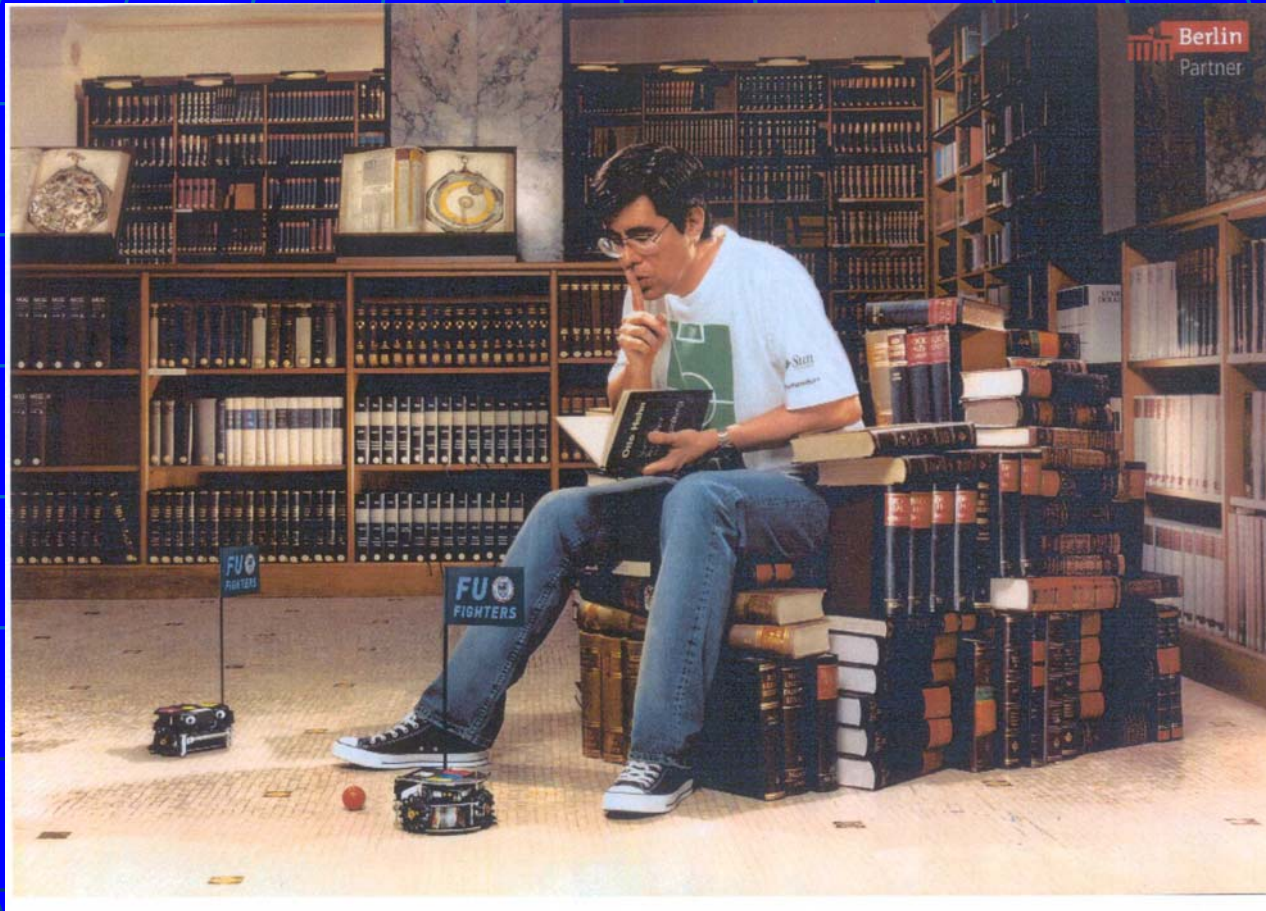


Computer Vision and Control for Autonomous Robots



Prof. Dr. Raul Rojas
FU Berlin

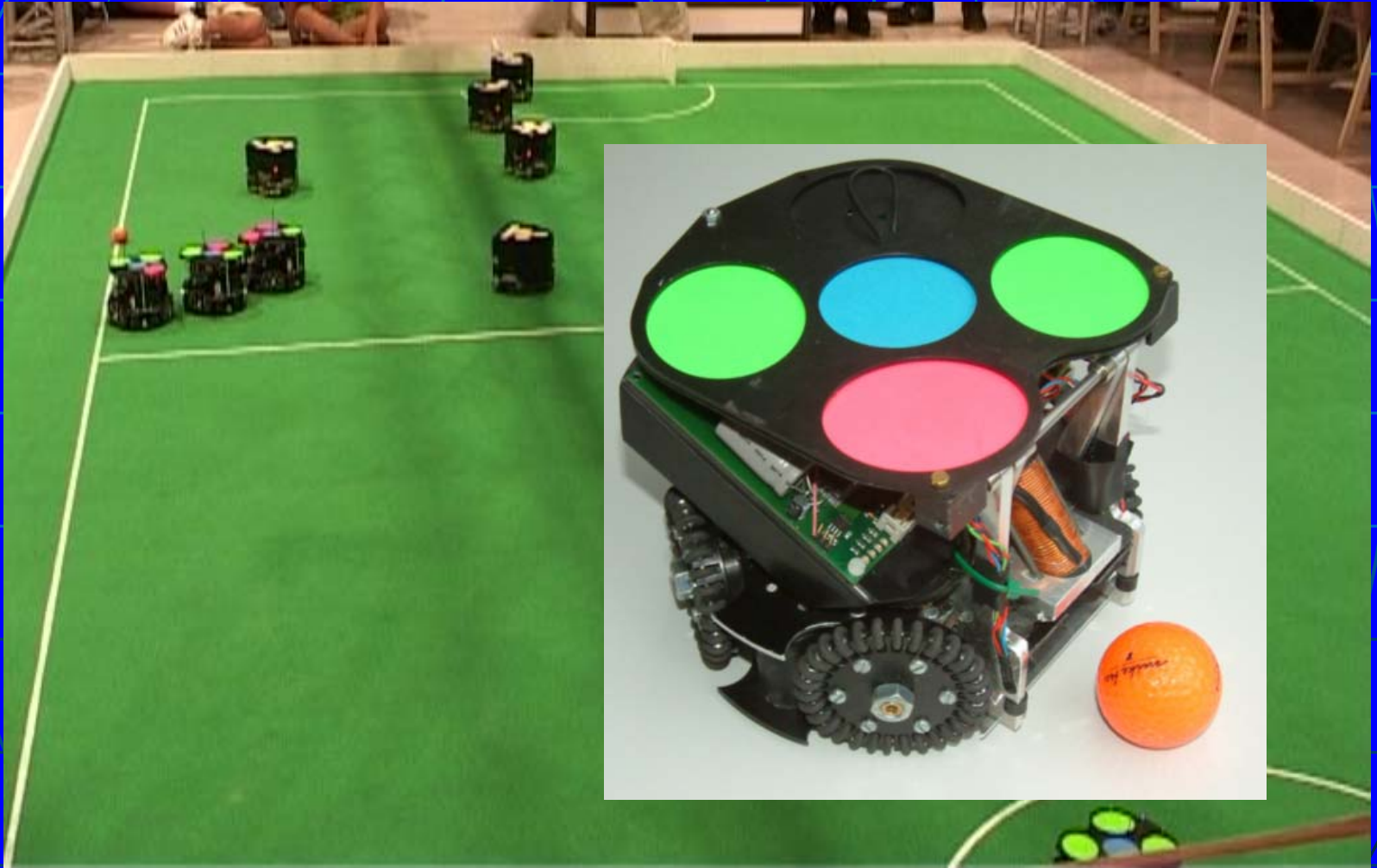
Embodied Intelligence: A new Paradigm for AI

- Intelligence needs a body: mechanics
- Computer vision in real time
- "Artificial Intelligence is the art and science of the subconscious"
 - Energy management
 - Local control
- Communication between agents
- Coordination and team behavior
- Adaptation and learning

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

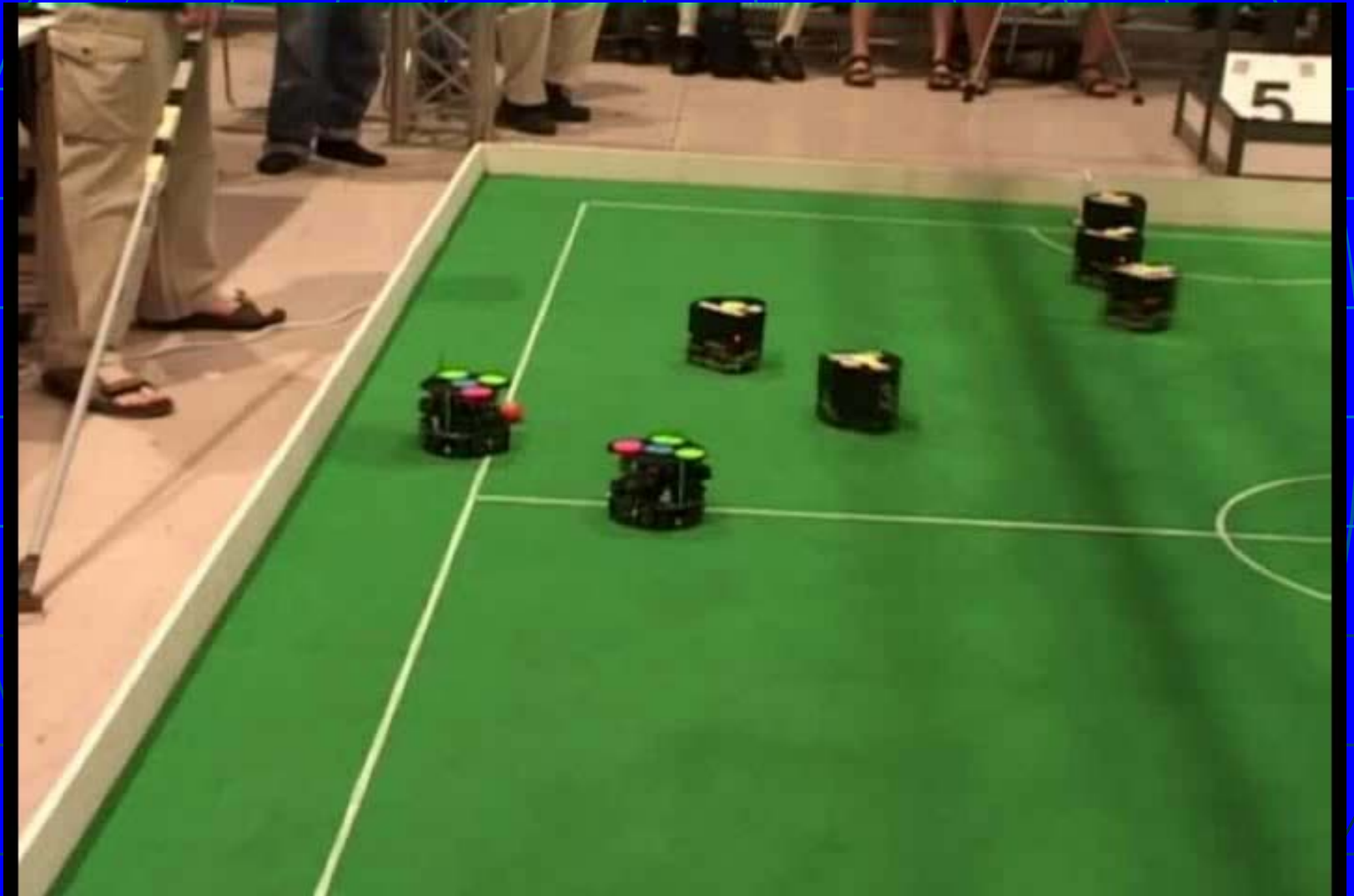
Small-Size Liga



4.5 by 5 meter field

Five vs five

Lisbon 2004



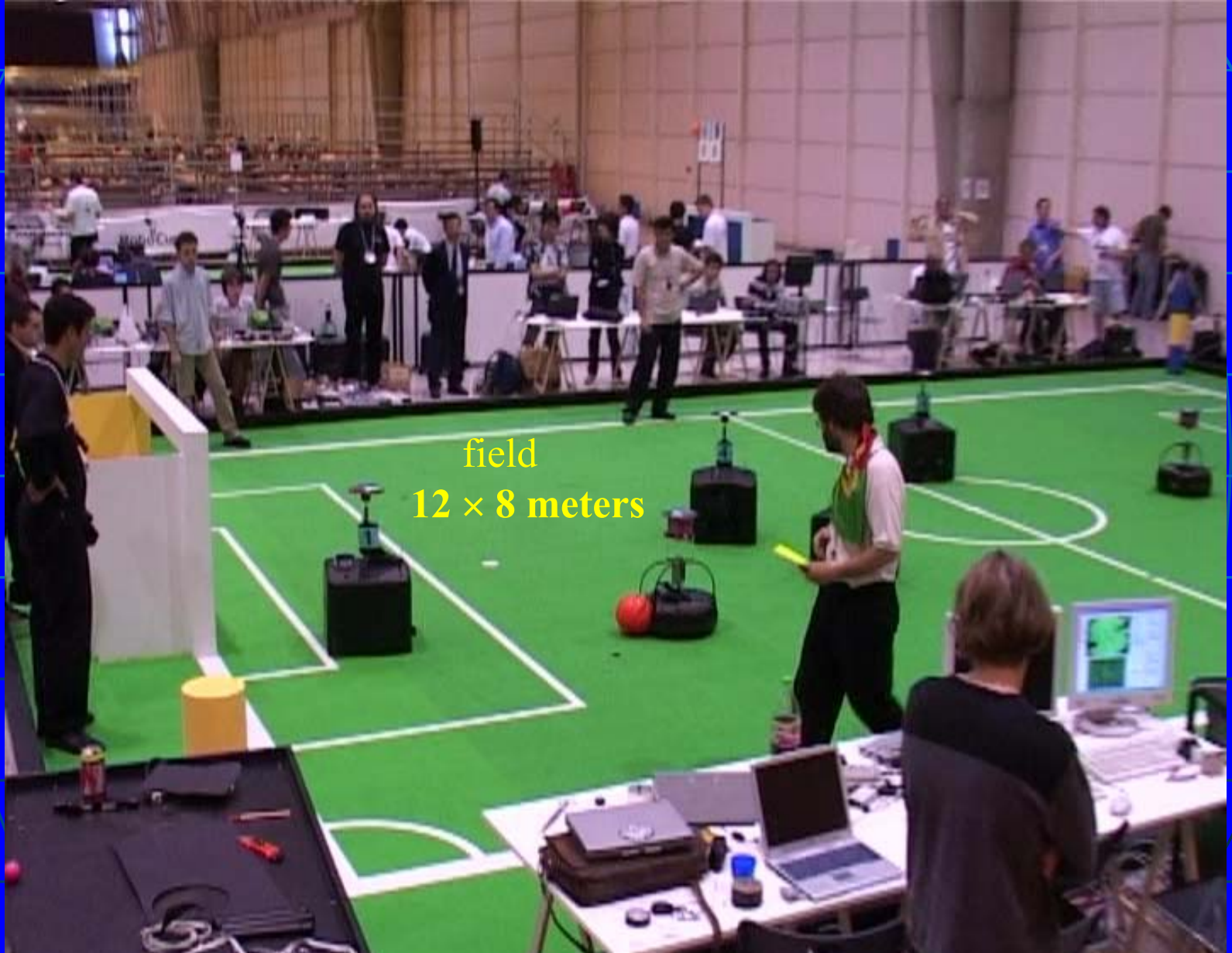
Kicking the distance



Mid-size league

four
on
four

field
 12×8 meters



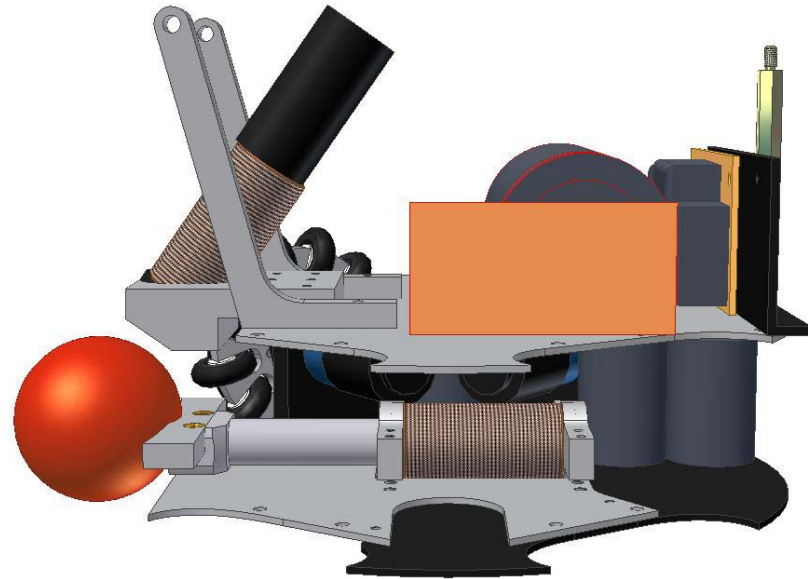
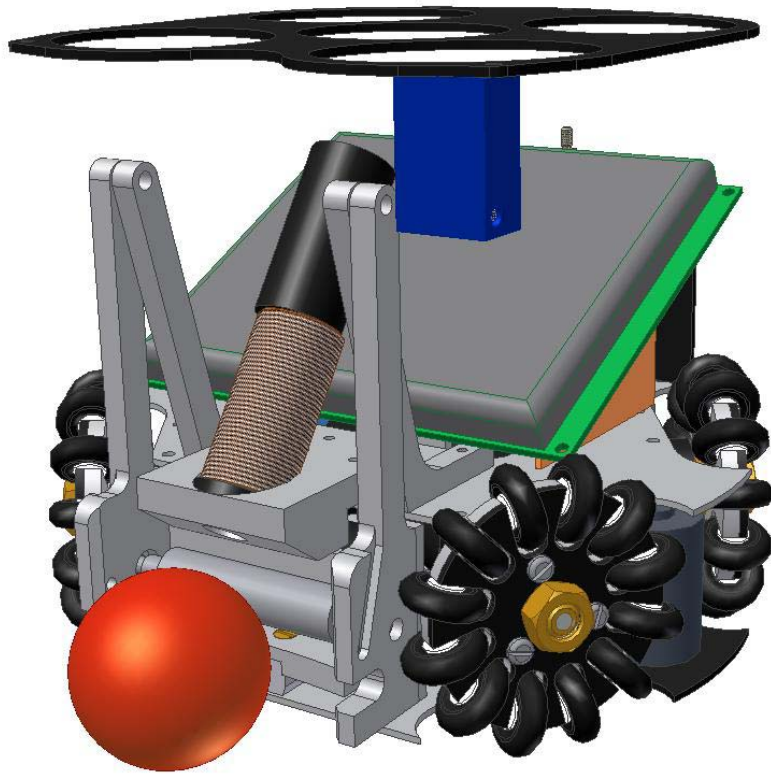
Lisbon 2004



