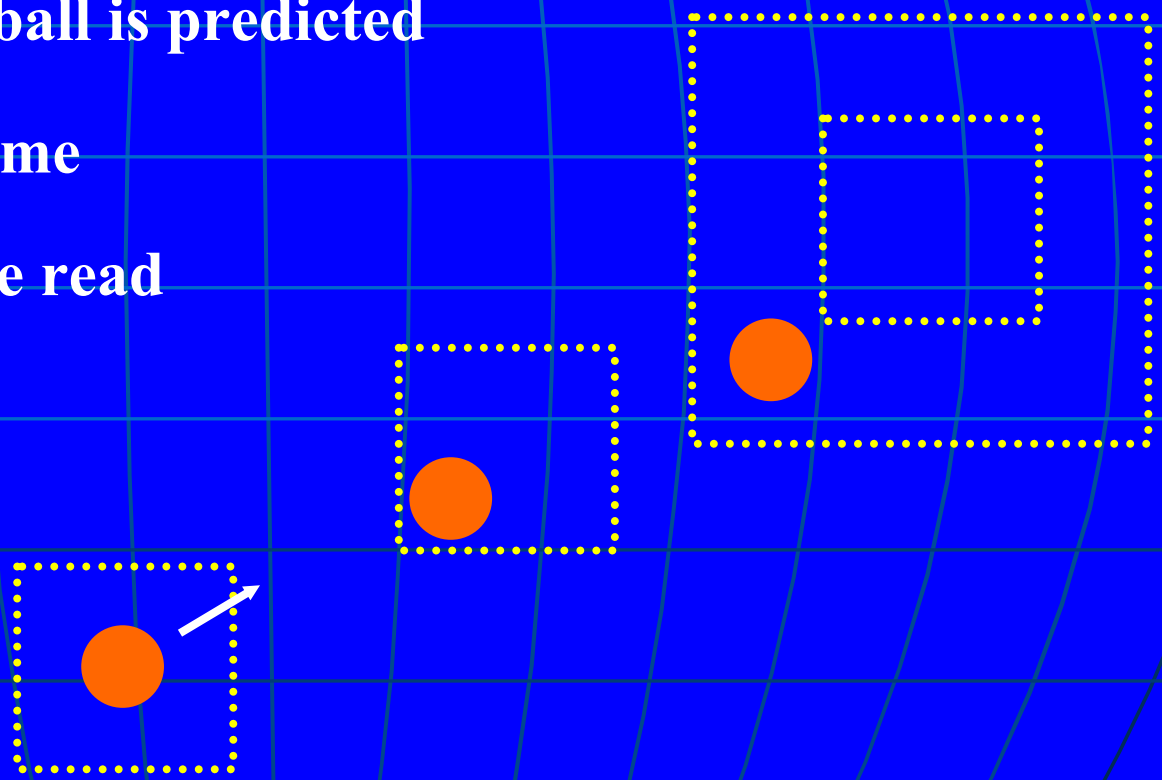
Figure 2

Adaptive color maps

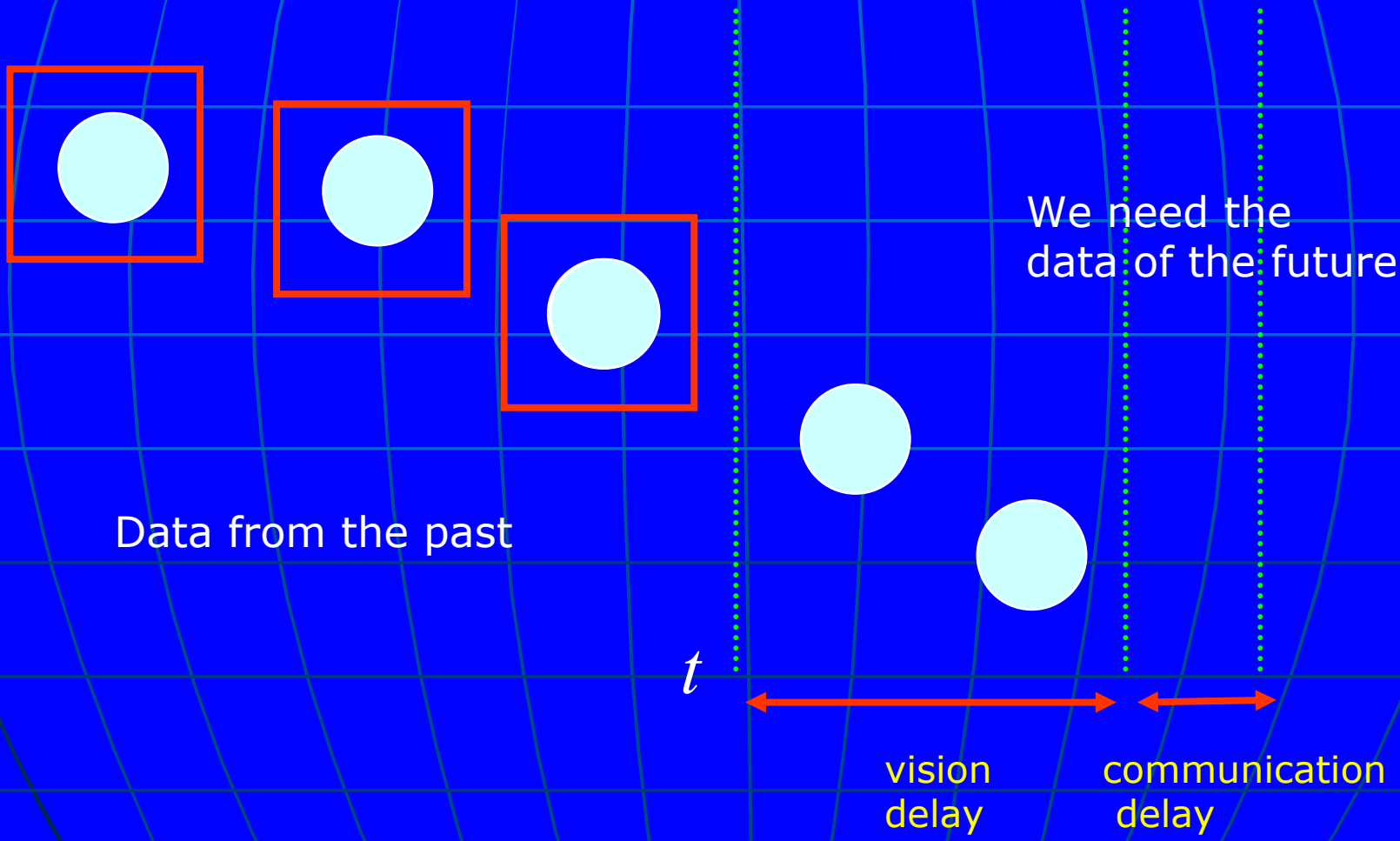


Tracking helps computer vision

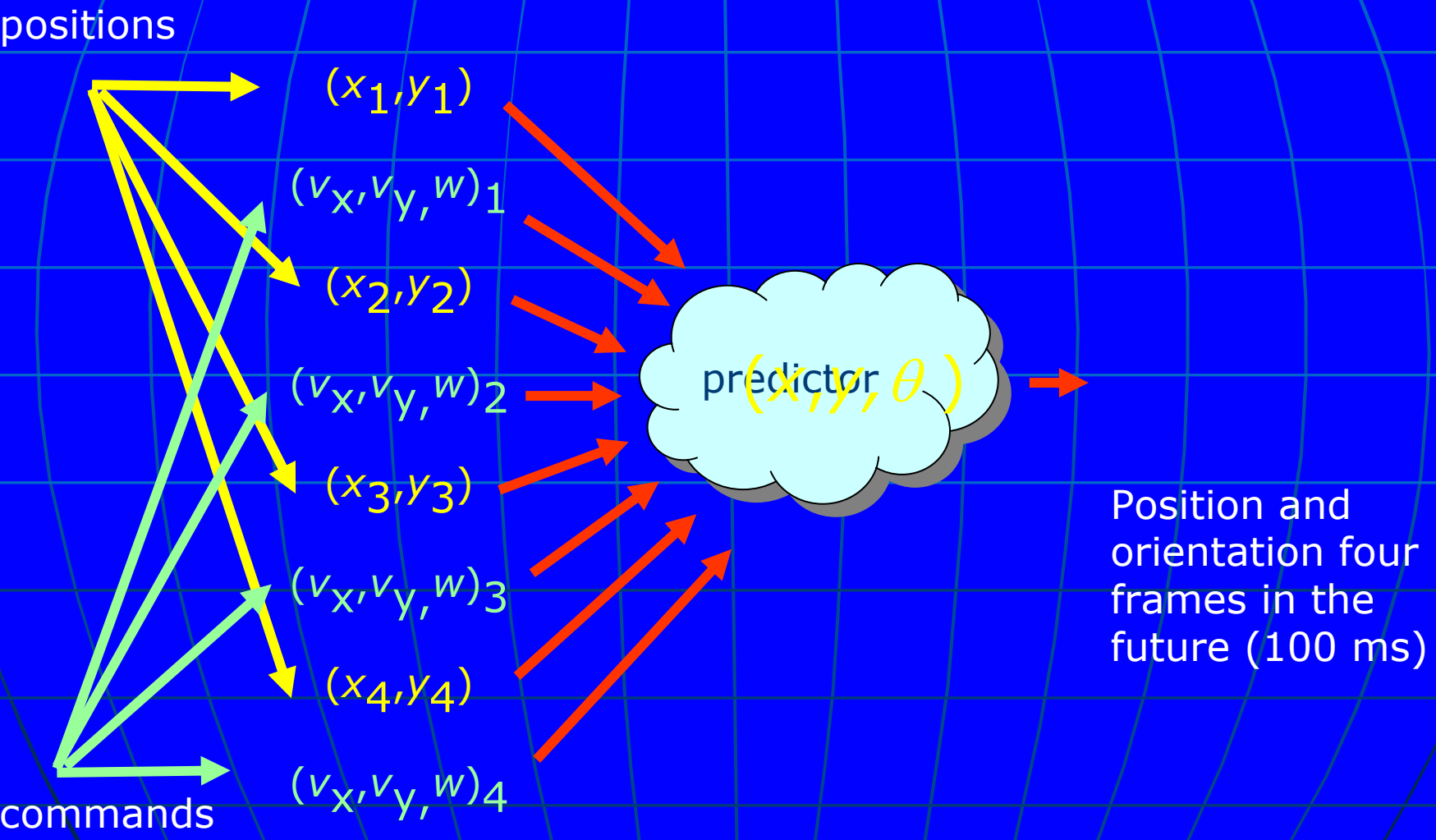
- **the position of the ball is predicted**
- **variable search frame**
- **just a few pixels are read**

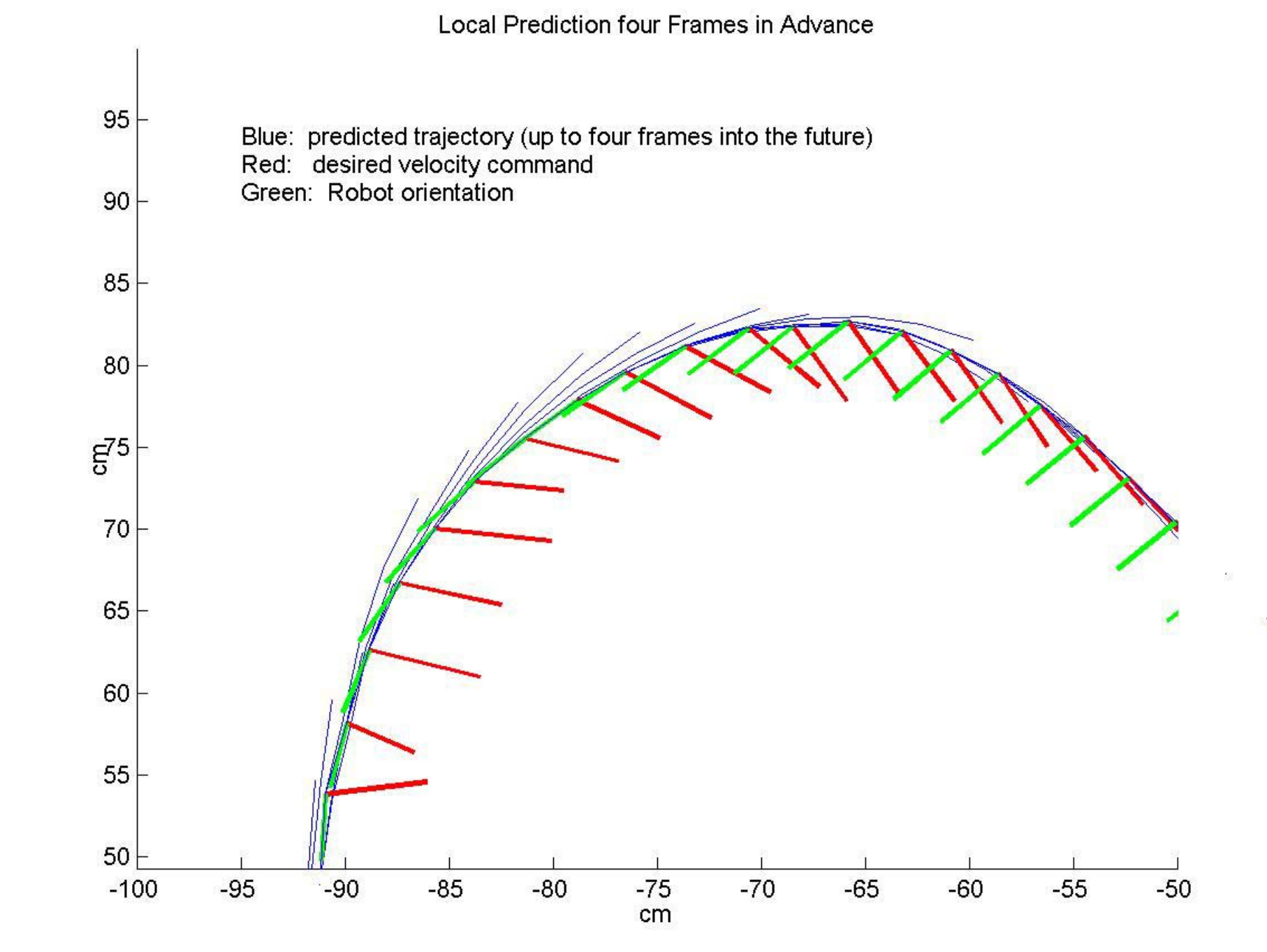


Tracking the robots



Predict the robot‘s movement

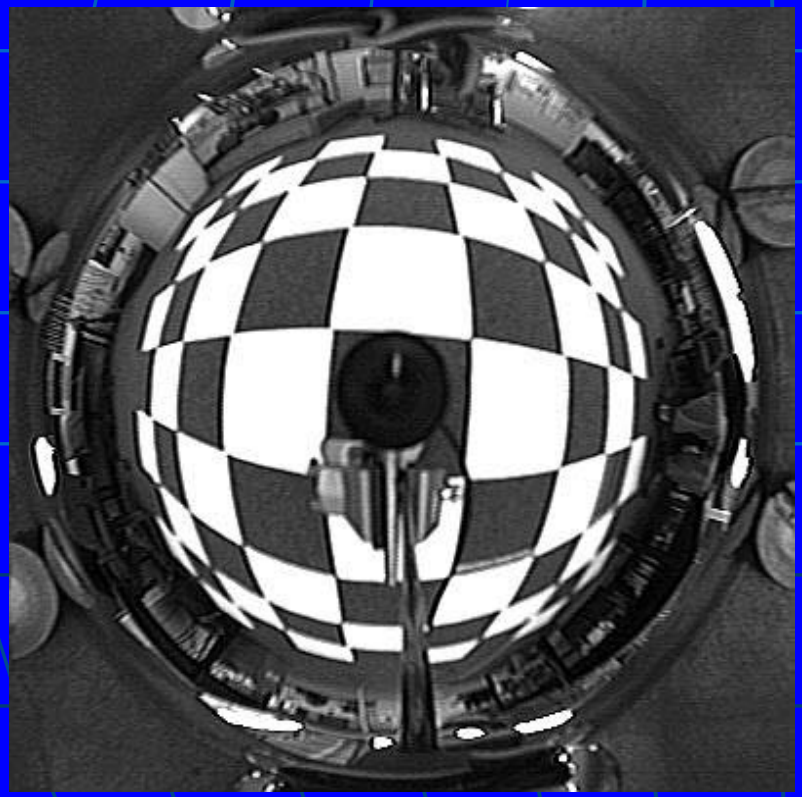



Local Prediction four Frames in Advance
Blue: predicted trajectory (up to four frames into the future)
Red: desired velocity command
Green: Robot orientation
95
90
85
80
75
70
65
60
55
50
cm
-100
-95
-90
-85
-80
-75
-70
-65
-60
-55
-50
cm