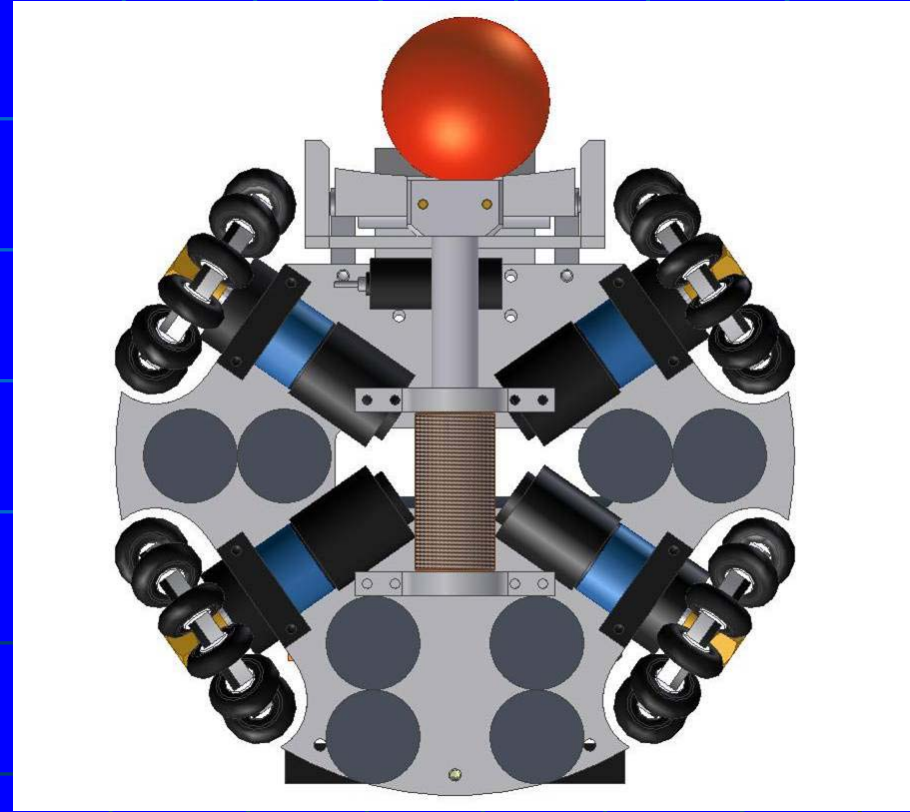
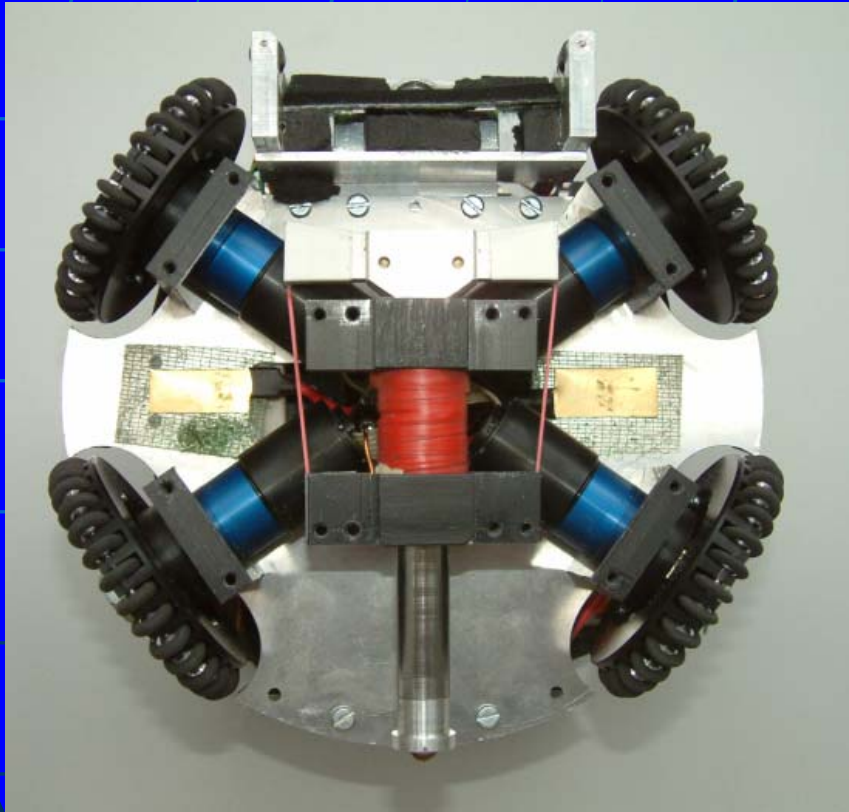
Pressuring the goalie



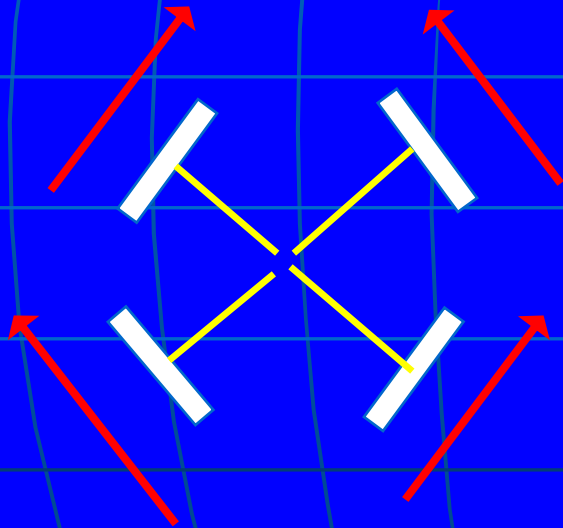
Our small-size robots



Omnidirectional Design



Omnidirectional Control



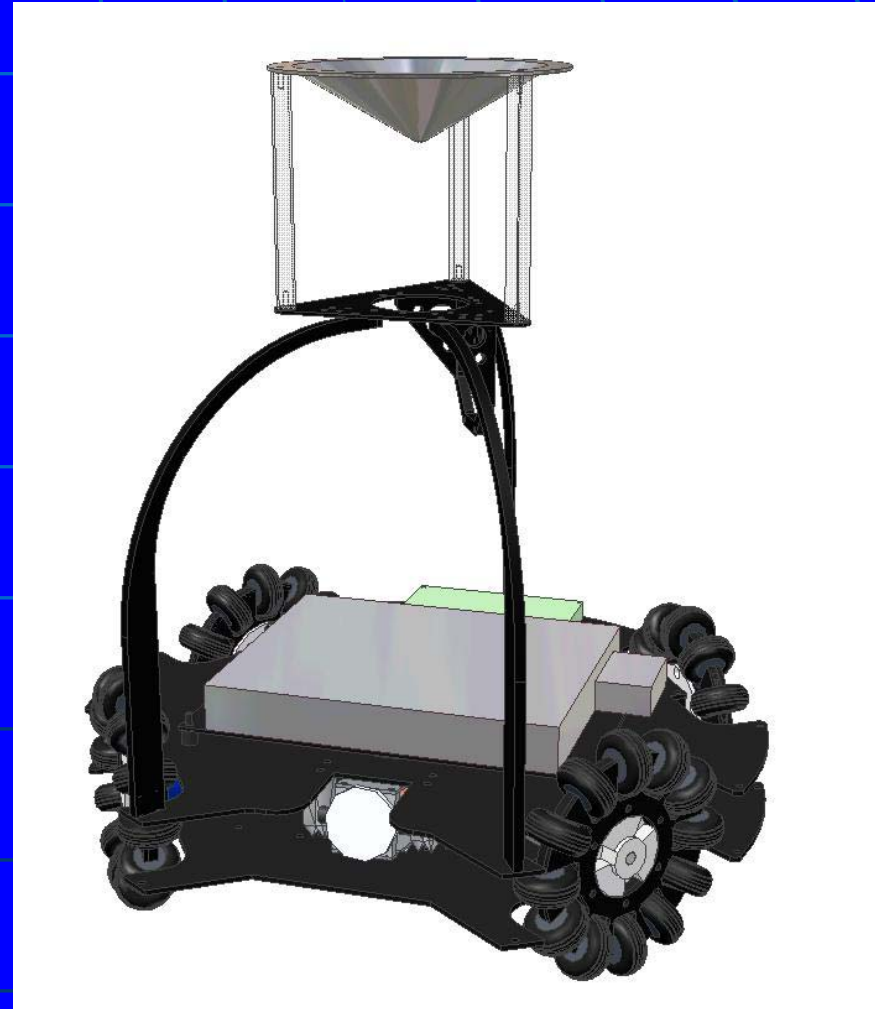
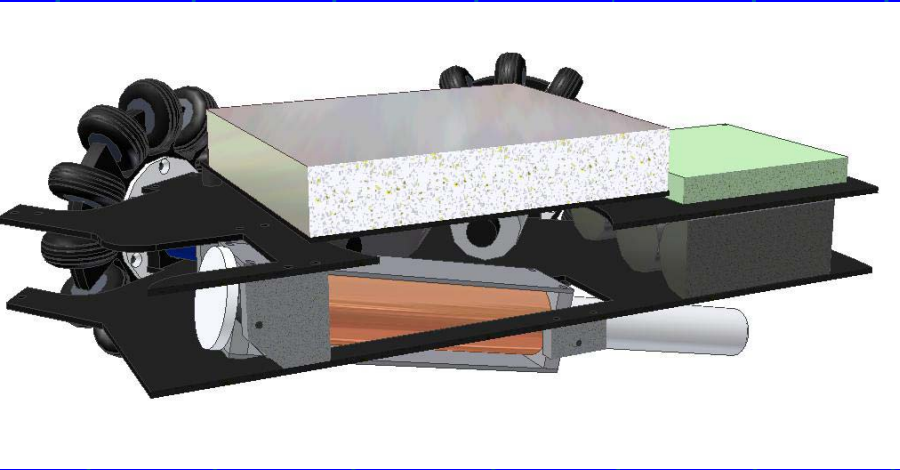
Our mid-size robots



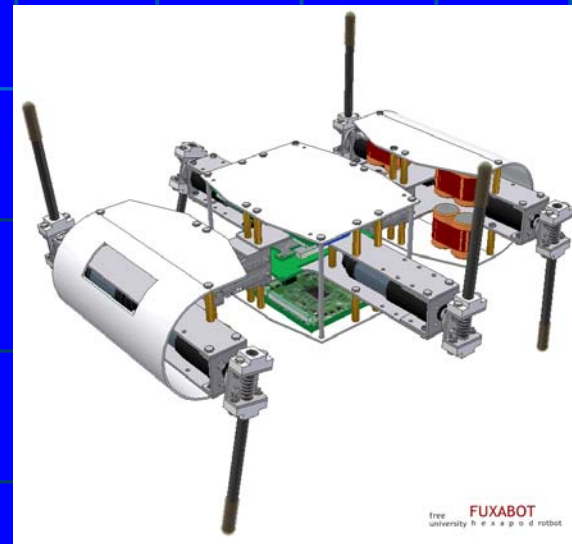
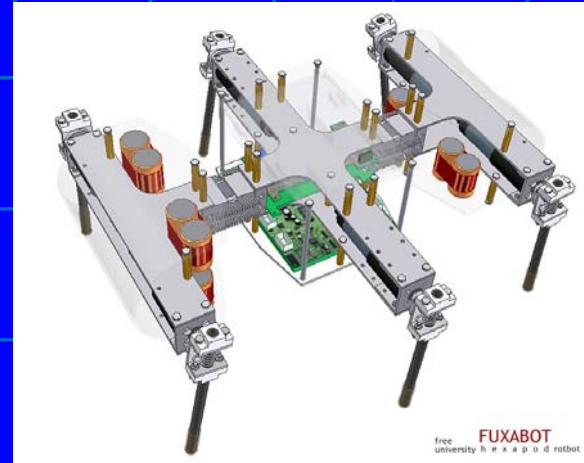
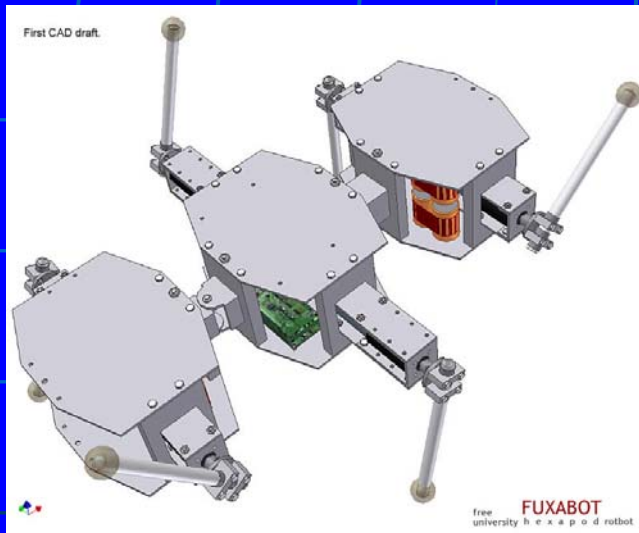
Omnidirectional vision