II Local vision

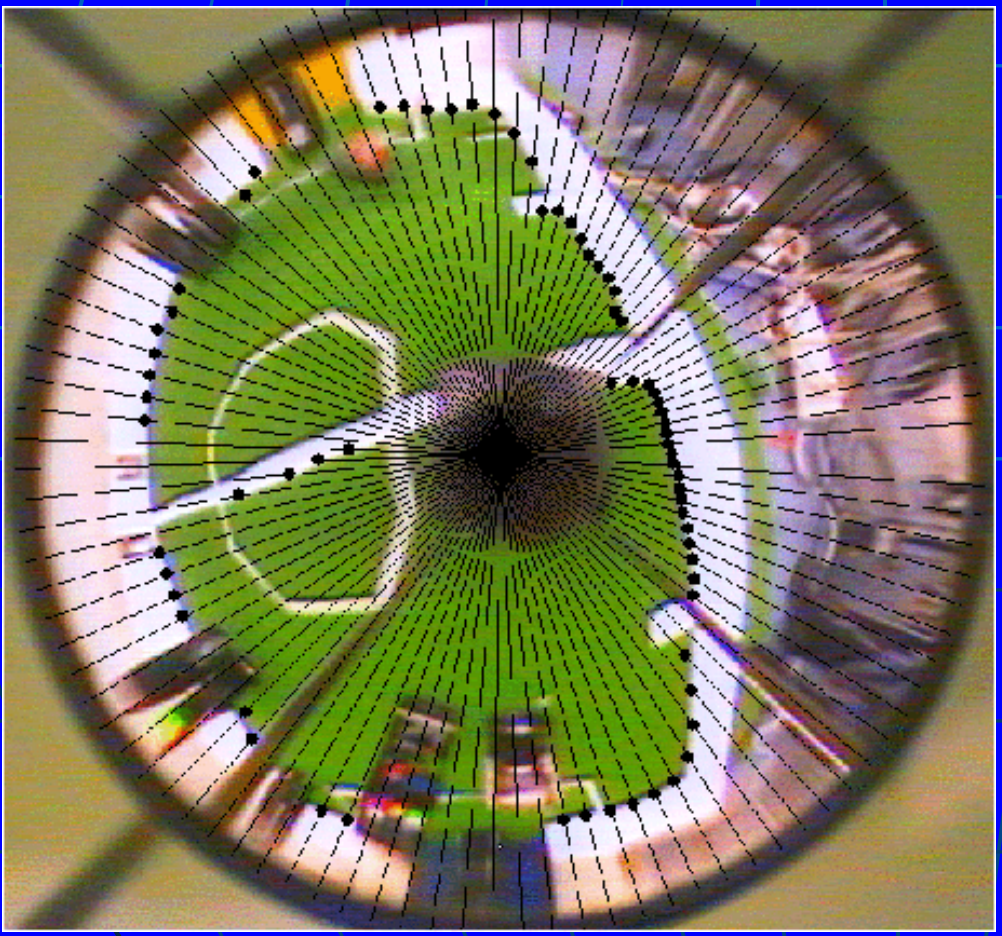
Our first omnivision robots

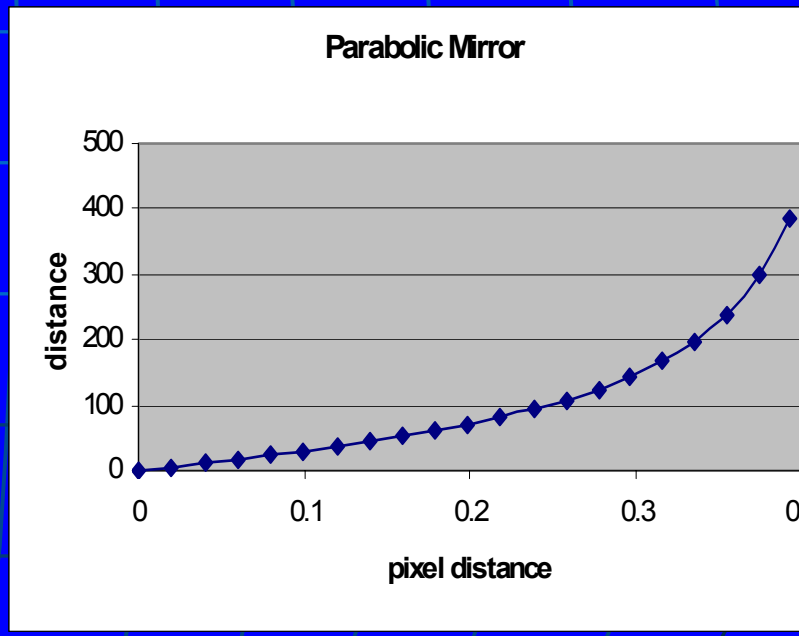
Spherical and parabolic transformations



The field seen with our mirror

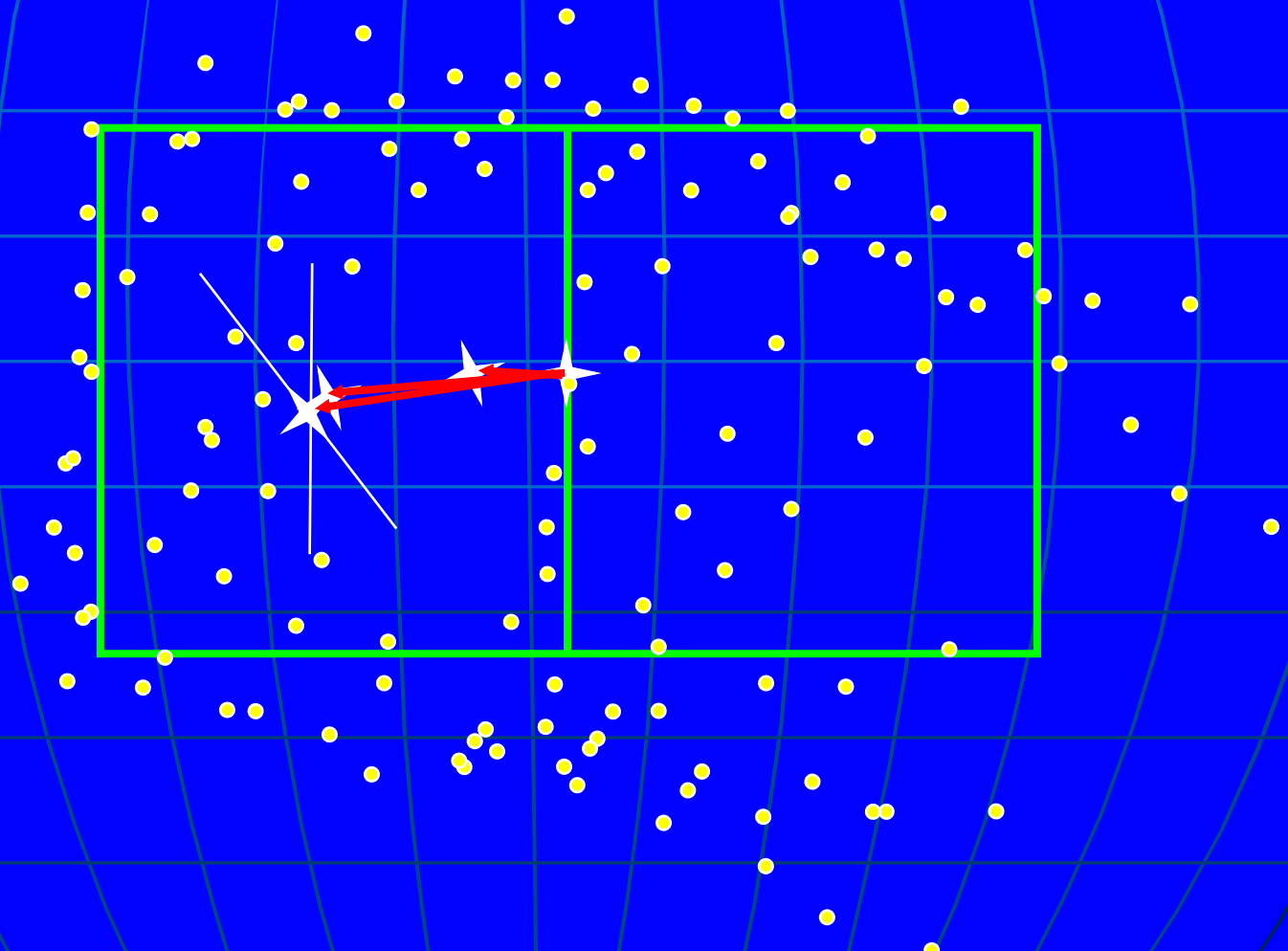
Locating the robot



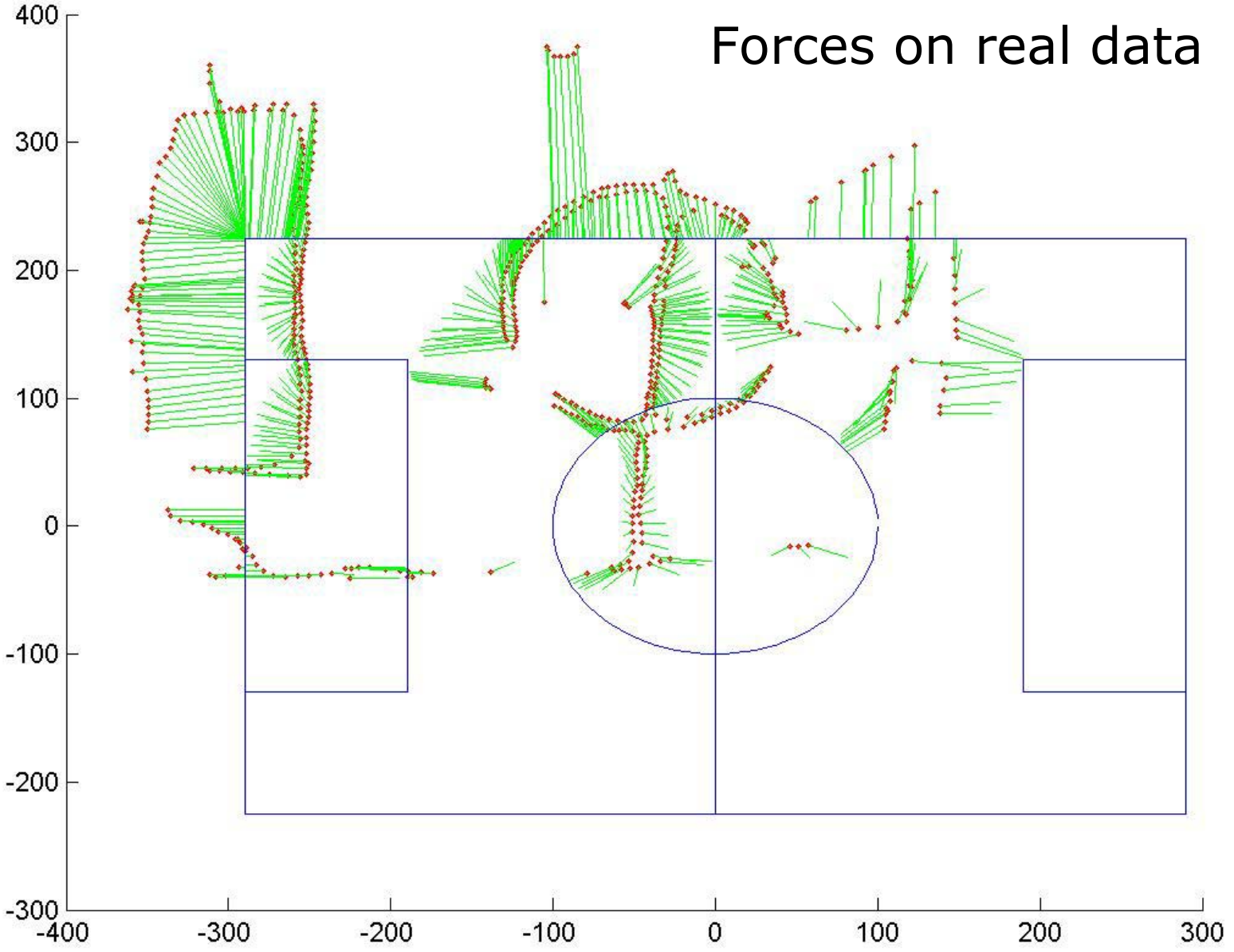


Expectation-Maximization

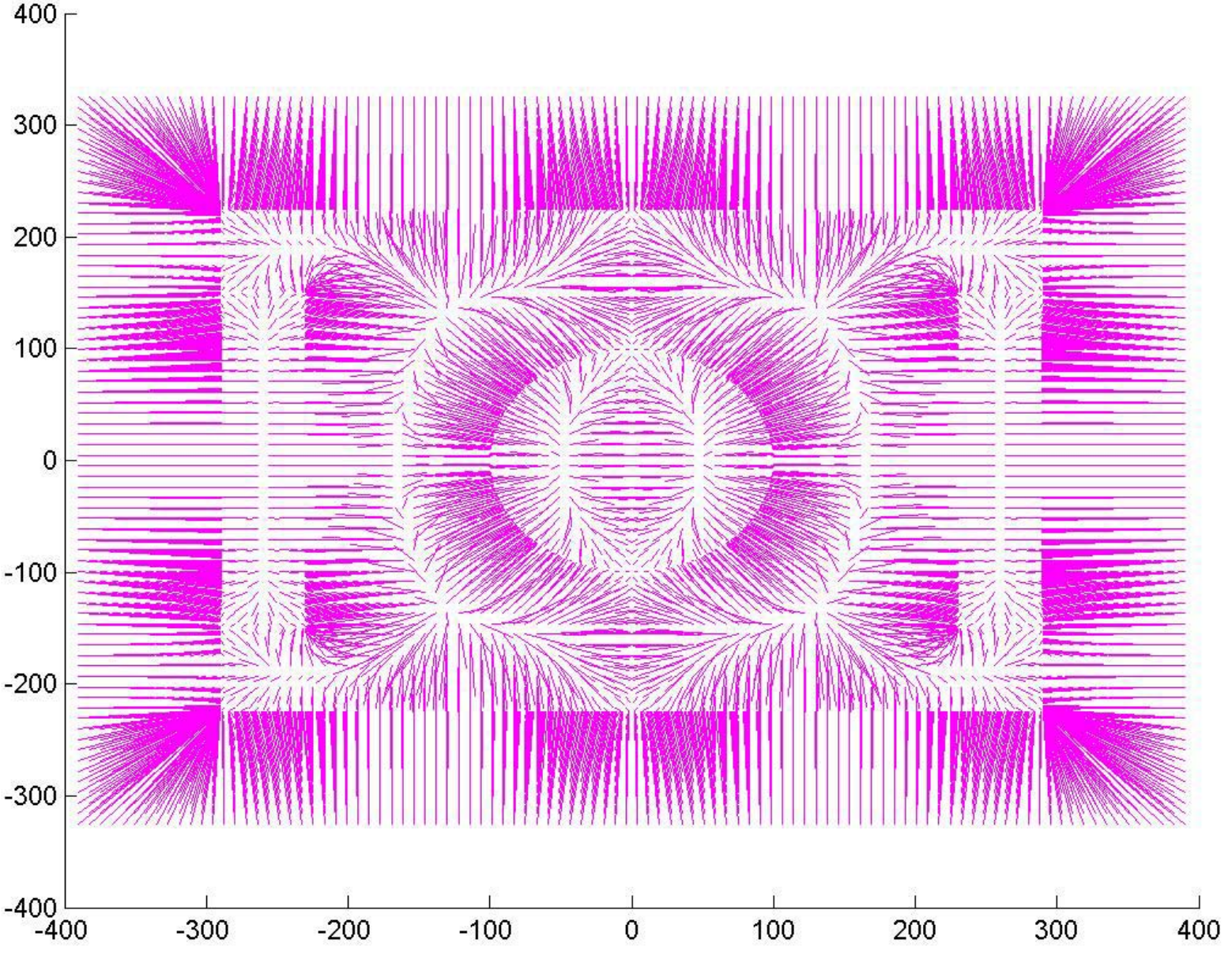
The model „attracts“ the cloud of points

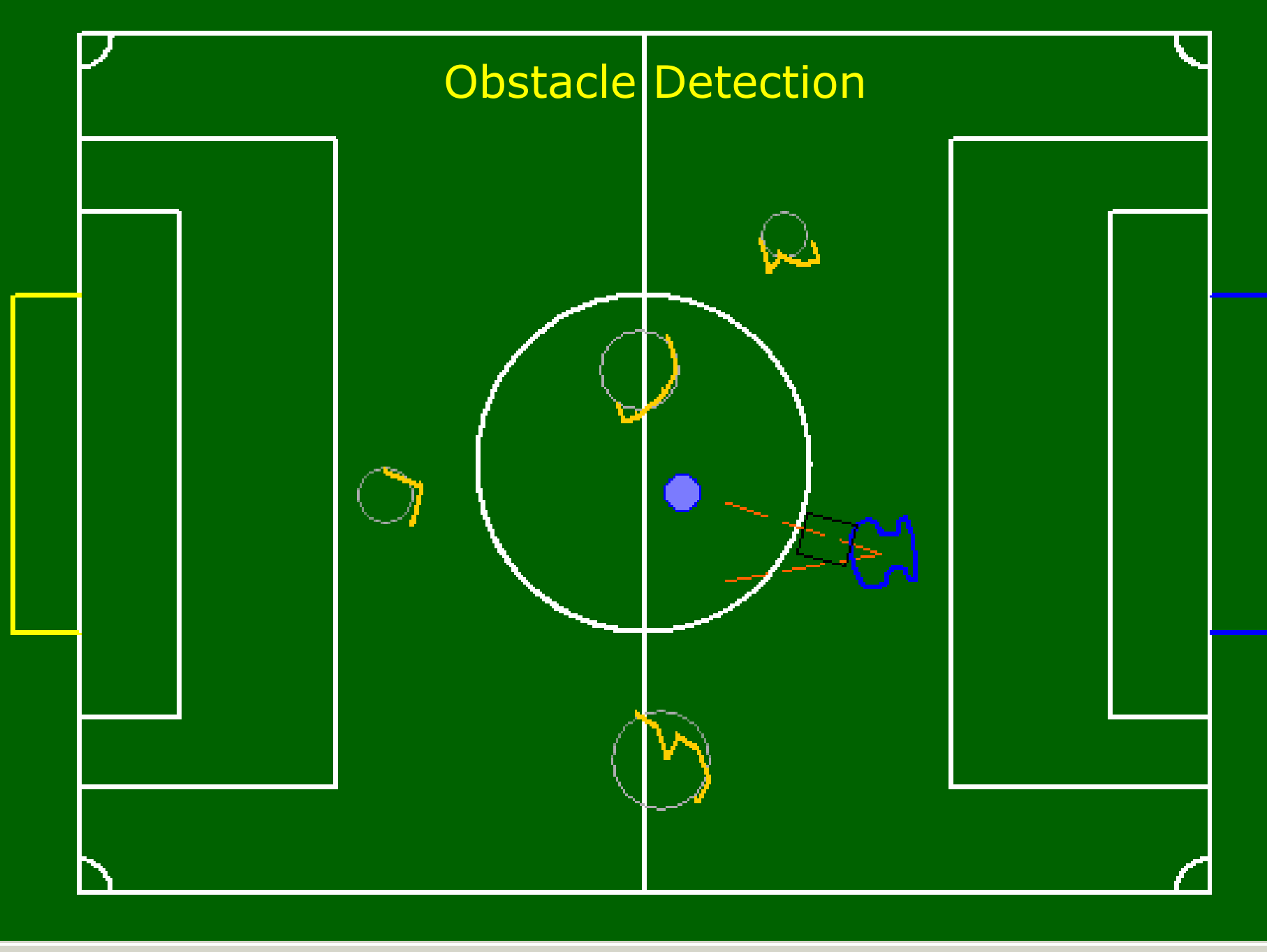


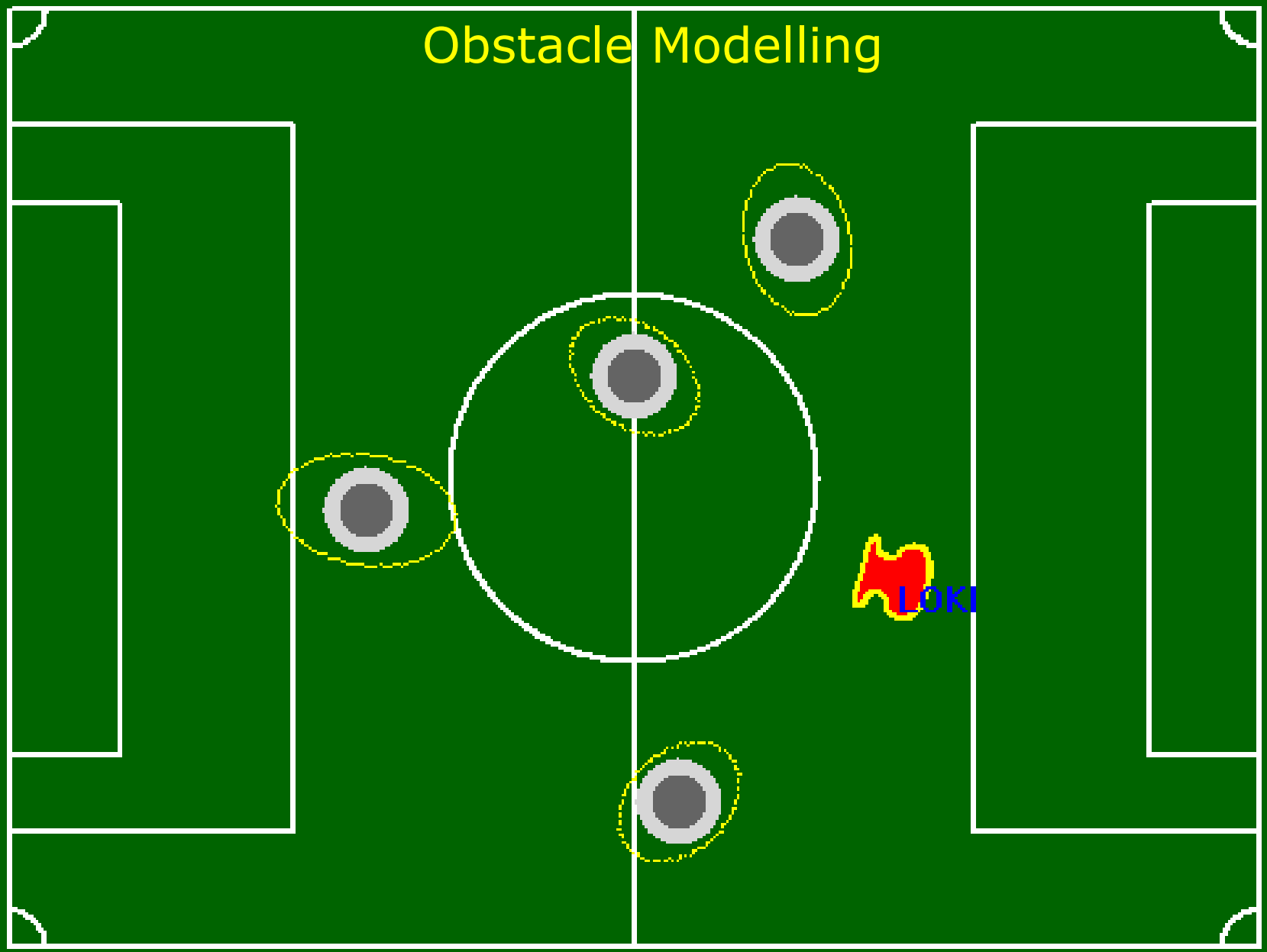
Forces on real data

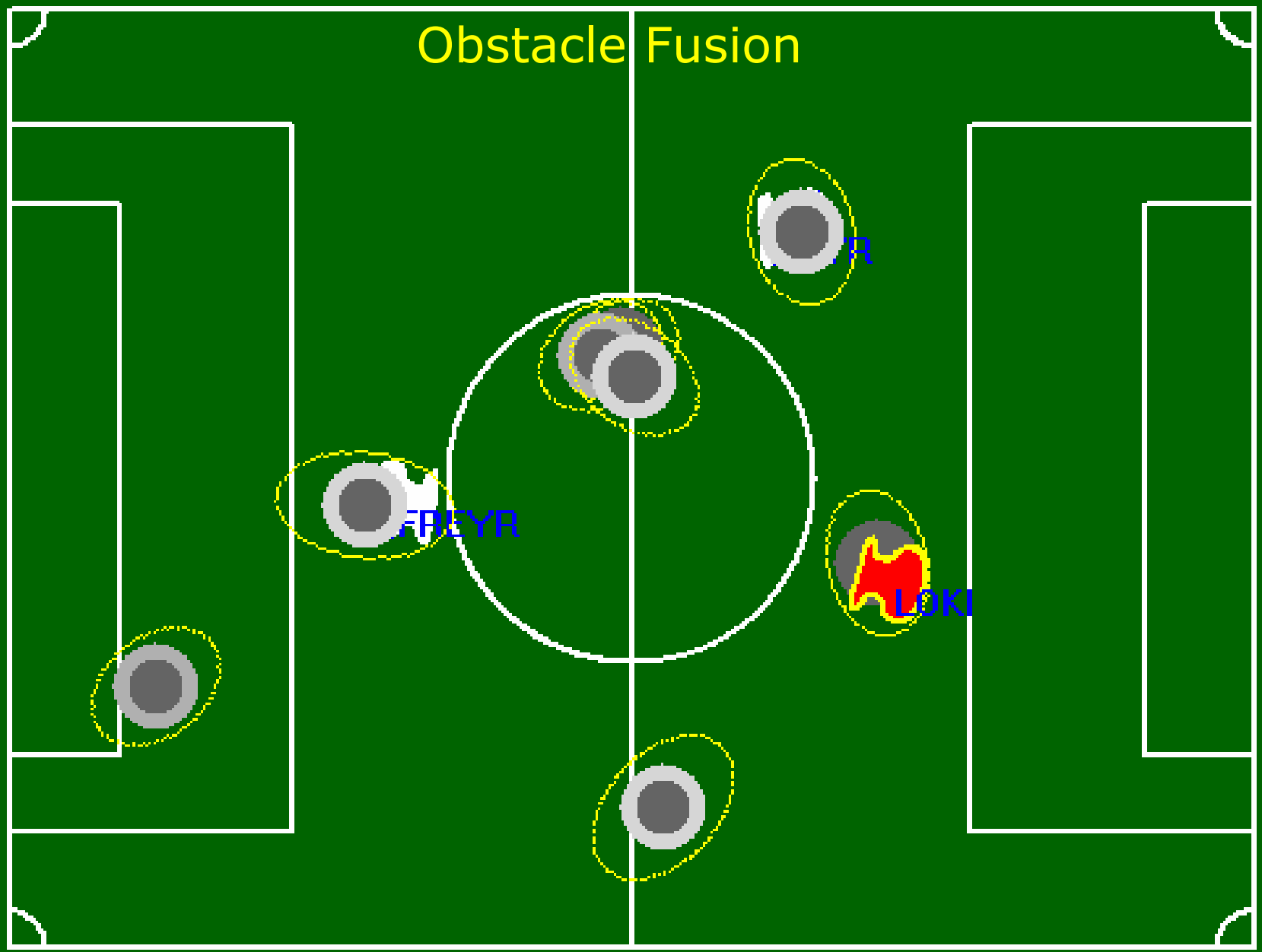


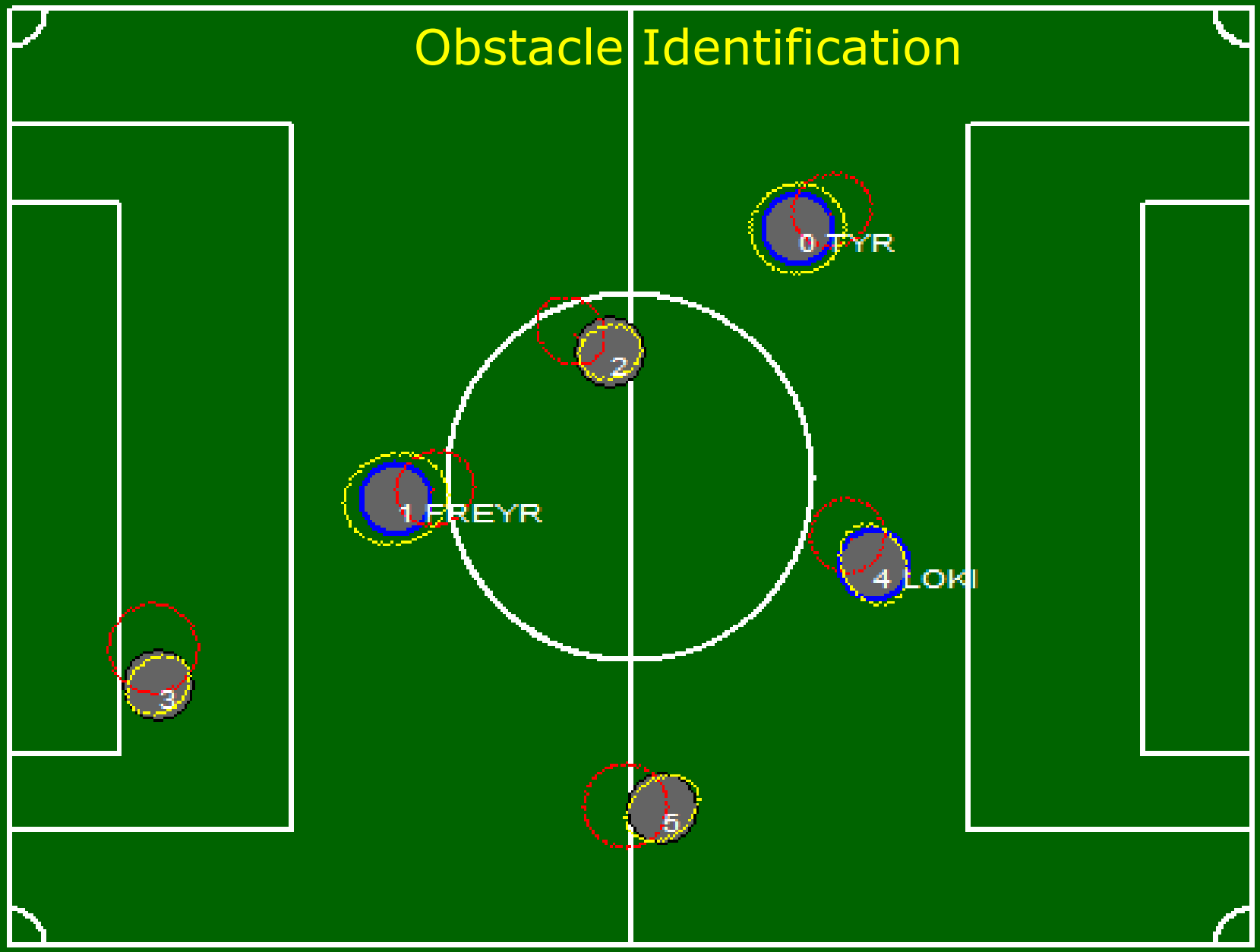
Precomputed resultant forces for each coordinate