- Laptop for control
- Firewire video camera

CAD Design



FUXABOT: The Hexapod

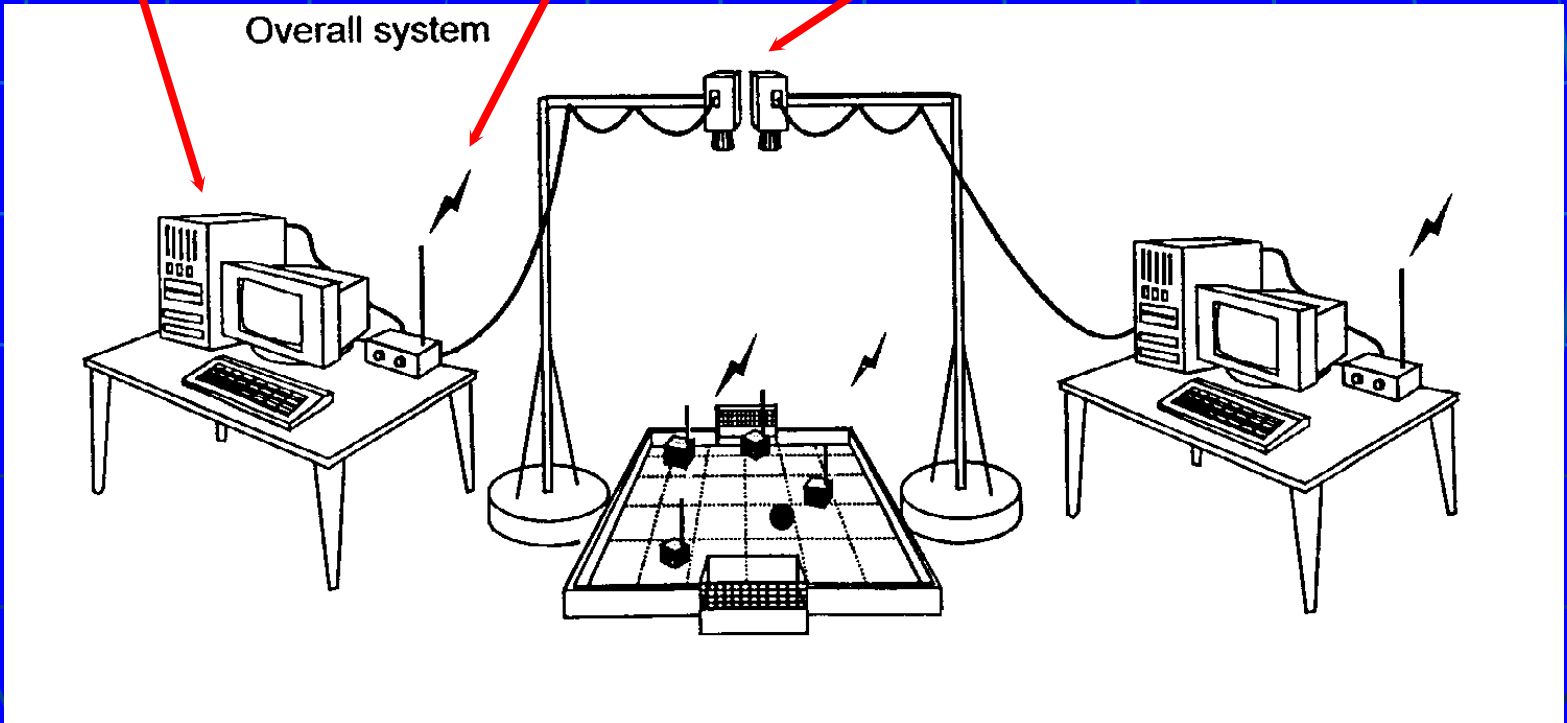




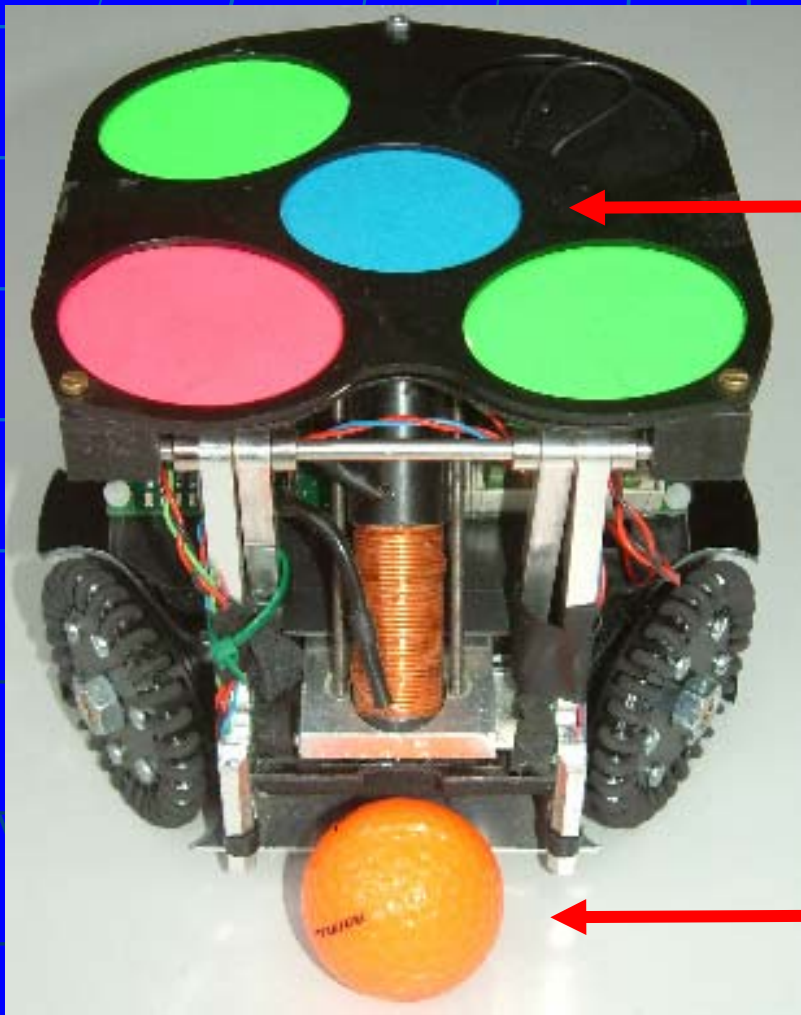
I Global vision

Global vision

computer wireless communication global camera



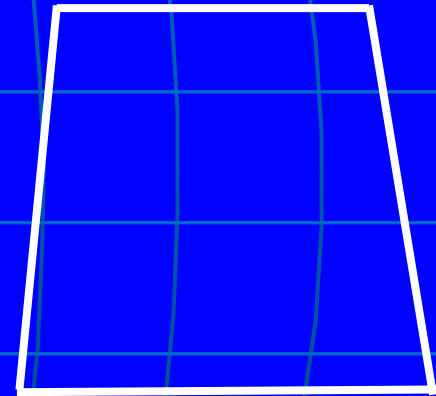
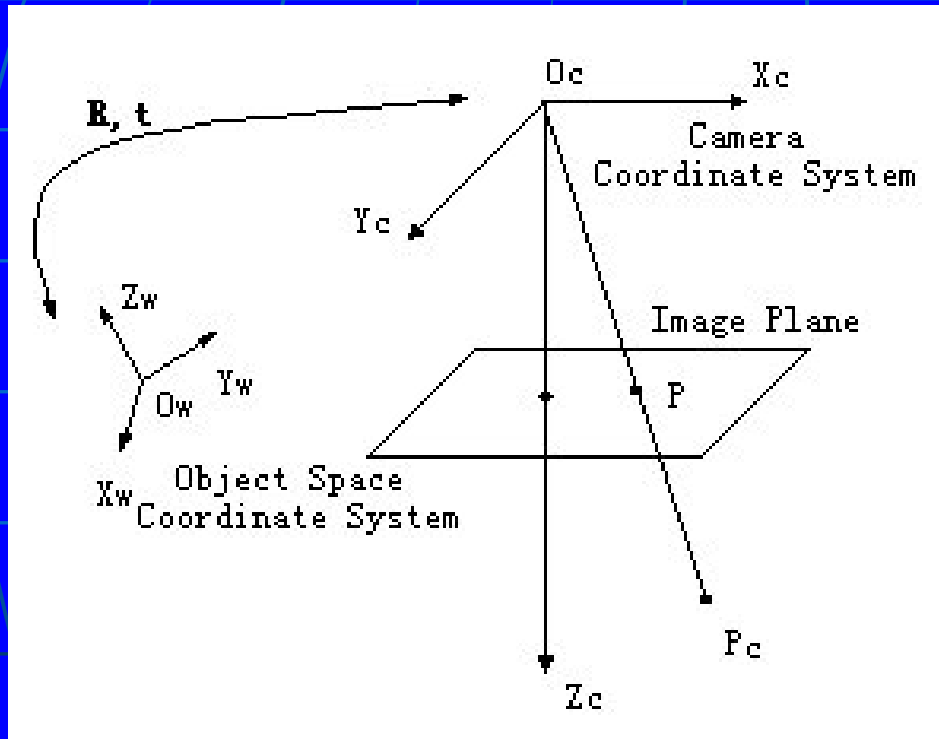
The world is colored