Obstacle Detection

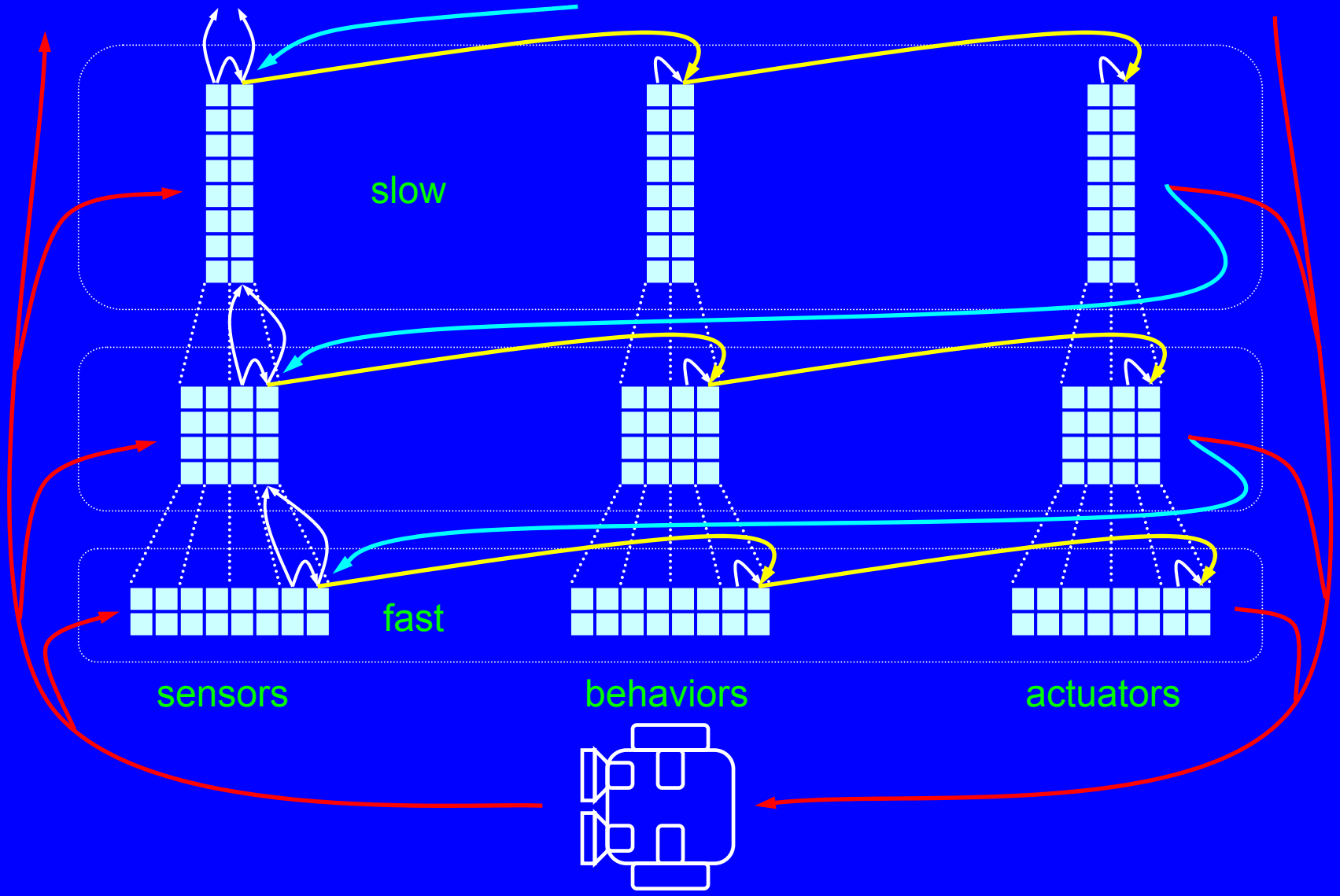

Obstacle Modelling
LOKI


Obstacle Fusion
R
FREYR
LOKI

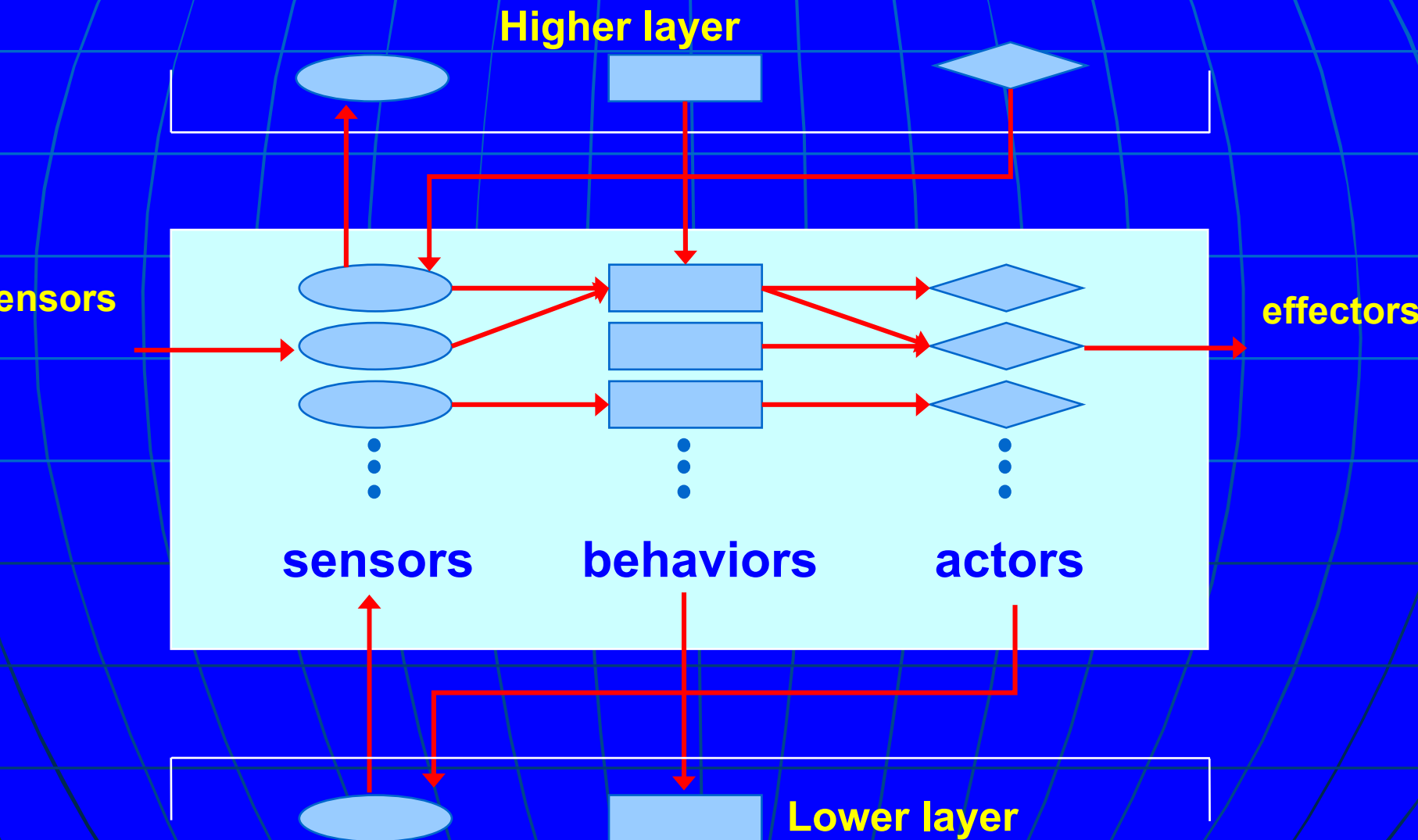

Obstacle Identification
0 TYR
2
1 FREYR
4 LOKI
3
5

III Reactive Behavior

Reactive Behavior Control

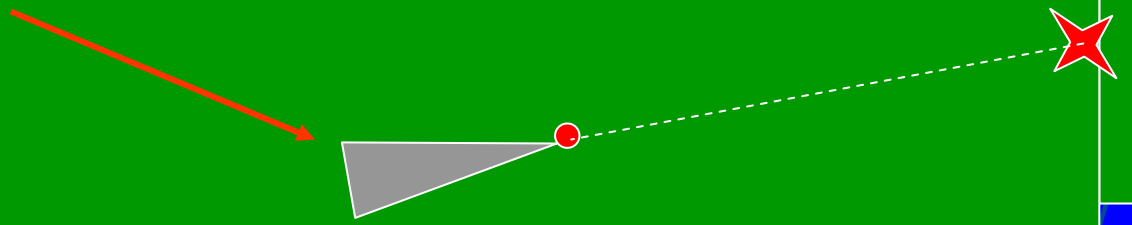


Structure of a layer



Kicking reflex

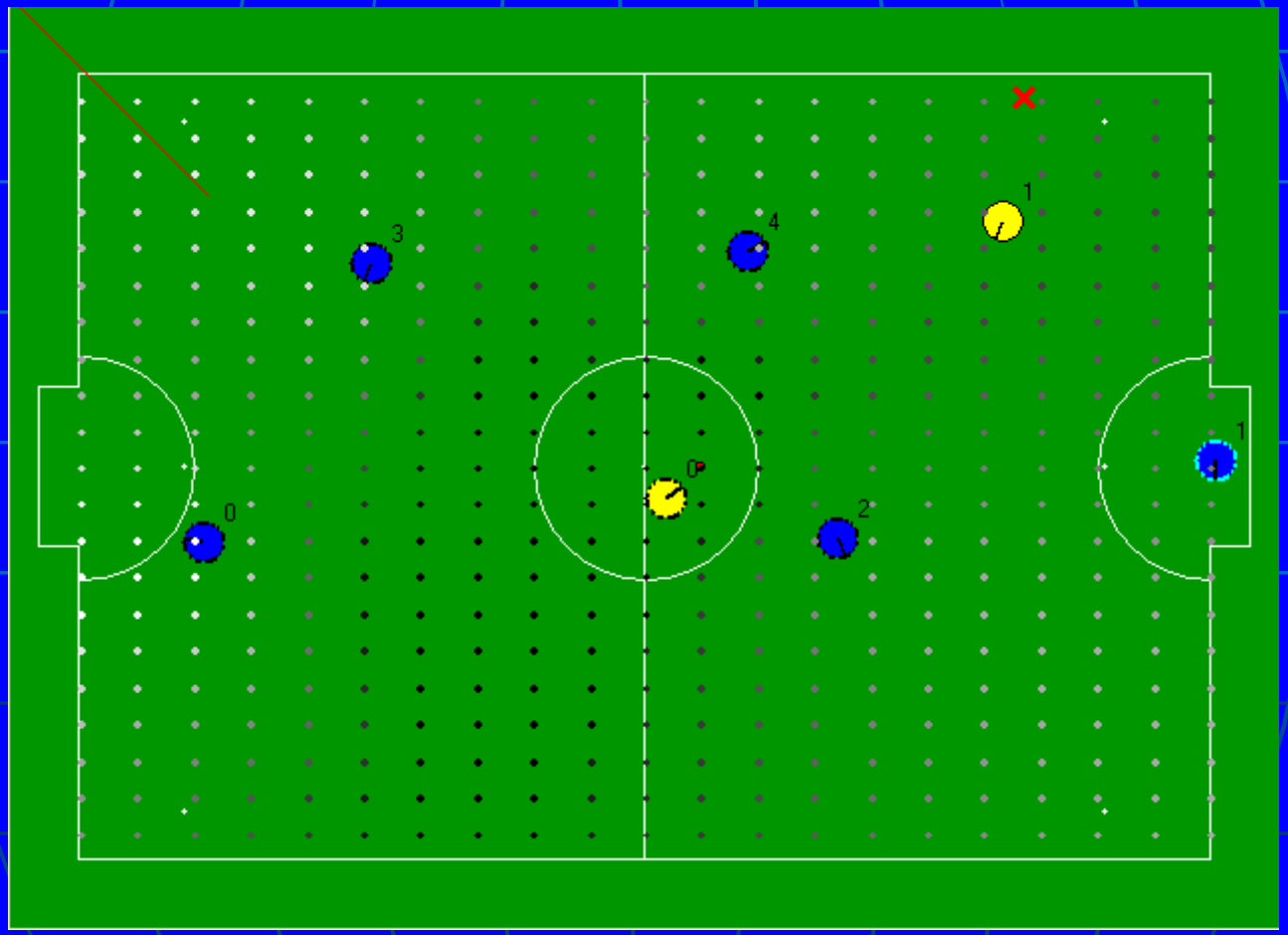
Kicking reflex activated



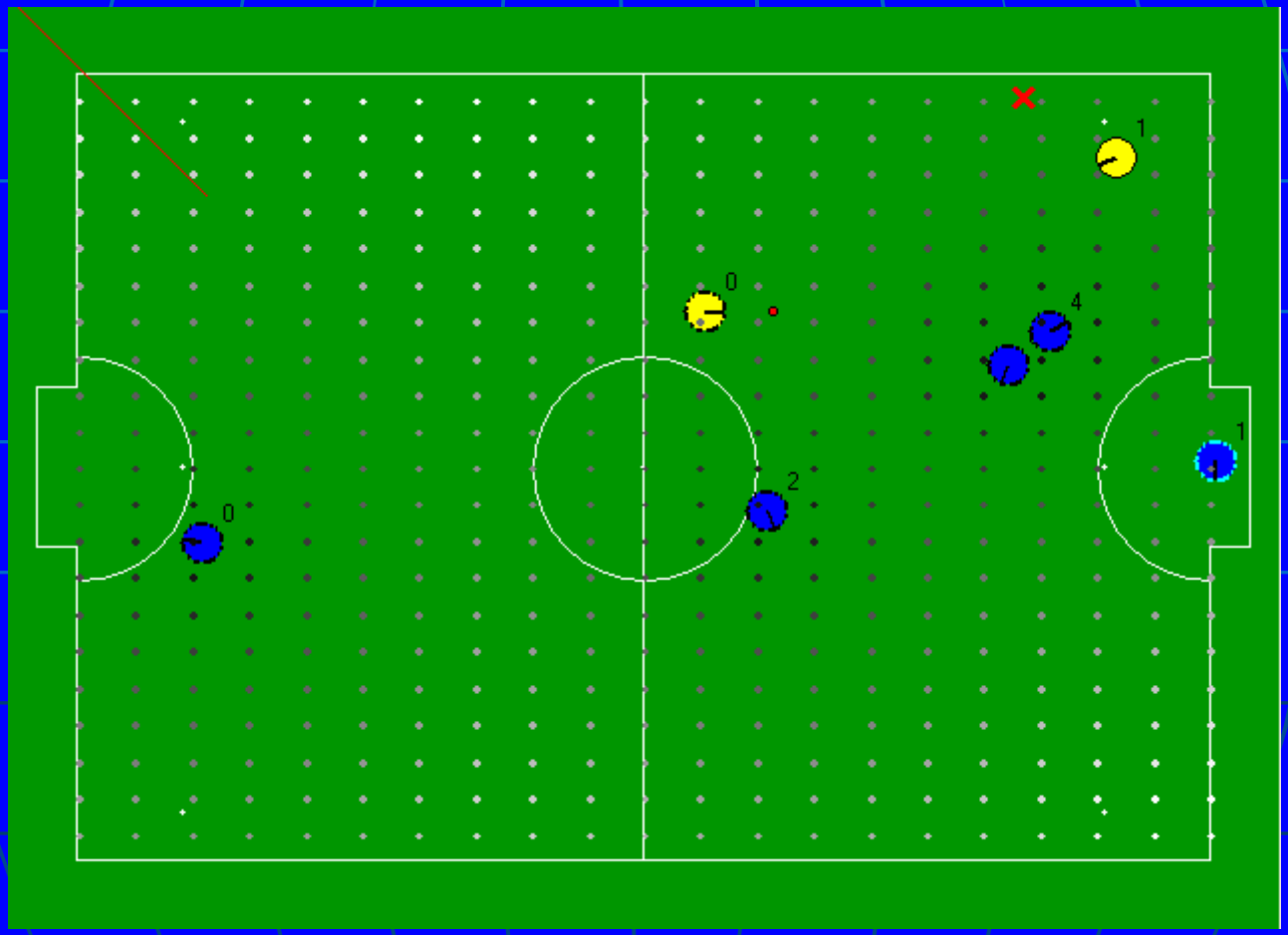
Screenshot of control software