Team color

ball

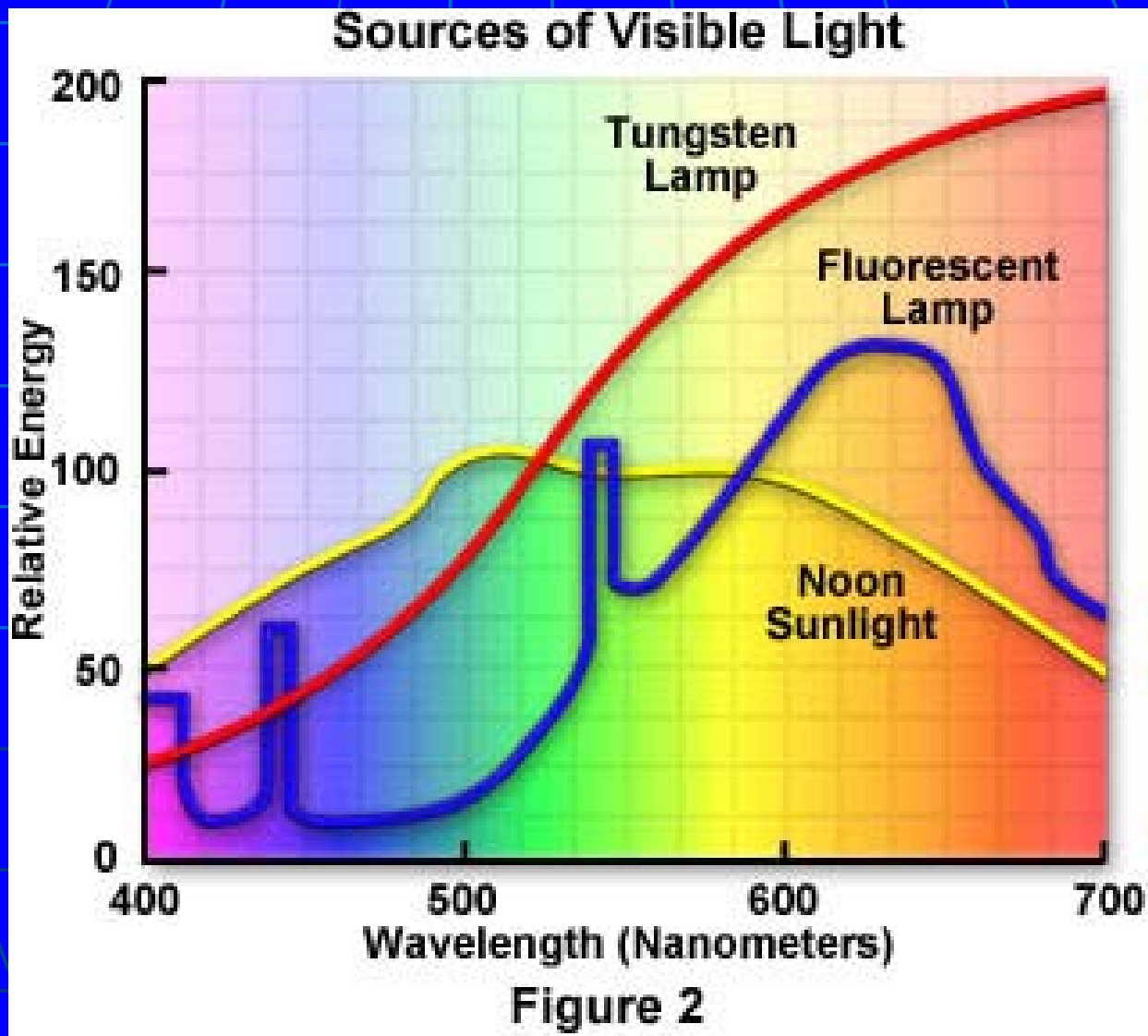
Projective Transformation



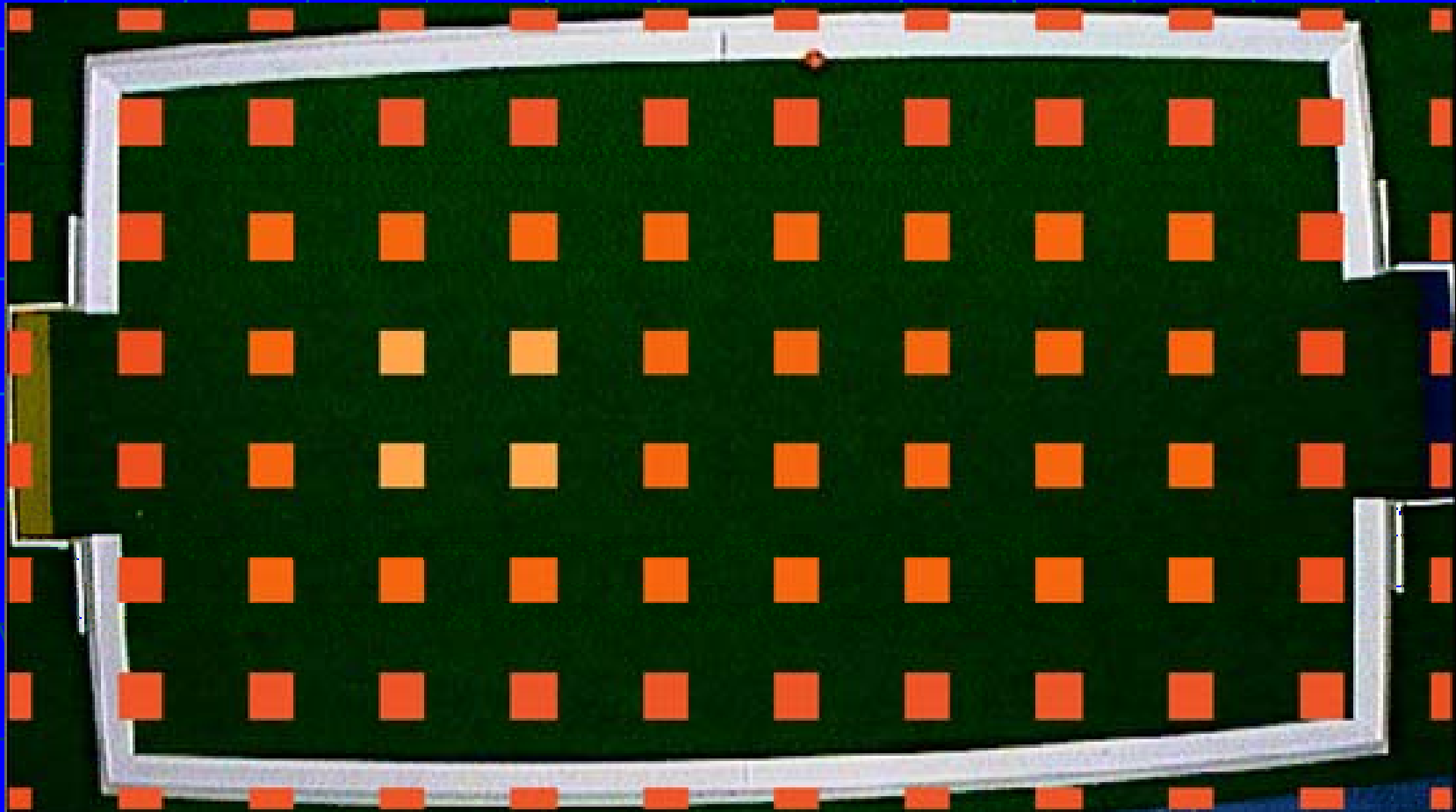
Automatic camera calibration



Illumination artifacts

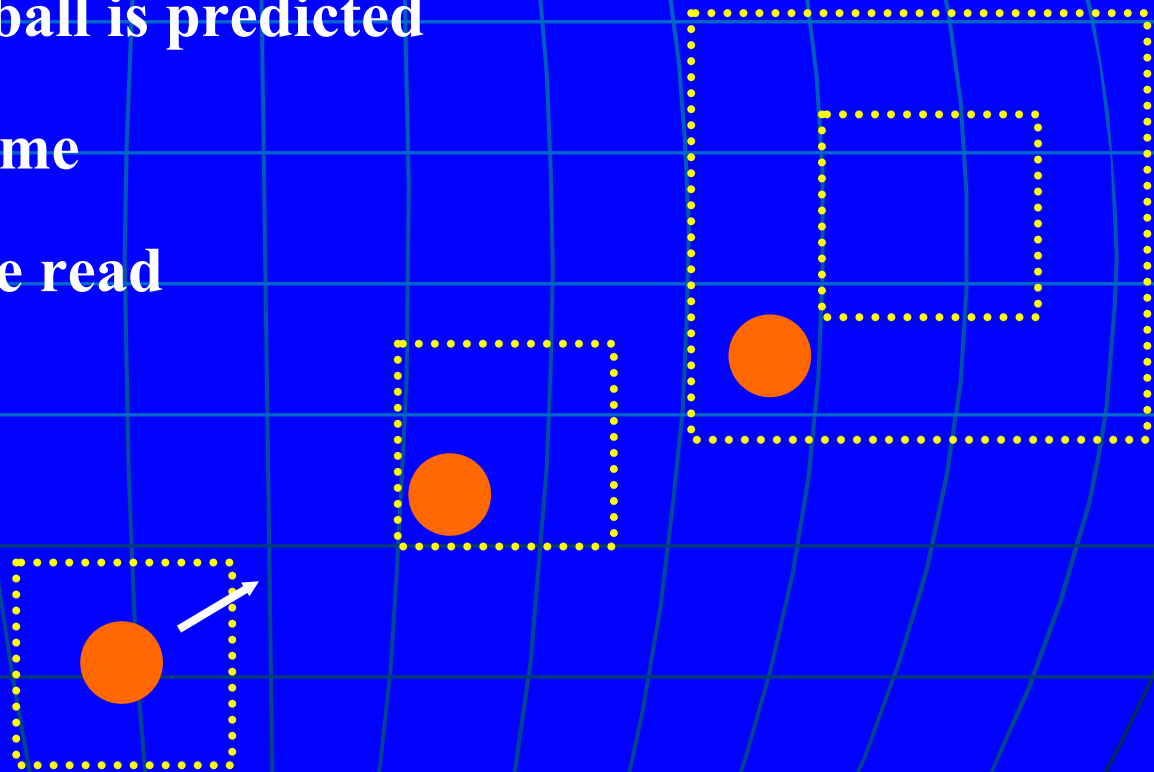


Adaptive color maps

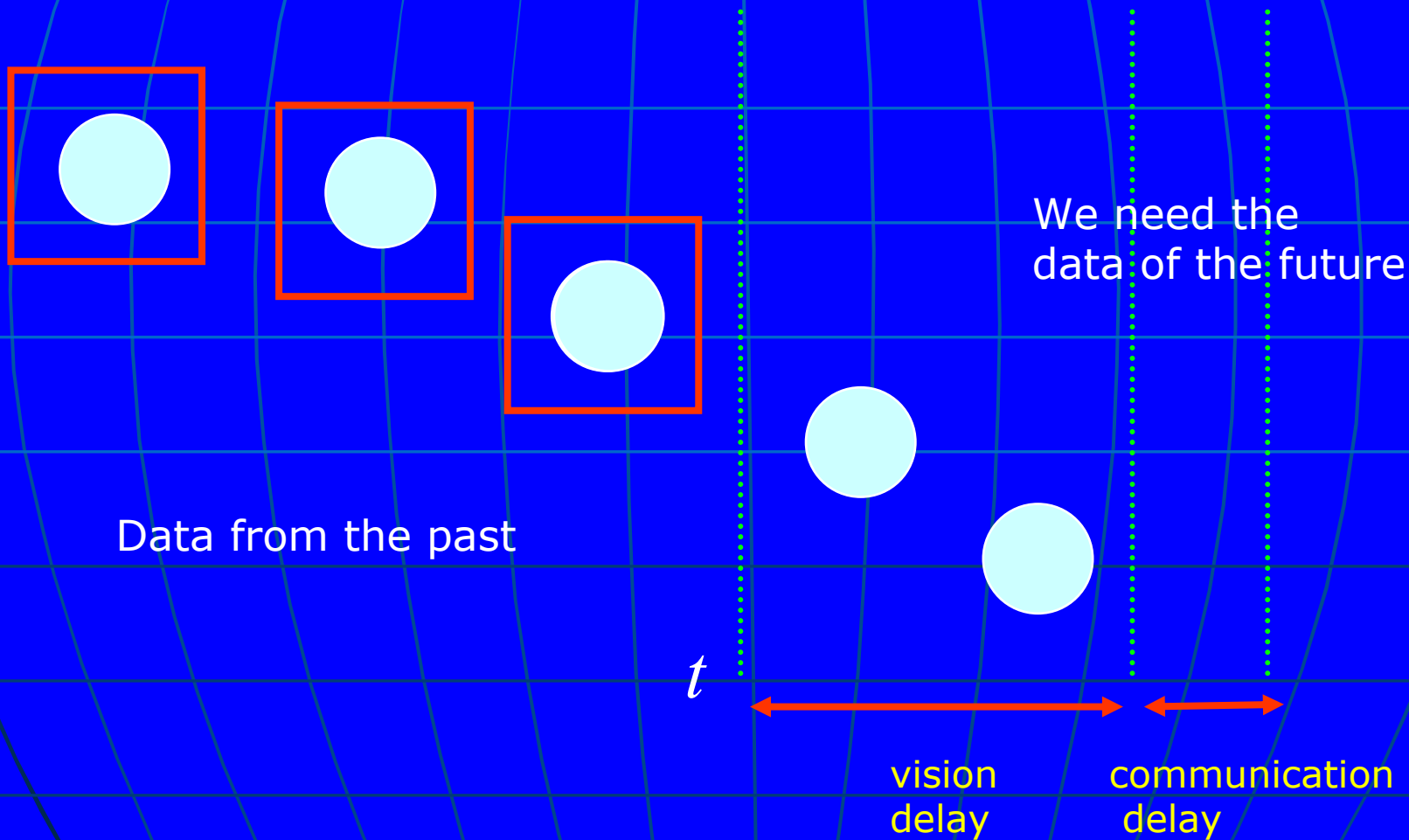


Tracking helps computer vision

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

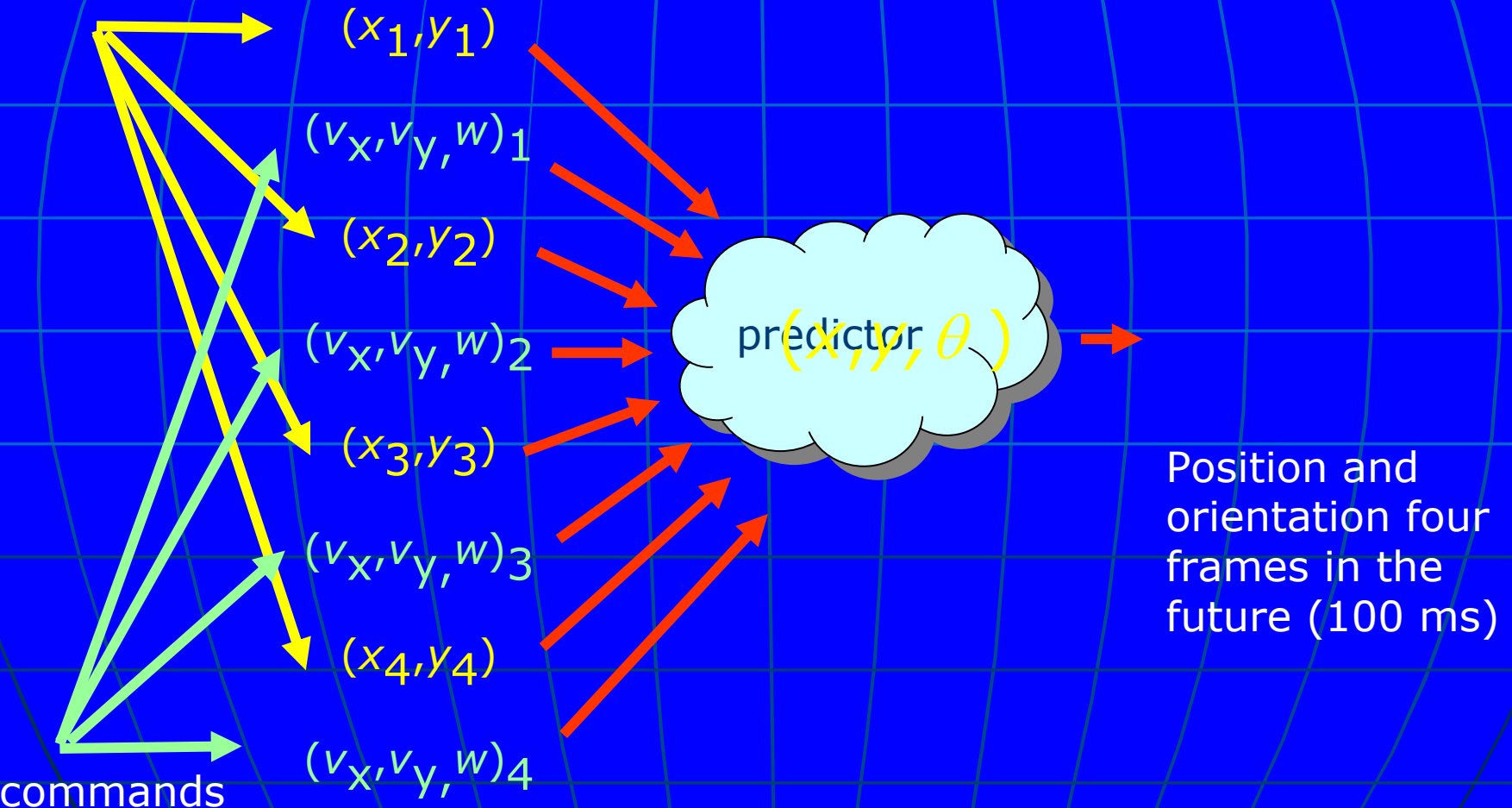


Tracking the robots

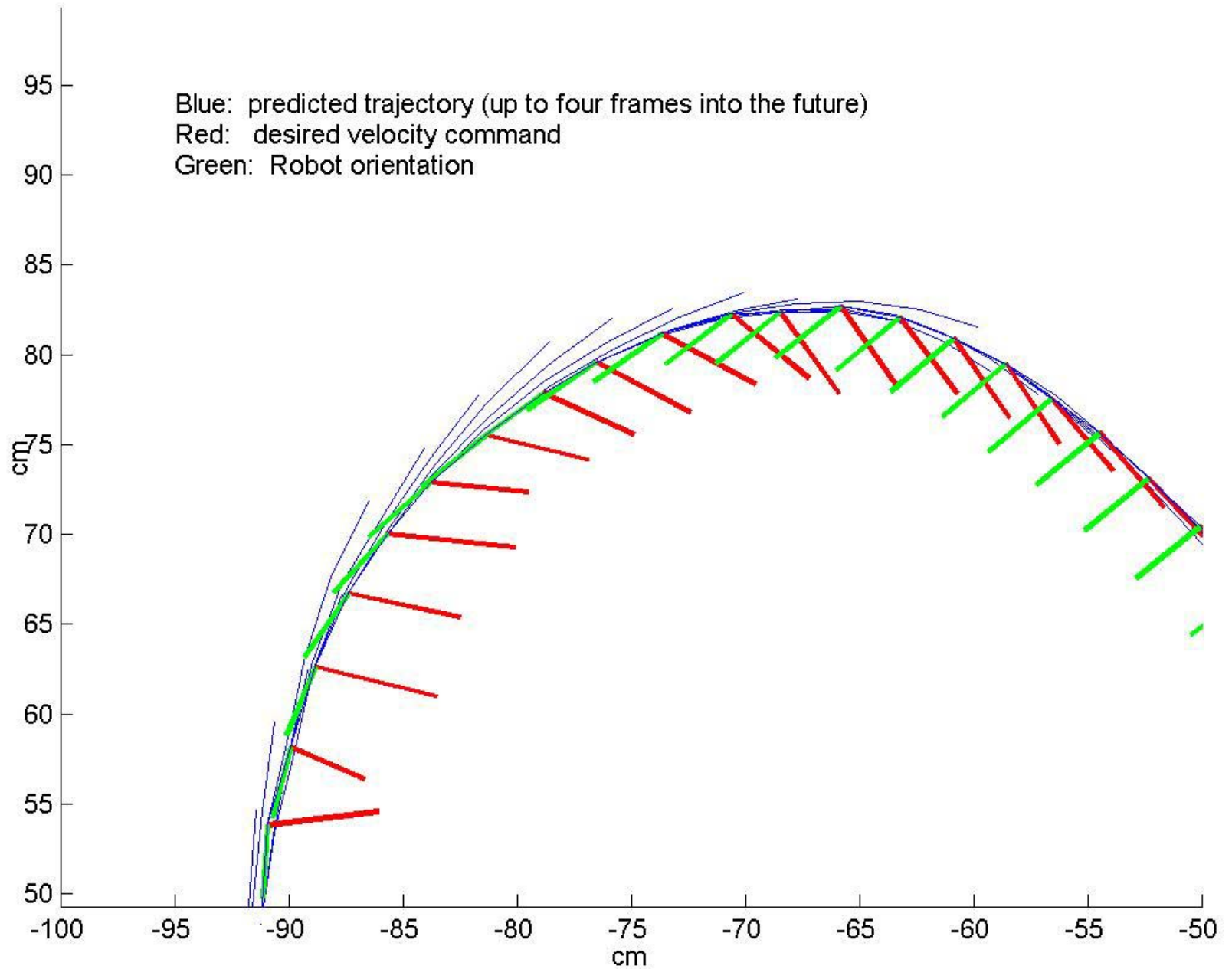


Predict the robot's movement

positions

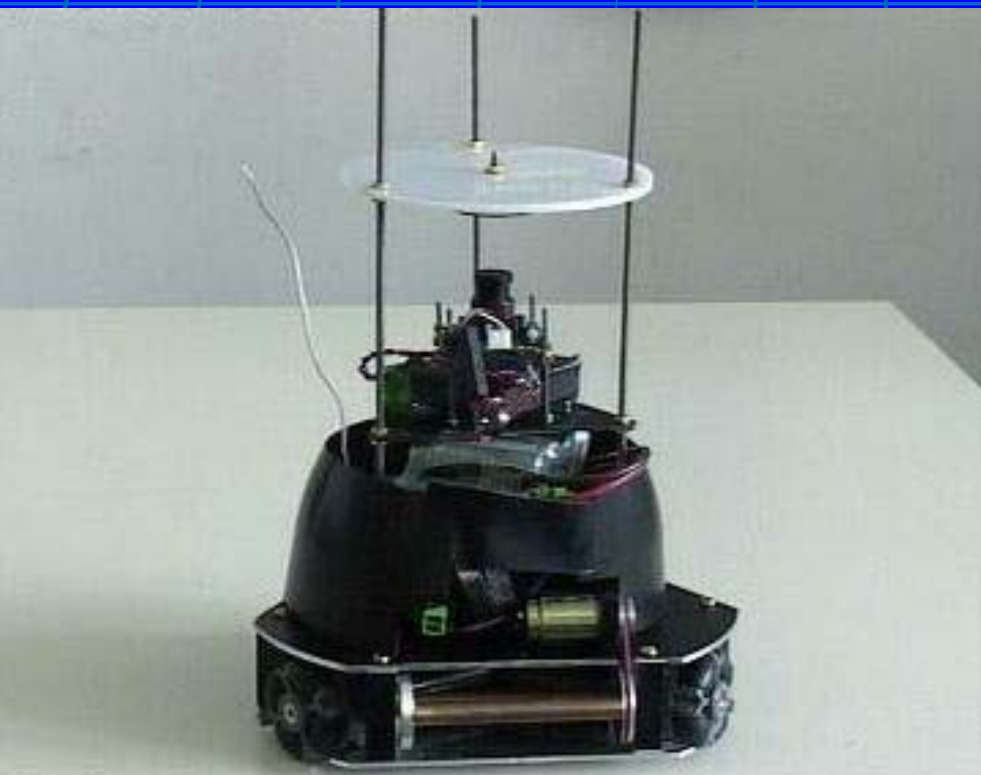


Local Prediction four Frames in Advance

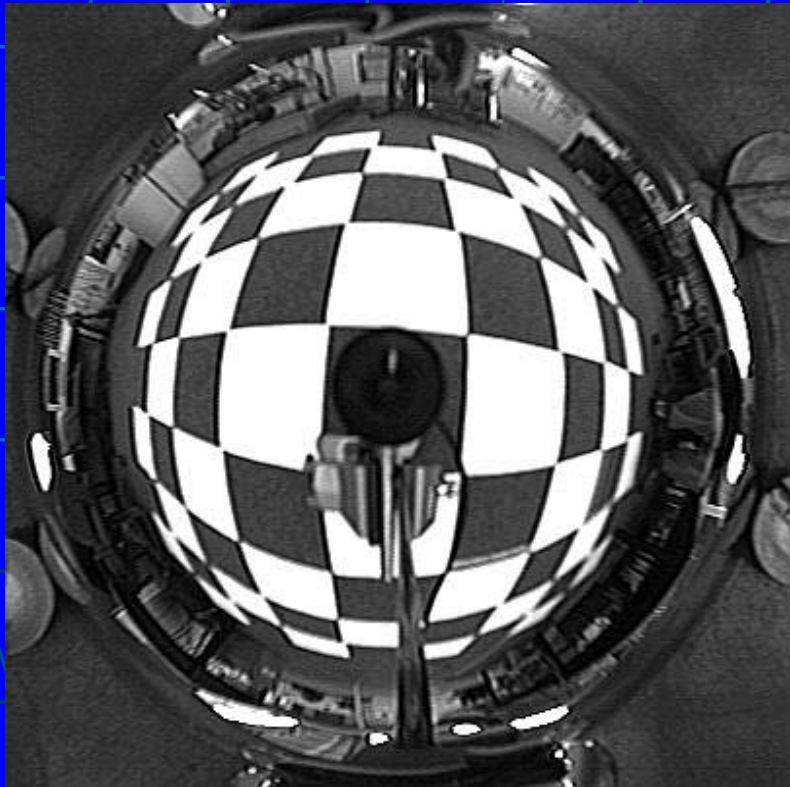


II Local vision

Our first omnivision robots



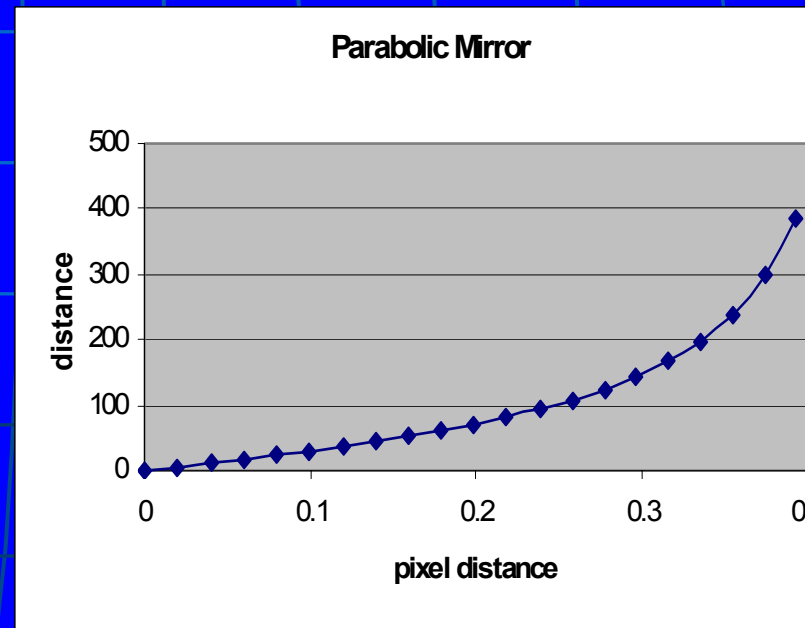
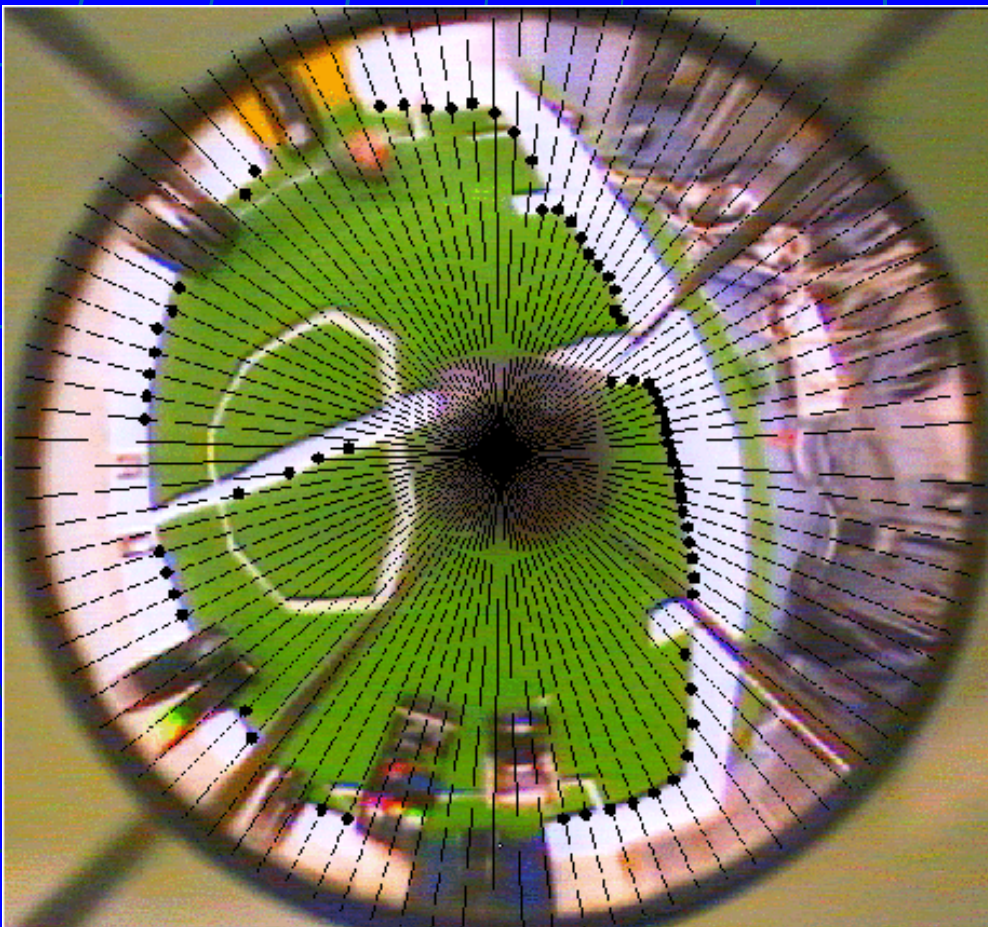
Spherical and parabolic transformations



The field seen with our mirror

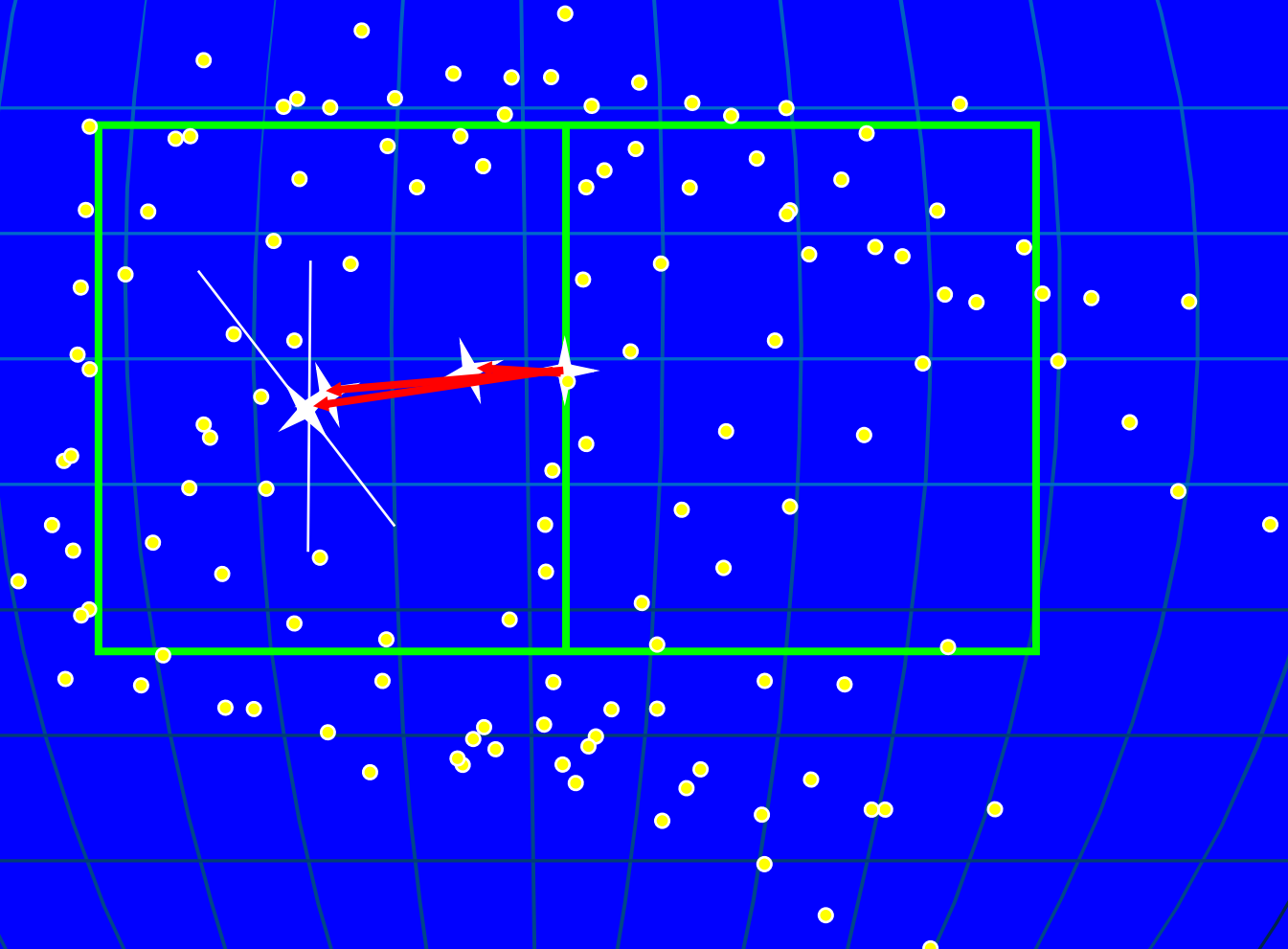


Locating the robot

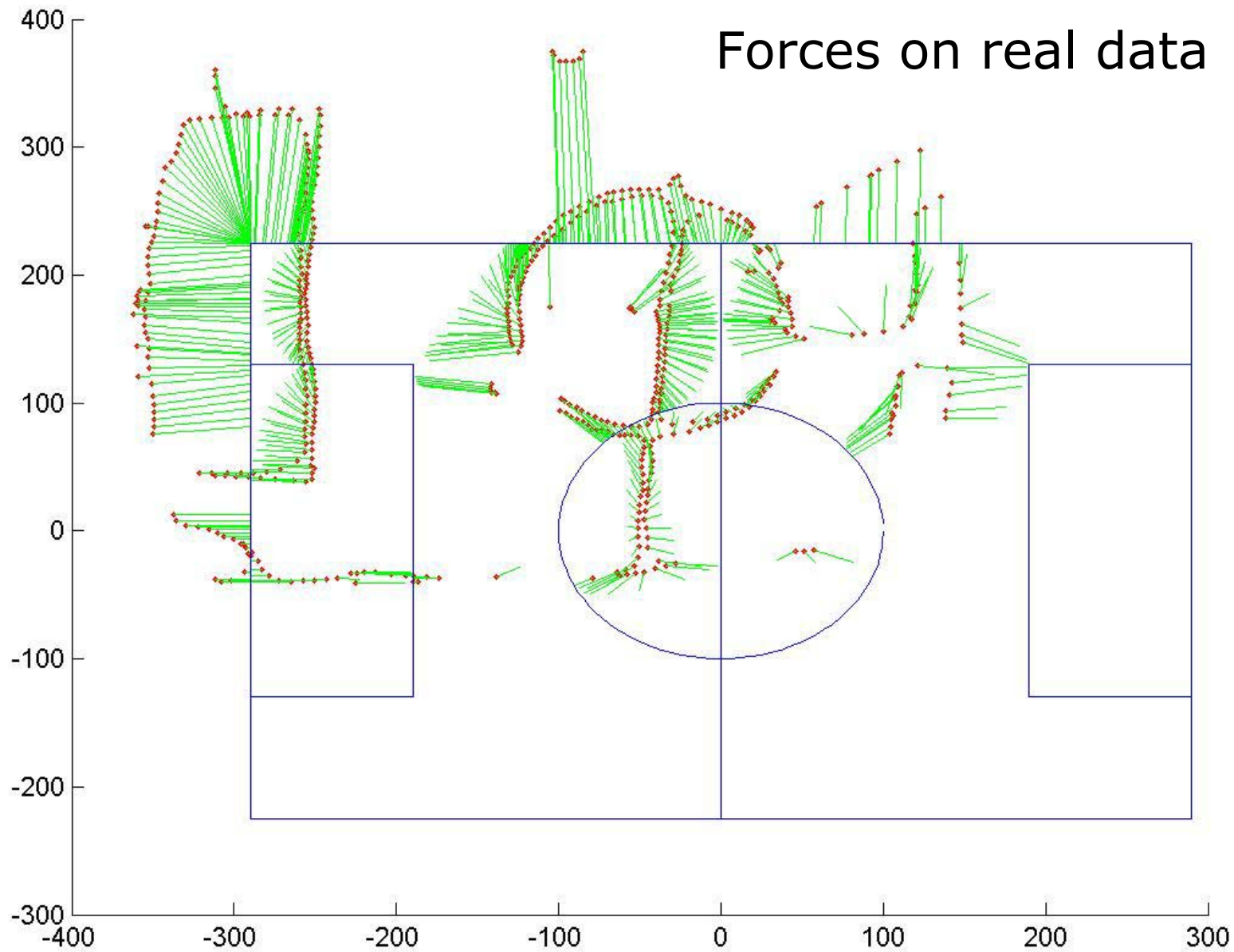


Expectation-Maximization

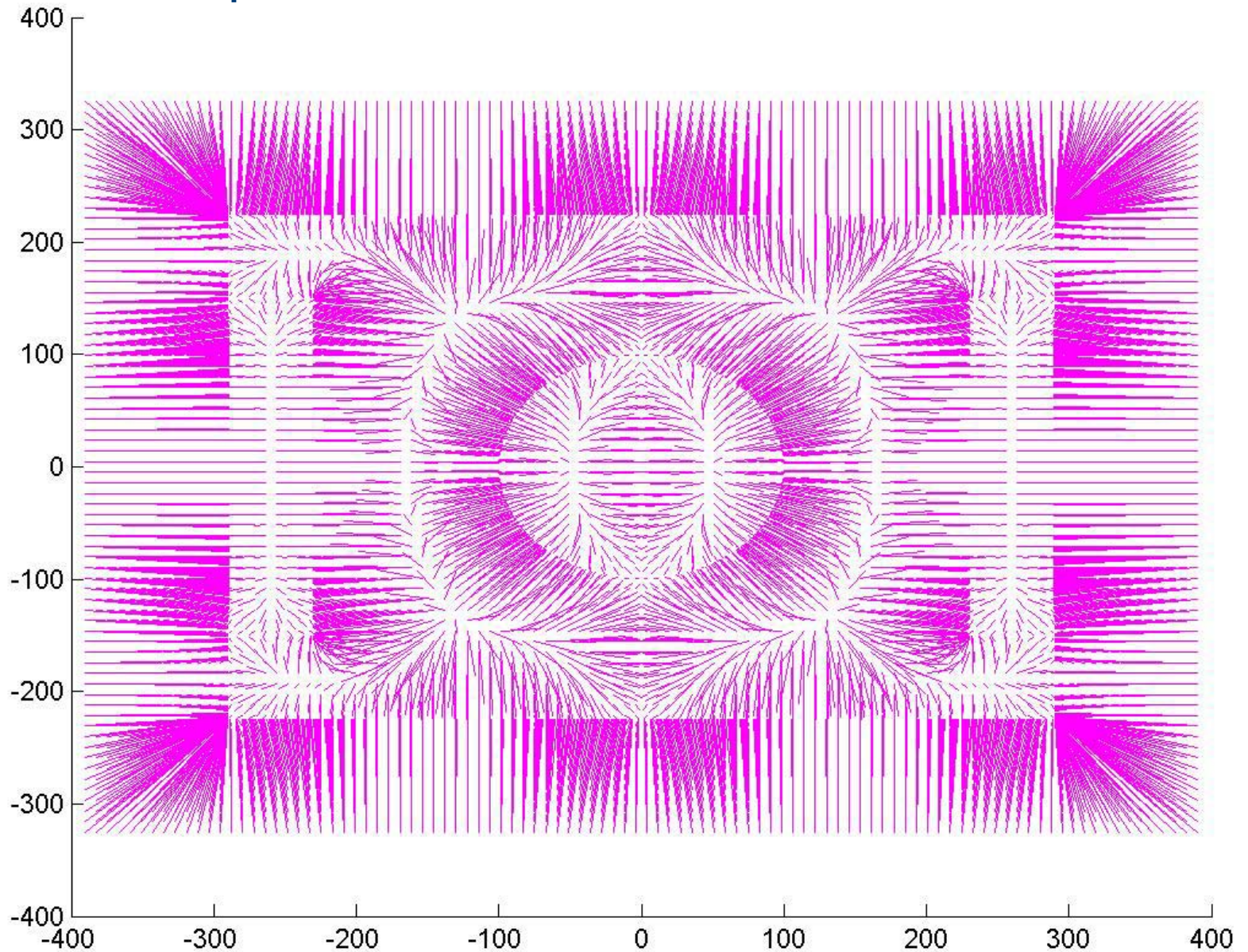
The model „attracts“ the cloud of points