IV Learning and Coaching the robots

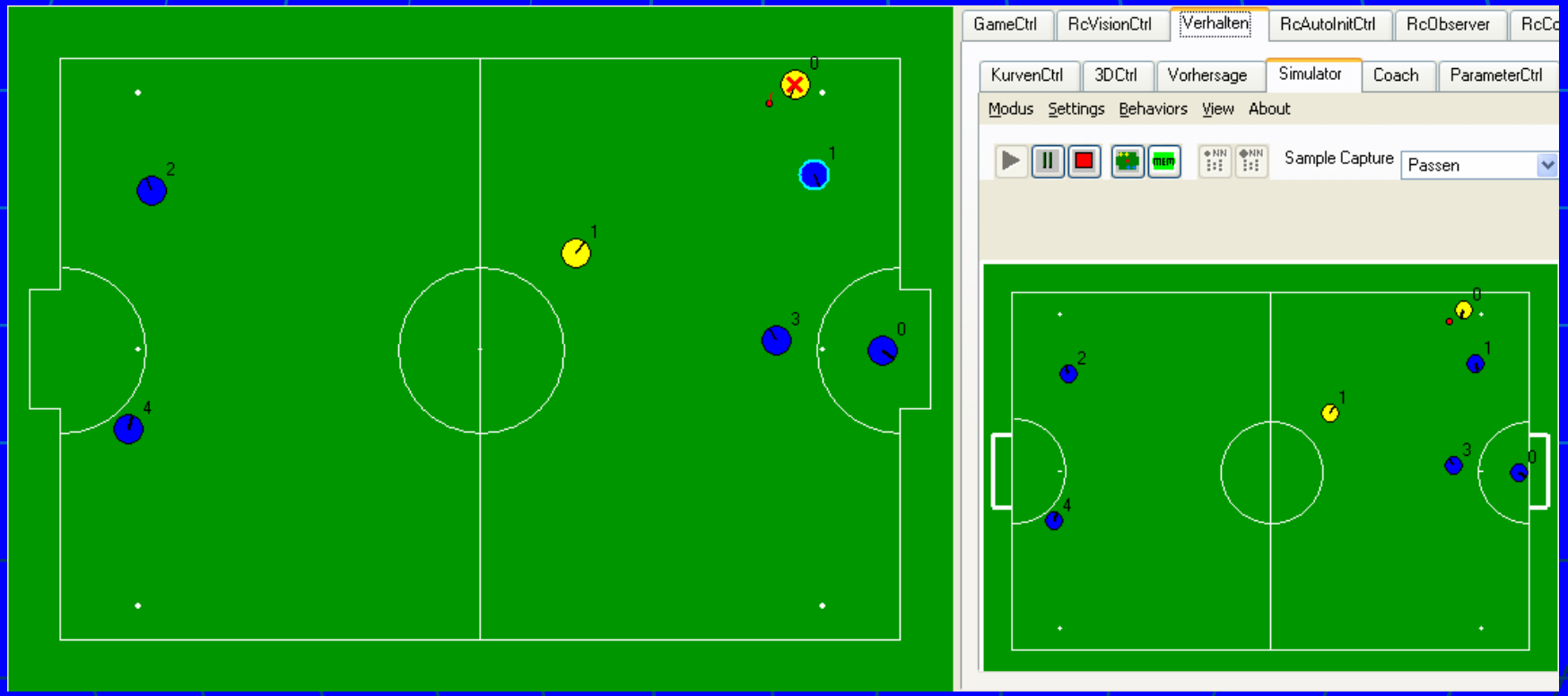
Anpassbarkeit



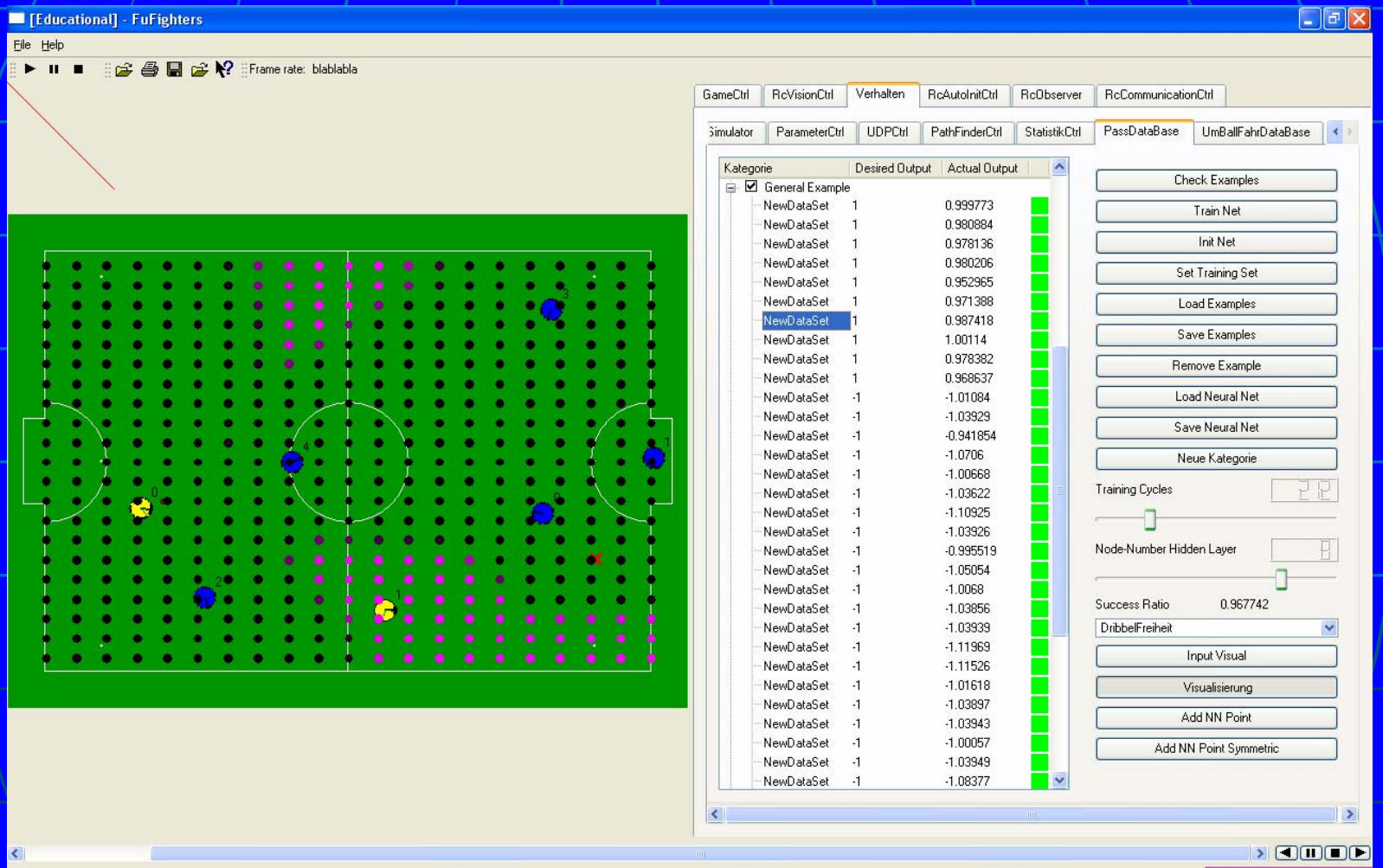
Raumfreiheit



Beispiel-Eingabe



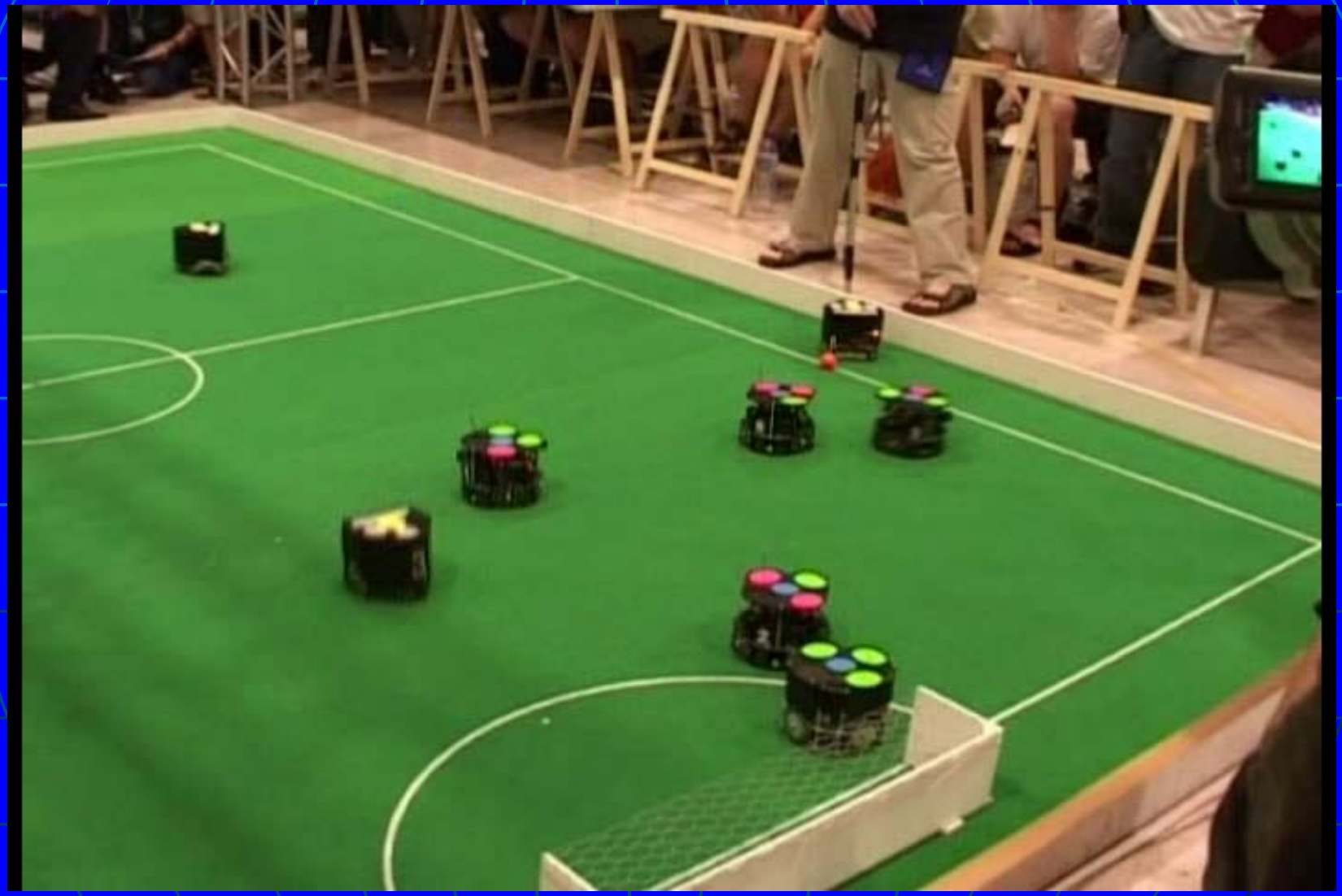
Learning to pass



Passing game

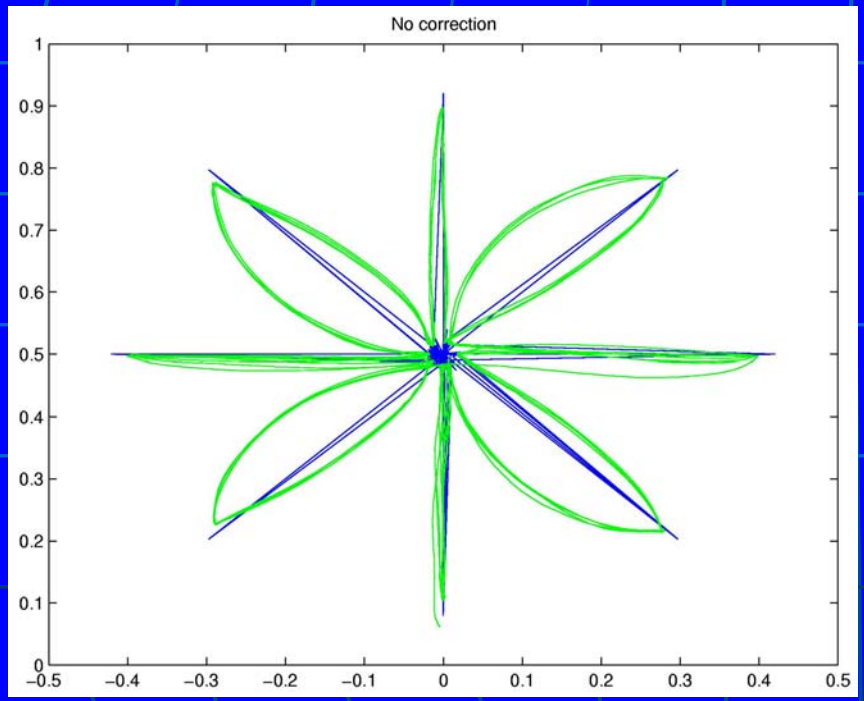
Team Play

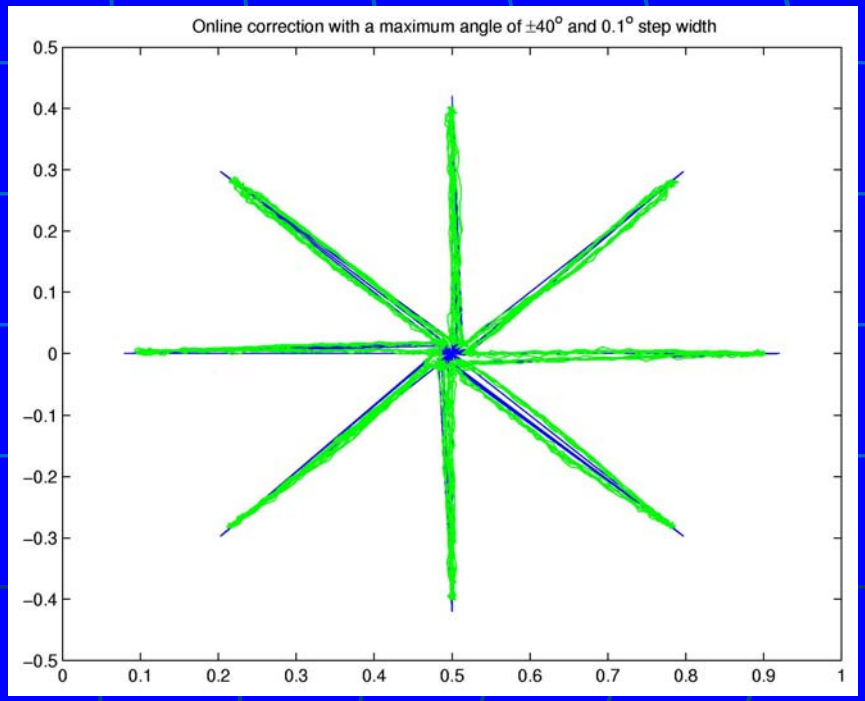
The Goalie



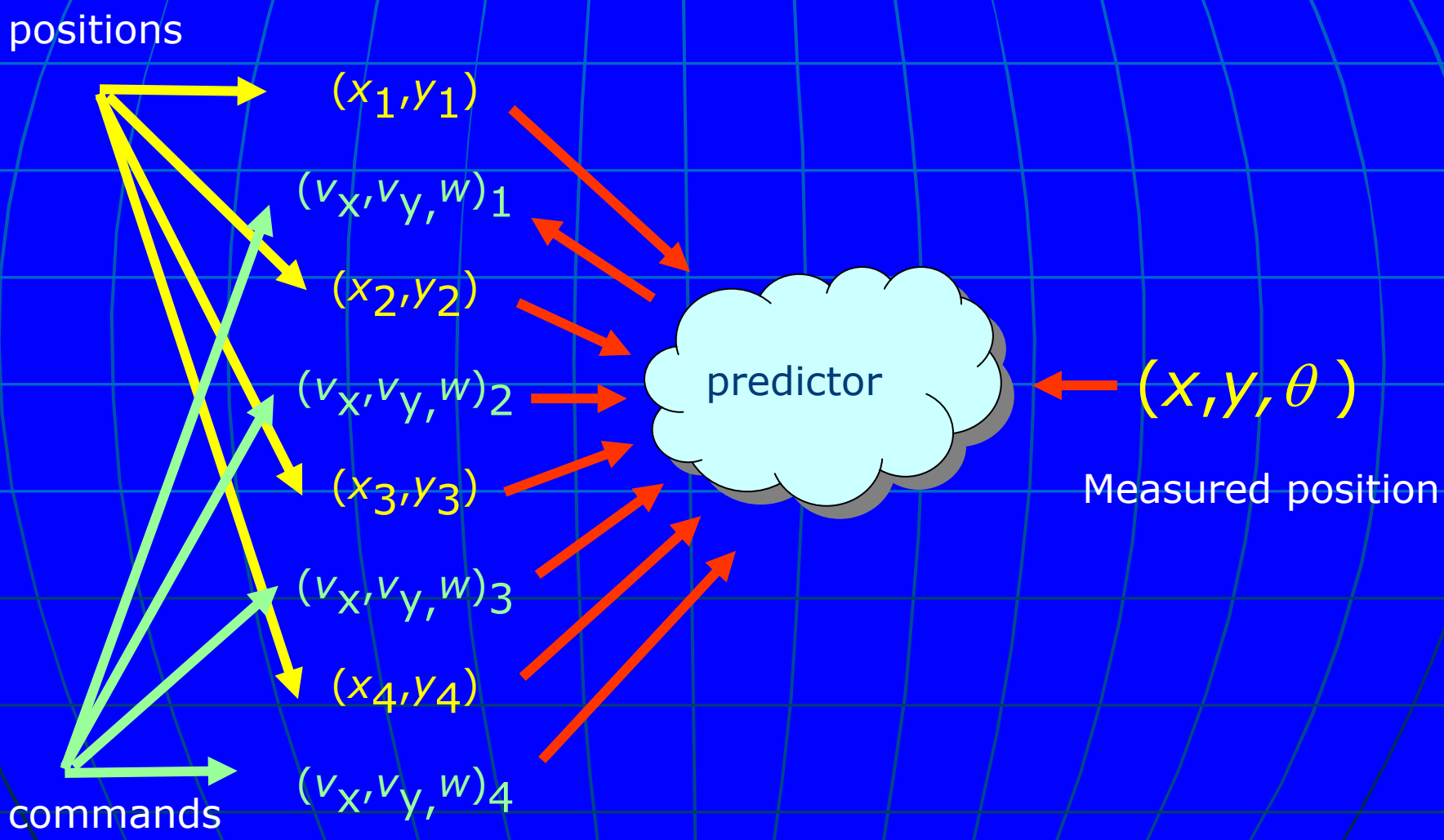
Goalie again

Learning: robot heal yourself

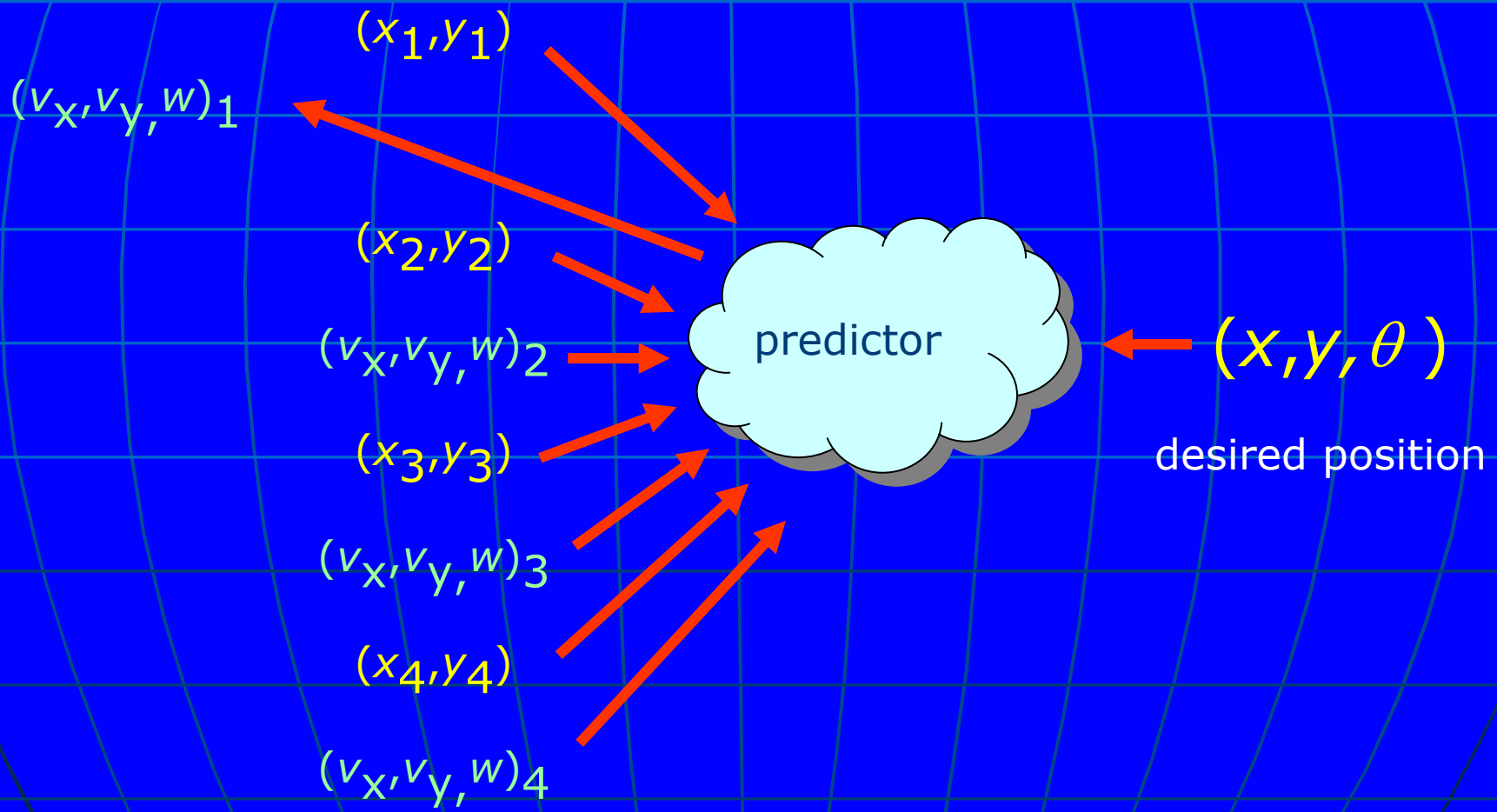