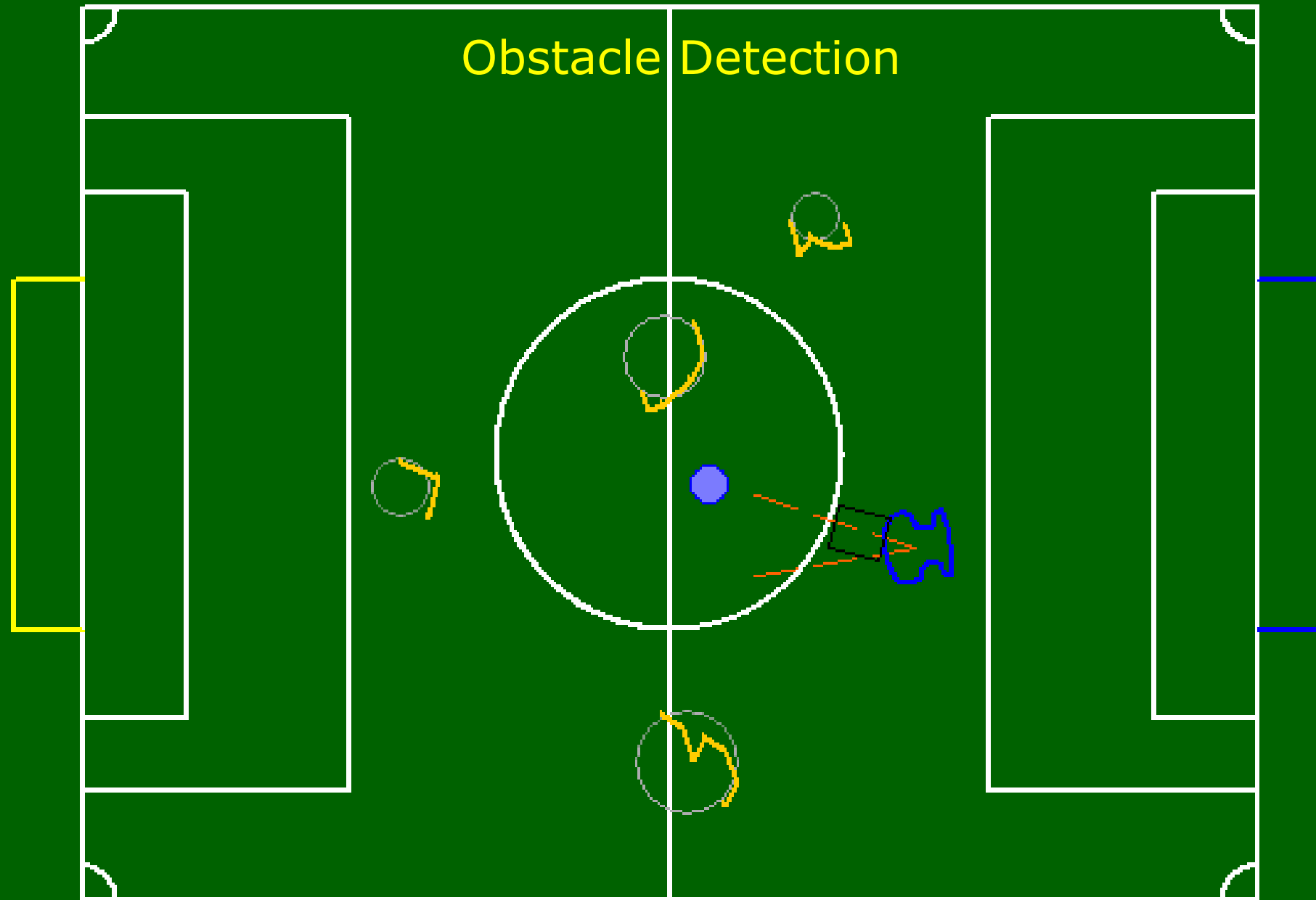
Forces on real data



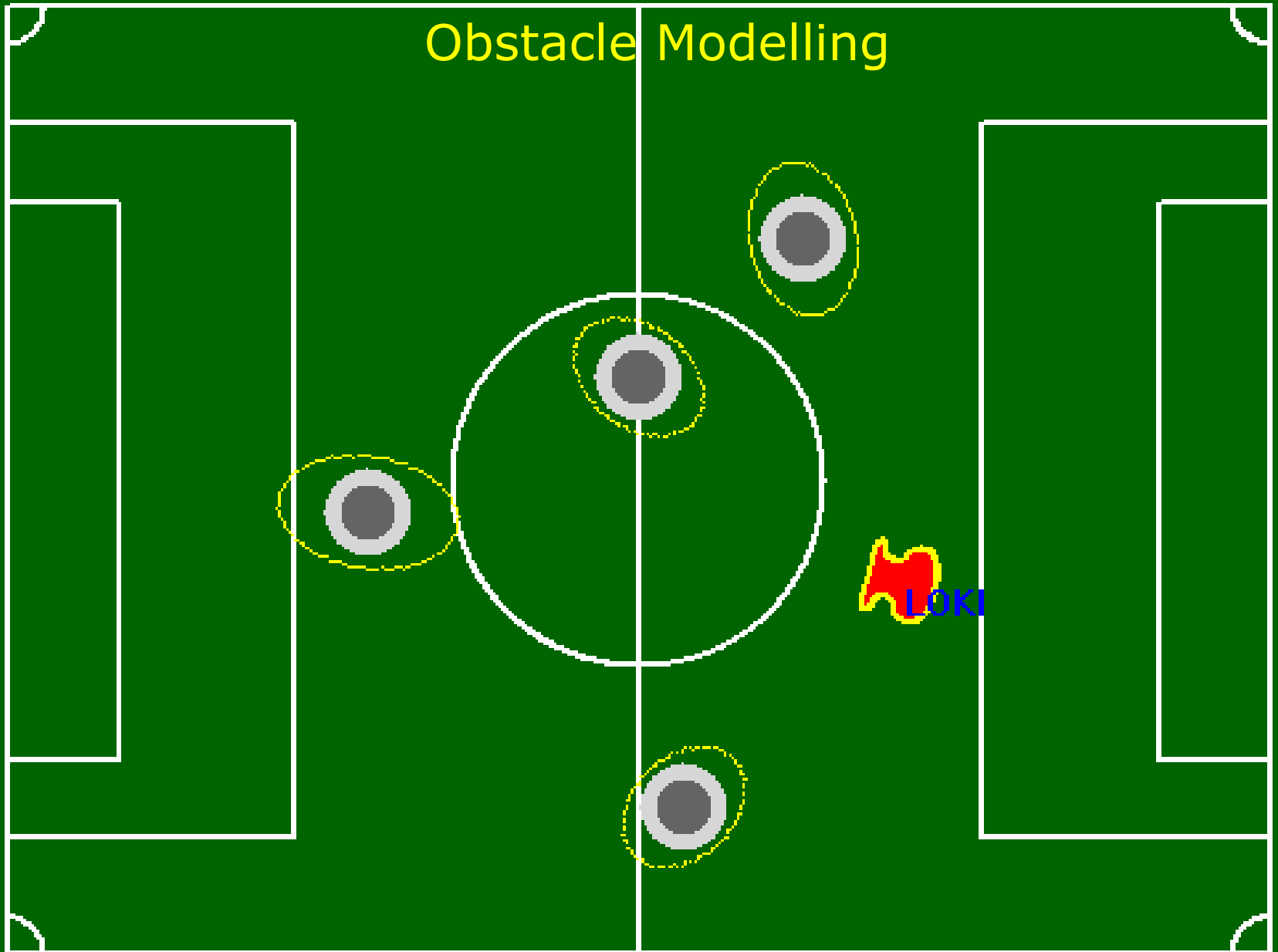
Precomputed resultant forces for each coordinate



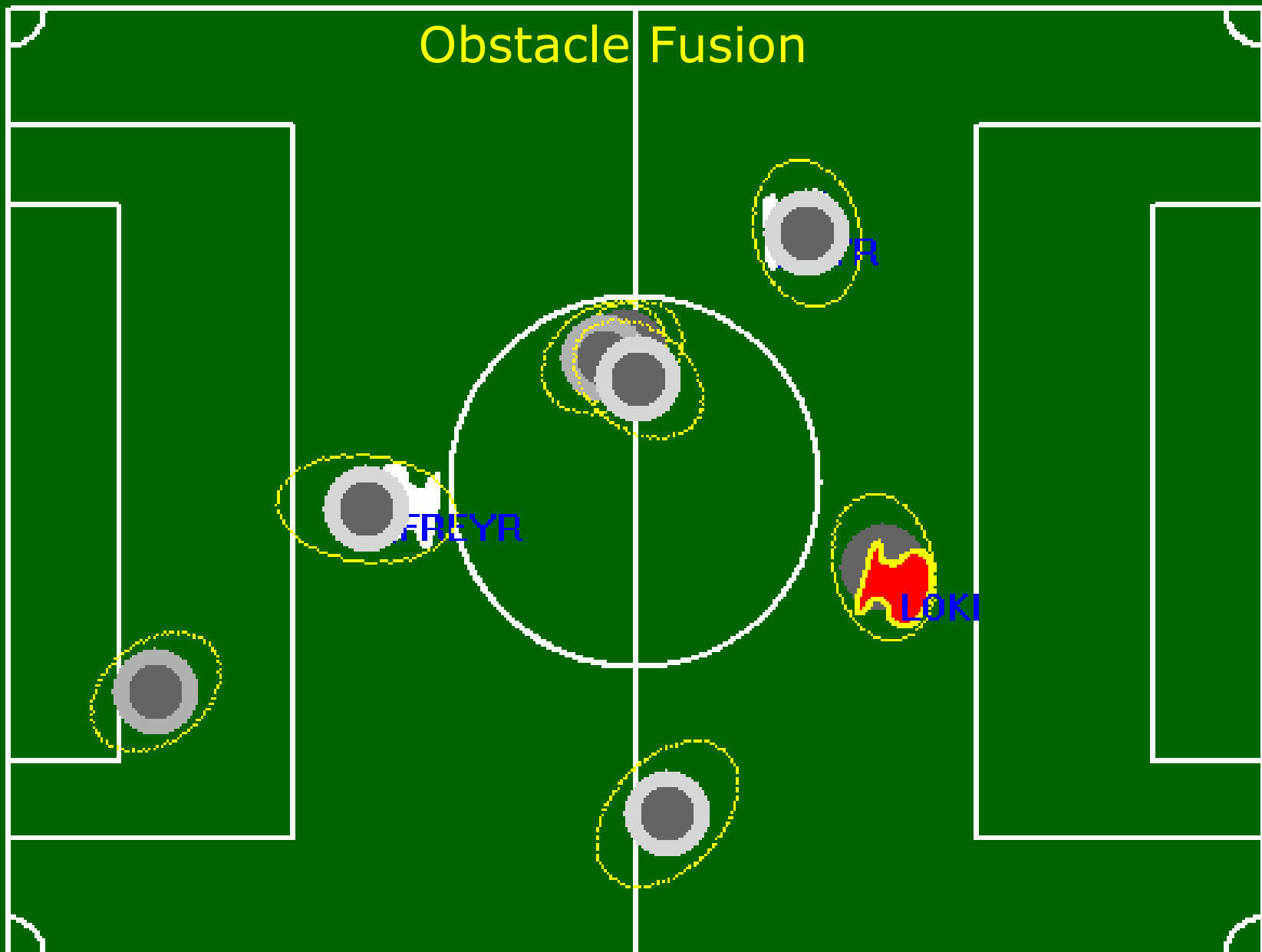
Obstacle Detection



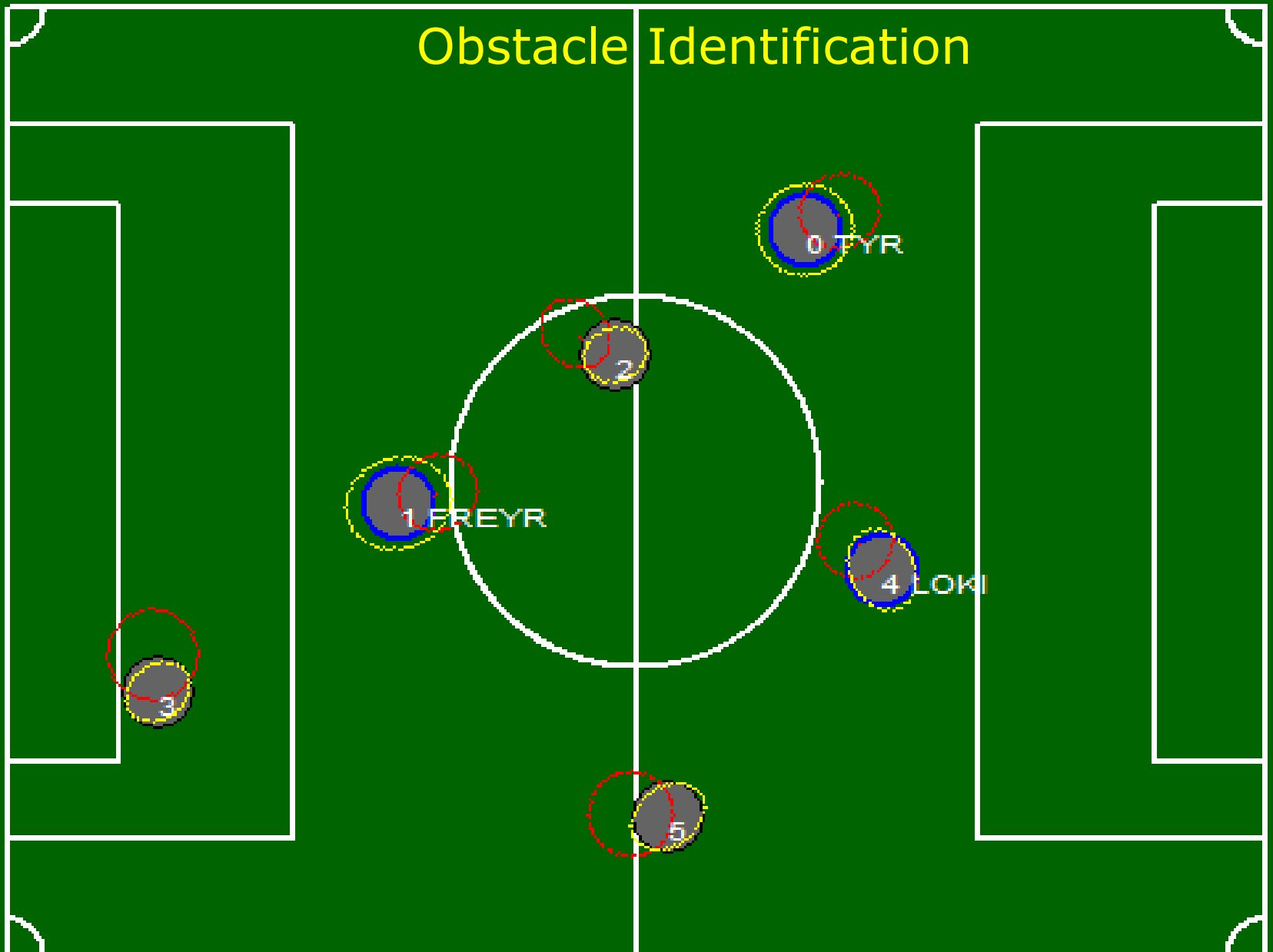
Obstacle Modelling



Obstacle Fusion

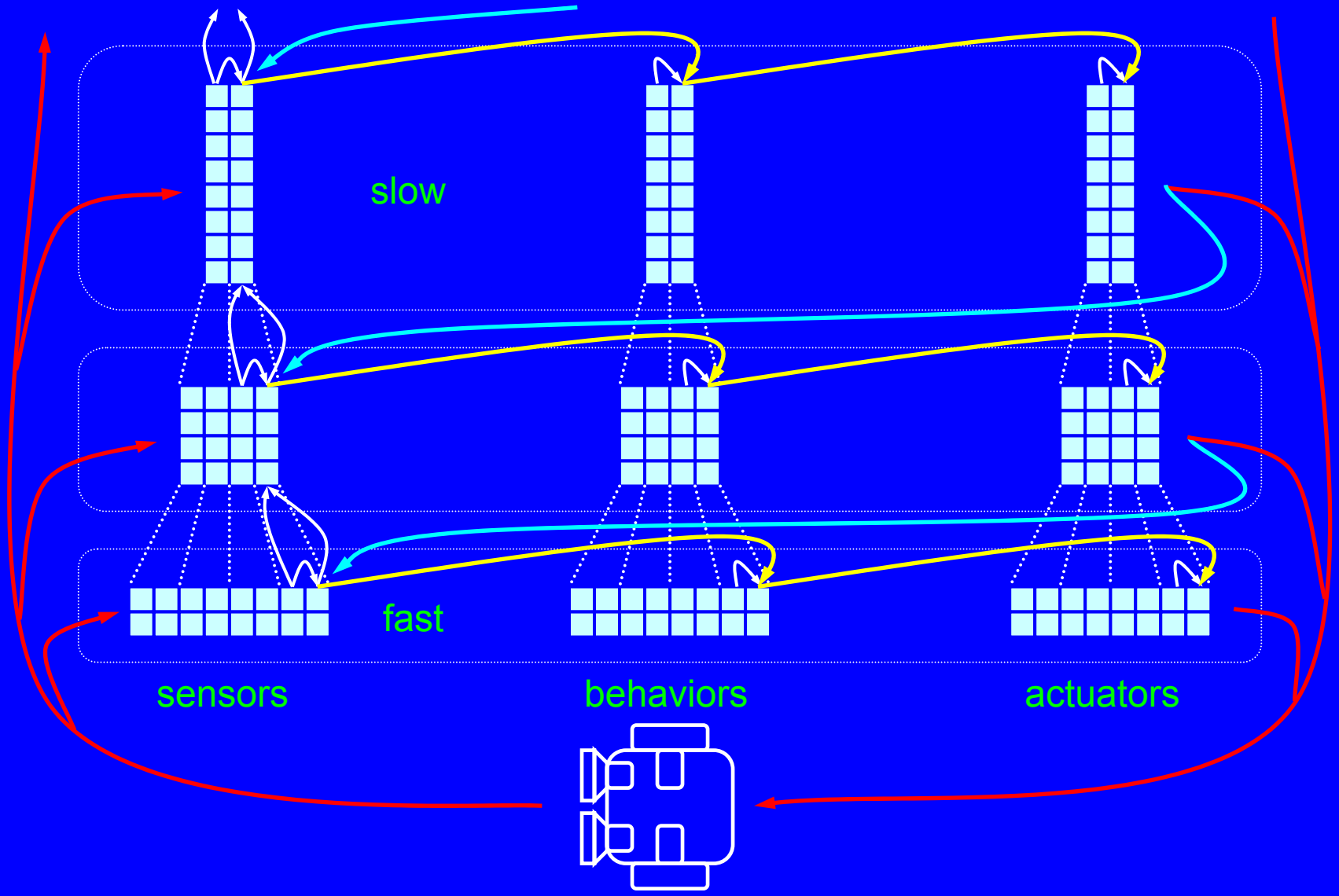


Obstacle Identification

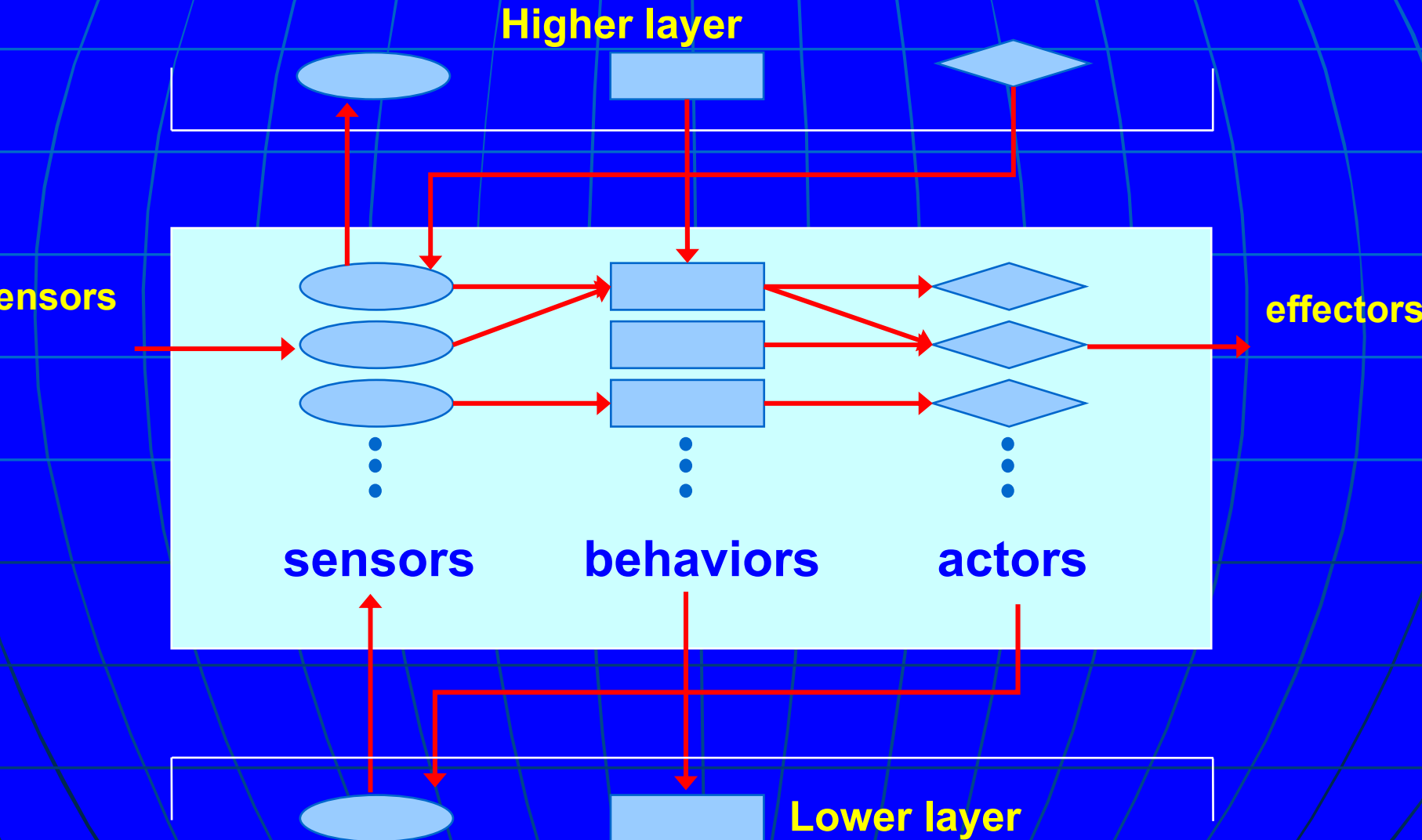


III Reactive Behavior

Reactive Behavior Control

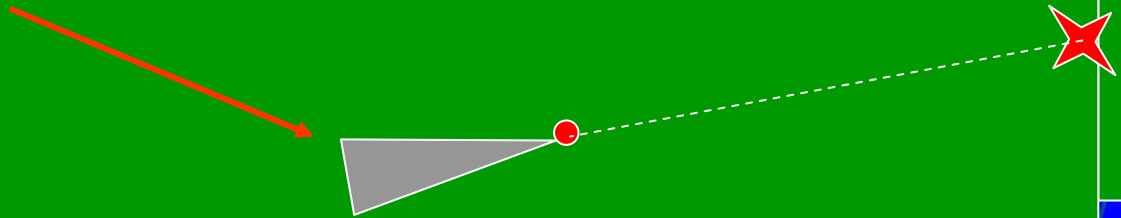


Structure of a layer

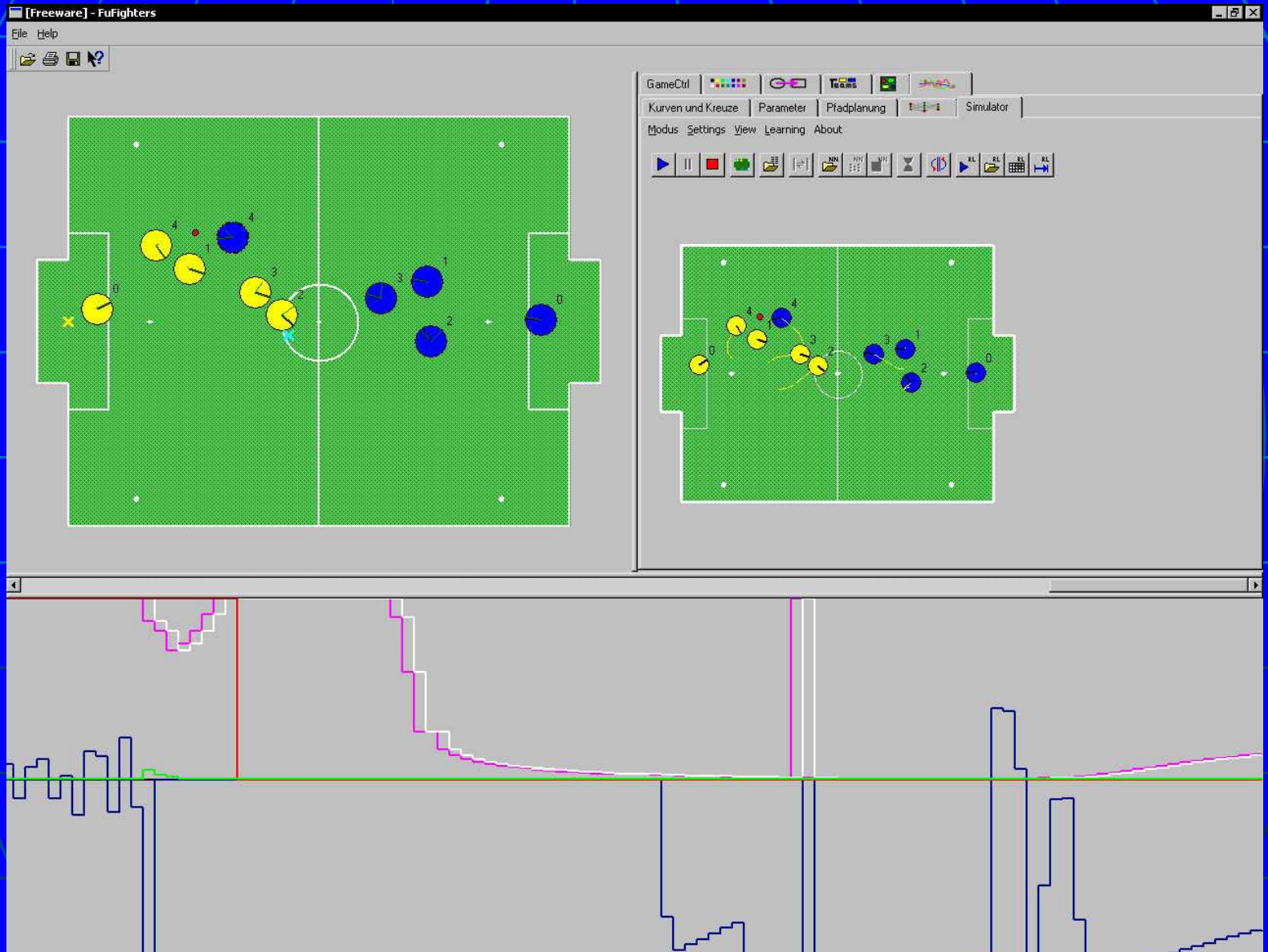


Kicking reflex

Kicking reflex activated

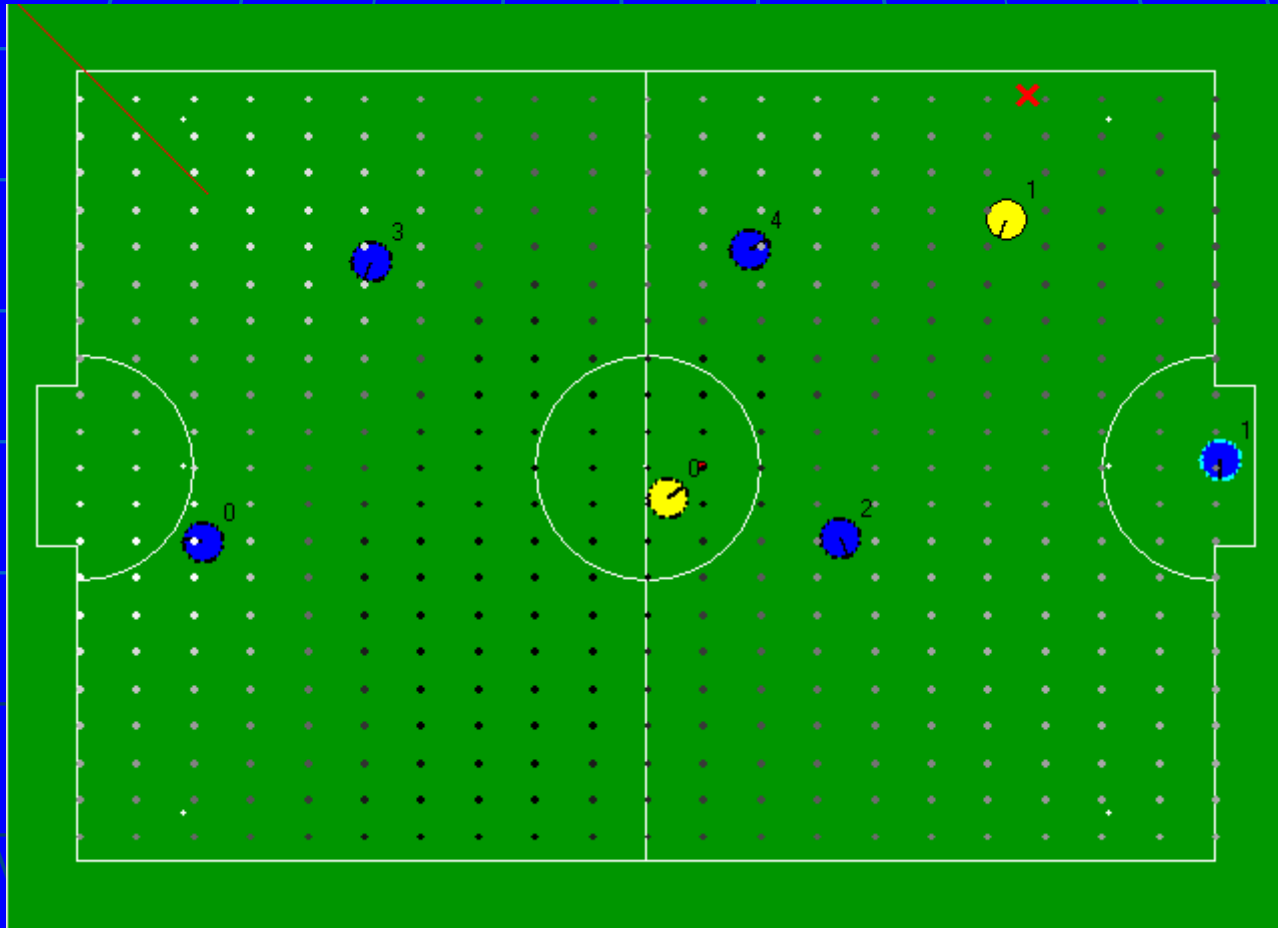


Screenshot of control software

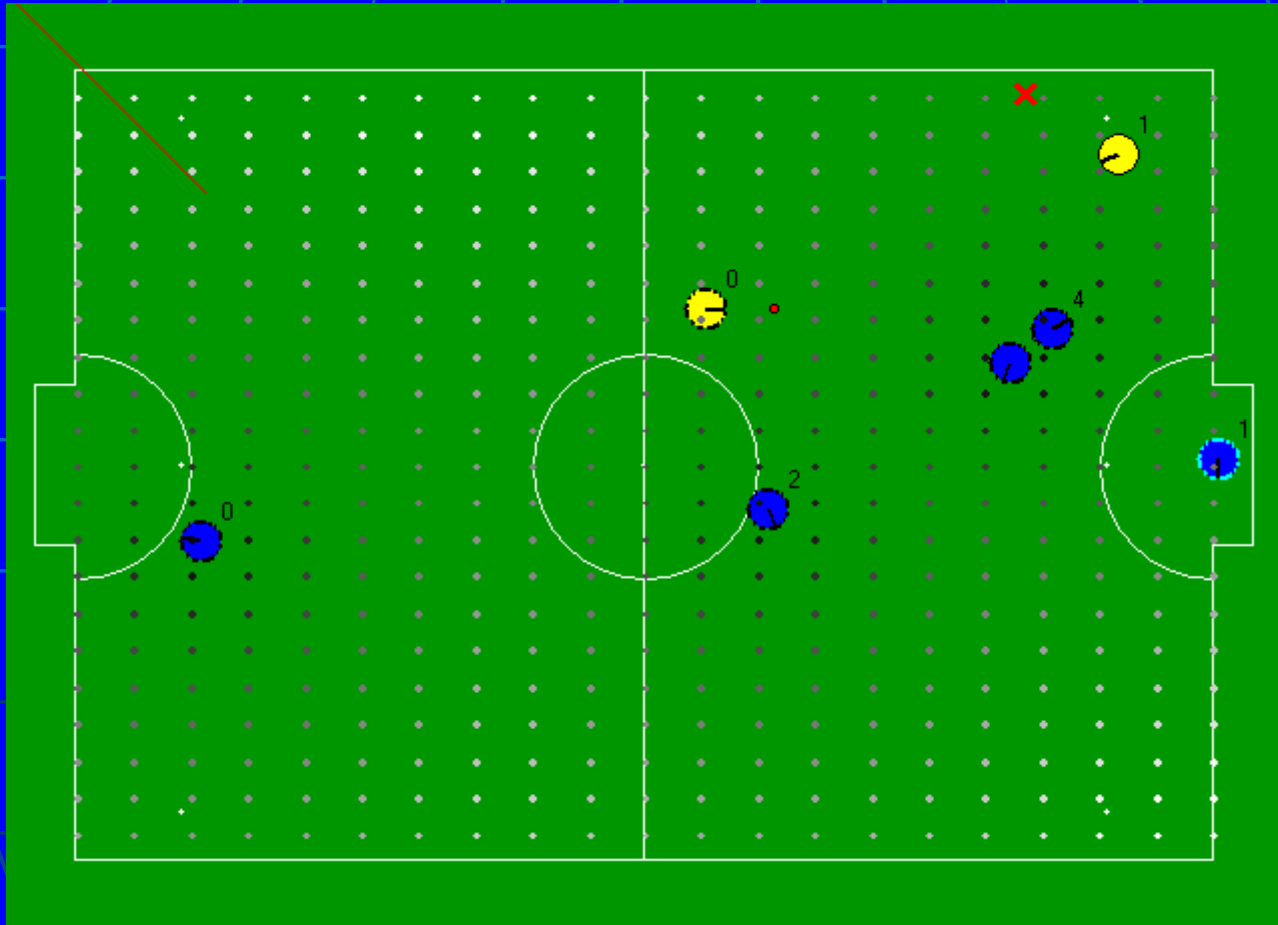


IV Learning and Coaching the robots

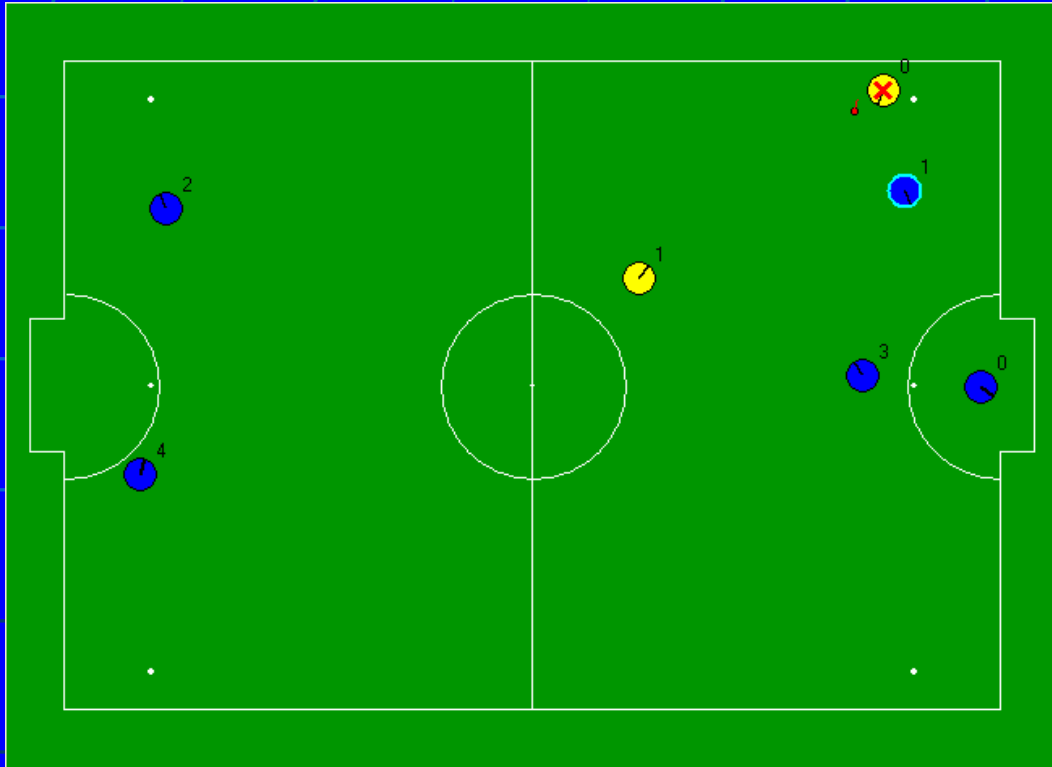
Anpassbarkeit



Raumfreiheit



Beispiel-Eingabe

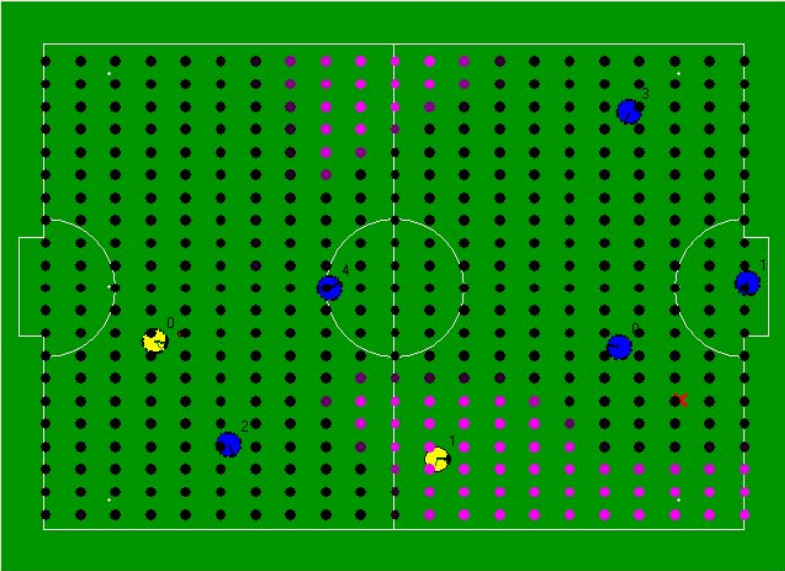


Learning to pass

[Educational] - FuFighters

File Help

▶ || ■ Frame rate: blablabla



GameCtrl RcVisionCtrl Verhalten RcAutolnitCtrl RcObserver RcCommunicationCtrl

Simulator ParameterCtrl UDPCtrl PathFinderCtrl StatistikCtrl PassDataBase UmBallFahrtDataBase

Kategorie	Desired Output	Actual Output
<input checked="" type="checkbox"/> General Example		
NewDataSet	1	0.999773
NewDataSet	1	0.980884
NewDataSet	1	0.978136
NewDataSet	1	0.980206
NewDataSet	1	0.952965
NewDataSet	1	0.971388
NewDataSet	1	0.987418