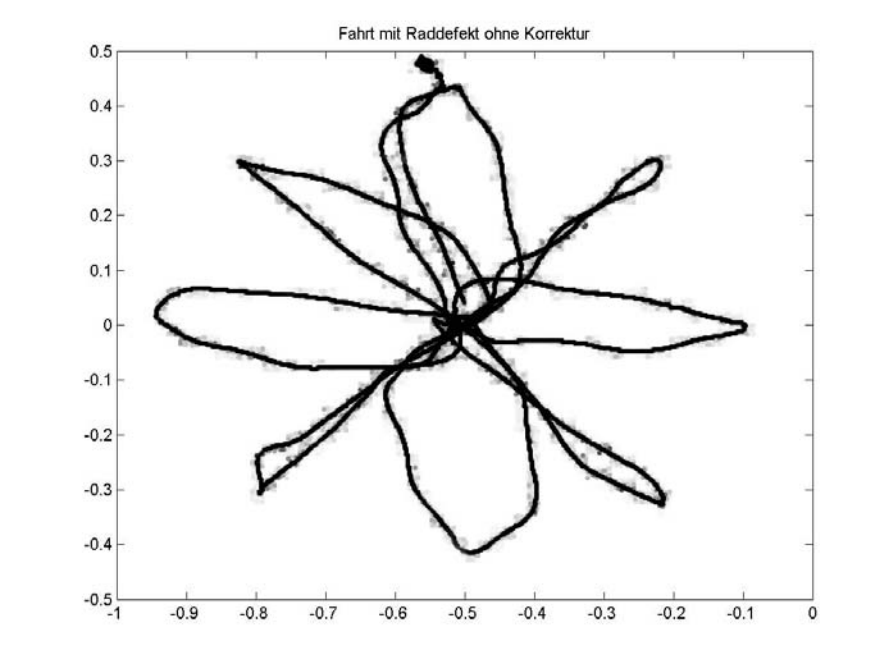
Learn what the robot does

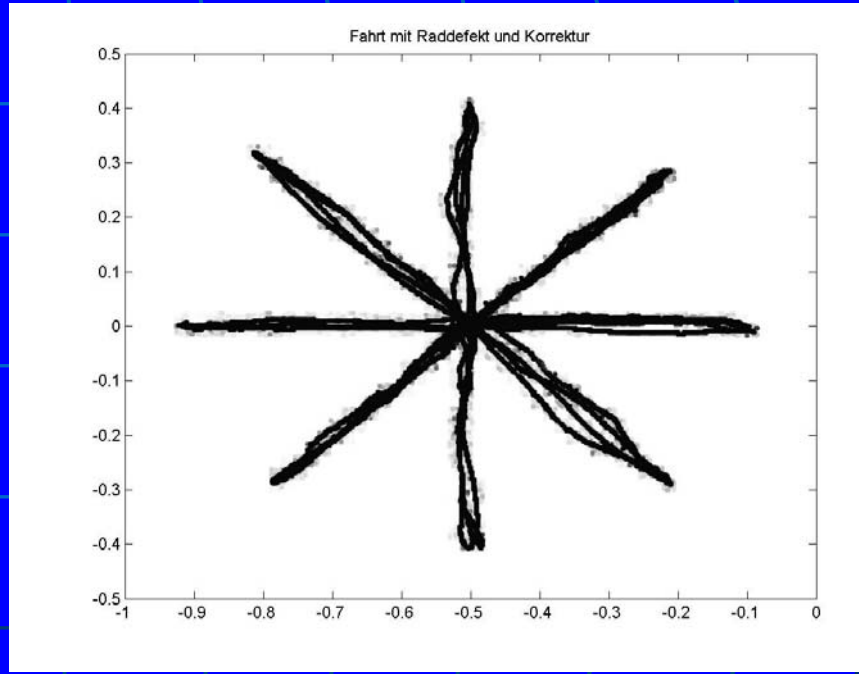


Invert the prediction



One burnt motor





V Summary and Outlook

FU Fighters

- 1999 Vizeweltmeister
- 2000 Europa- und Vizeweltmeister
- 2001 Vierter Platz
- 2002 Europa- und Vizeweltmeister
- 2003 Europameister
- Dritter Platz (small-size)
- Halbfinalist (mid-size)
- 2004 Weltmeister (small-size)
- Vierter Platz (mid-size)

Small-Size Team

Anna Egorova, Alexander Gloye, Mark Simon, Cüneyt Göktekin, Bastian Hecht, Achim Liers, Oliver Tenchio, Fabian Wiesel, Lina Ourima, Maria Jütte, Thomas Sunderman Susanne Schöttker-Söhl

Mid-size Team

Holger Freyther, Ketill Gunnarsson, Henning Heinold, Felix von Hundelshausen, Wolf Lindstrot, Marian Luft, Slav Petrov, Michael Schreiber, Frederik Zilly, Fabian Ruff, David Schneider, Markus Kettern

Detlef Müller und Feinwerktechnik

Fritz-Haber-Institut

- Georg Heyne
- Peter Zilske
- Torsten Vetter
- Ronald Nehring


FU Fighters