NewDataSet	1	1.00114
NewDataSet	1	0.978382
NewDataSet	1	0.968637
NewDataSet	-1	-1.01084
NewDataSet	-1	-1.03929
NewDataSet	-1	-0.941854
NewDataSet	-1	-1.0706
NewDataSet	-1	-1.00668
NewDataSet	-1	-1.03622
NewDataSet	-1	-1.10925
NewDataSet	-1	-1.03926
NewDataSet	-1	-0.995519
NewDataSet	-1	-1.05054
NewDataSet	-1	-1.0068
NewDataSet	-1	-1.03856
NewDataSet	-1	-1.03939
NewDataSet	-1	-1.11969
NewDataSet	-1	-1.11526
NewDataSet	-1	-1.01618
NewDataSet	-1	-1.03897
NewDataSet	-1	-1.03943
NewDataSet	-1	-1.00057
NewDataSet	-1	-1.03949
NewDataSet	-1	-1.08377

Check Examples

Train Net

Init Net

Set Training Set

Load Examples

Save Examples

Remove Example

Load Neural Net

Save Neural Net

Neue Kategorie

Training Cycles

Node-Number Hidden Layer

Success Ratio 0.967742

DribbelFreiheit

Input Visual

Visualisierung

Add NN Point

Add NN Point Symmetric

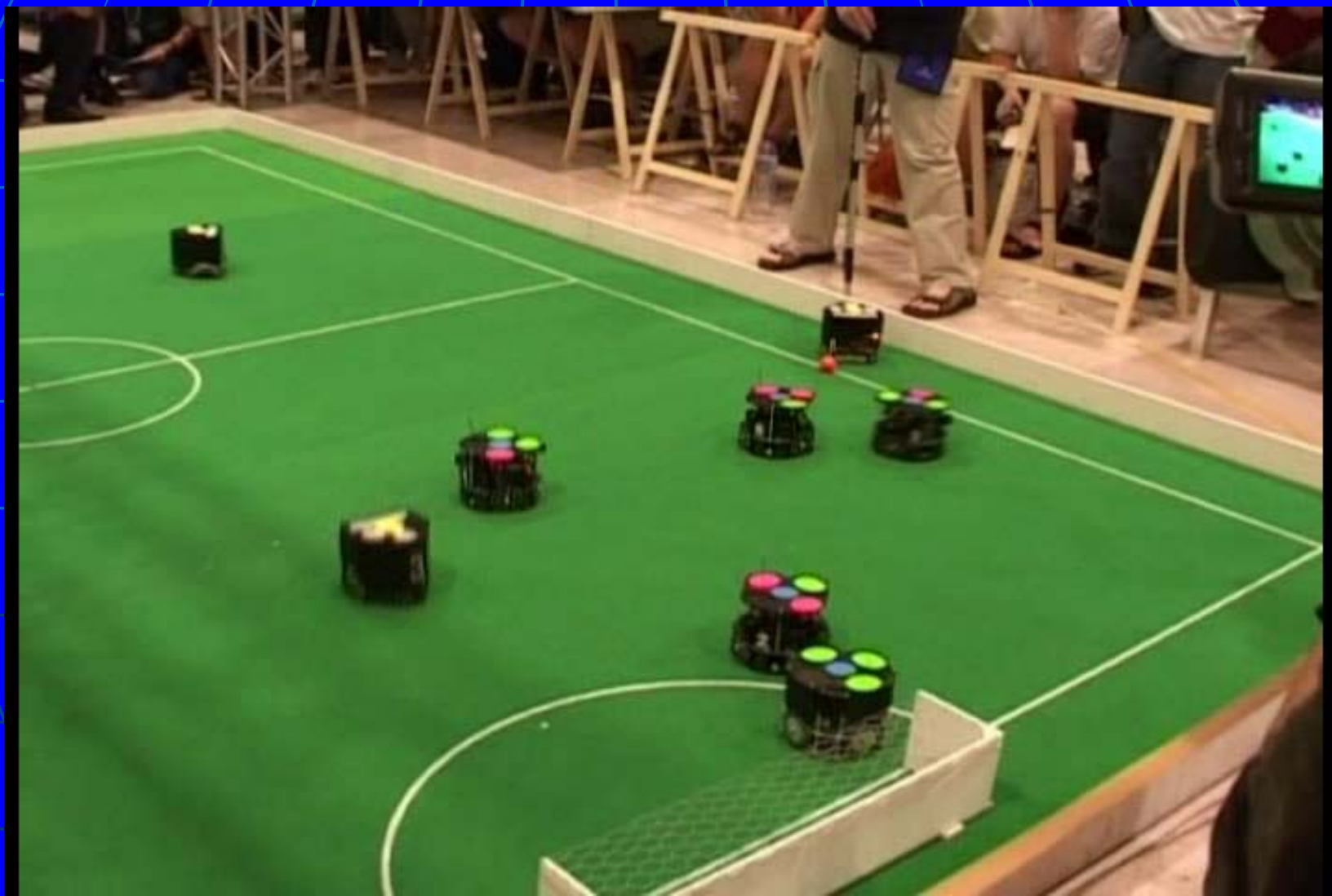
Passing game



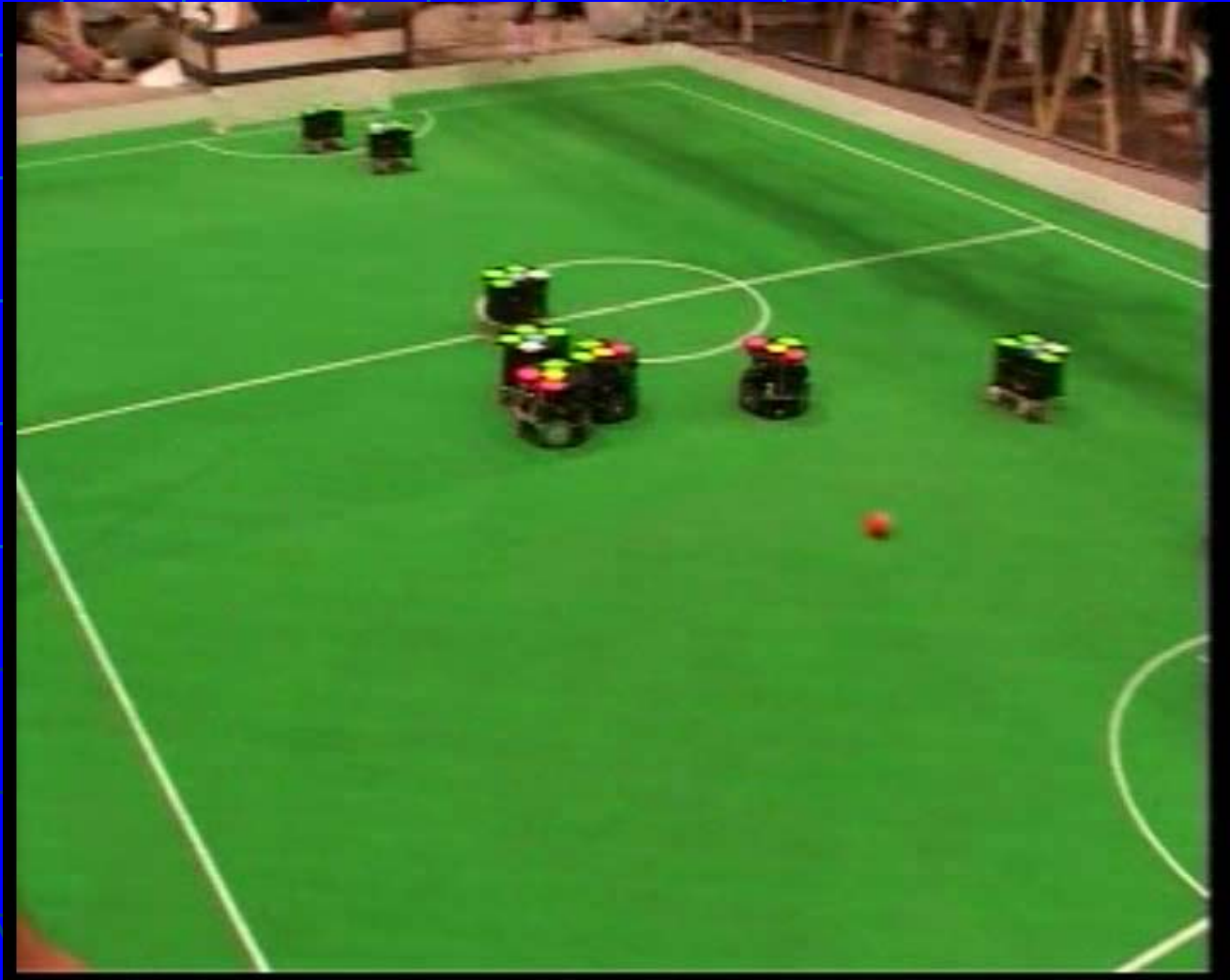
Team Play



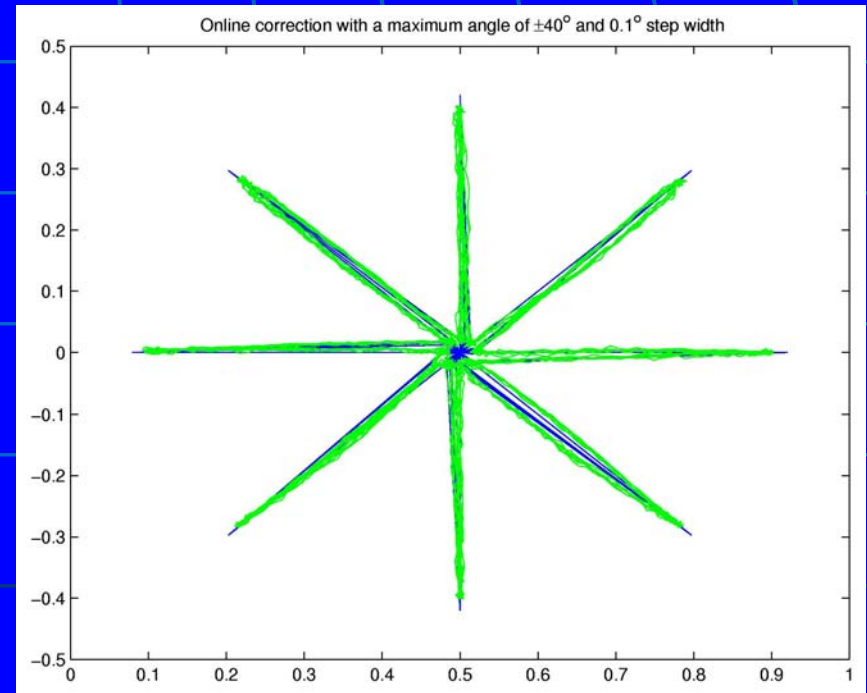
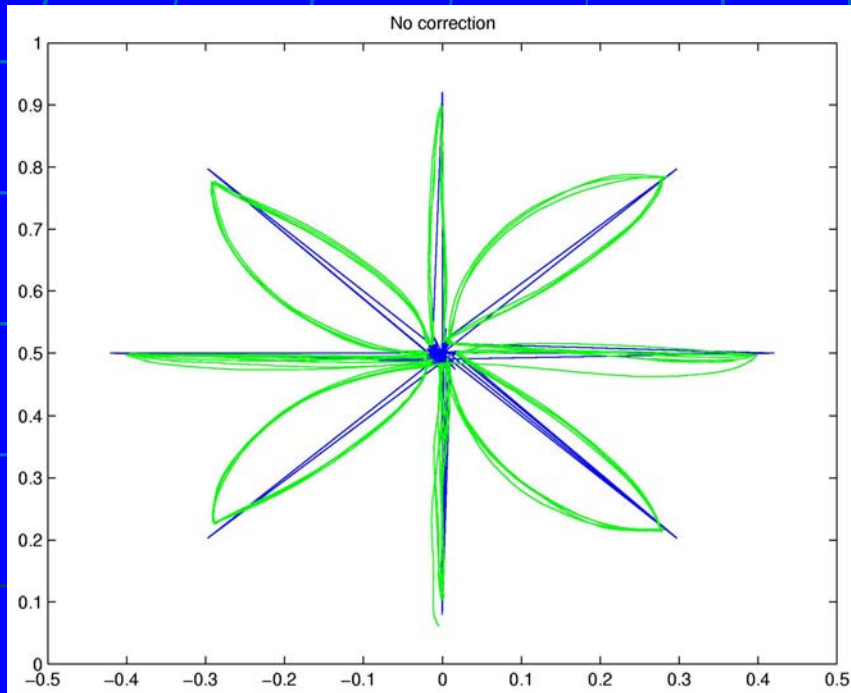
The Goalie



Goalie again



Learning: robot heal yourself



Learn what the robot does

positions

(x_1, y_1)

$(v_x, v_y, w)_1$

(x_2, y_2)

$(v_x, v_y, w)_2$

(x_3, y_3)

$(v_x, v_y, w)_3$

(x_4, y_4)

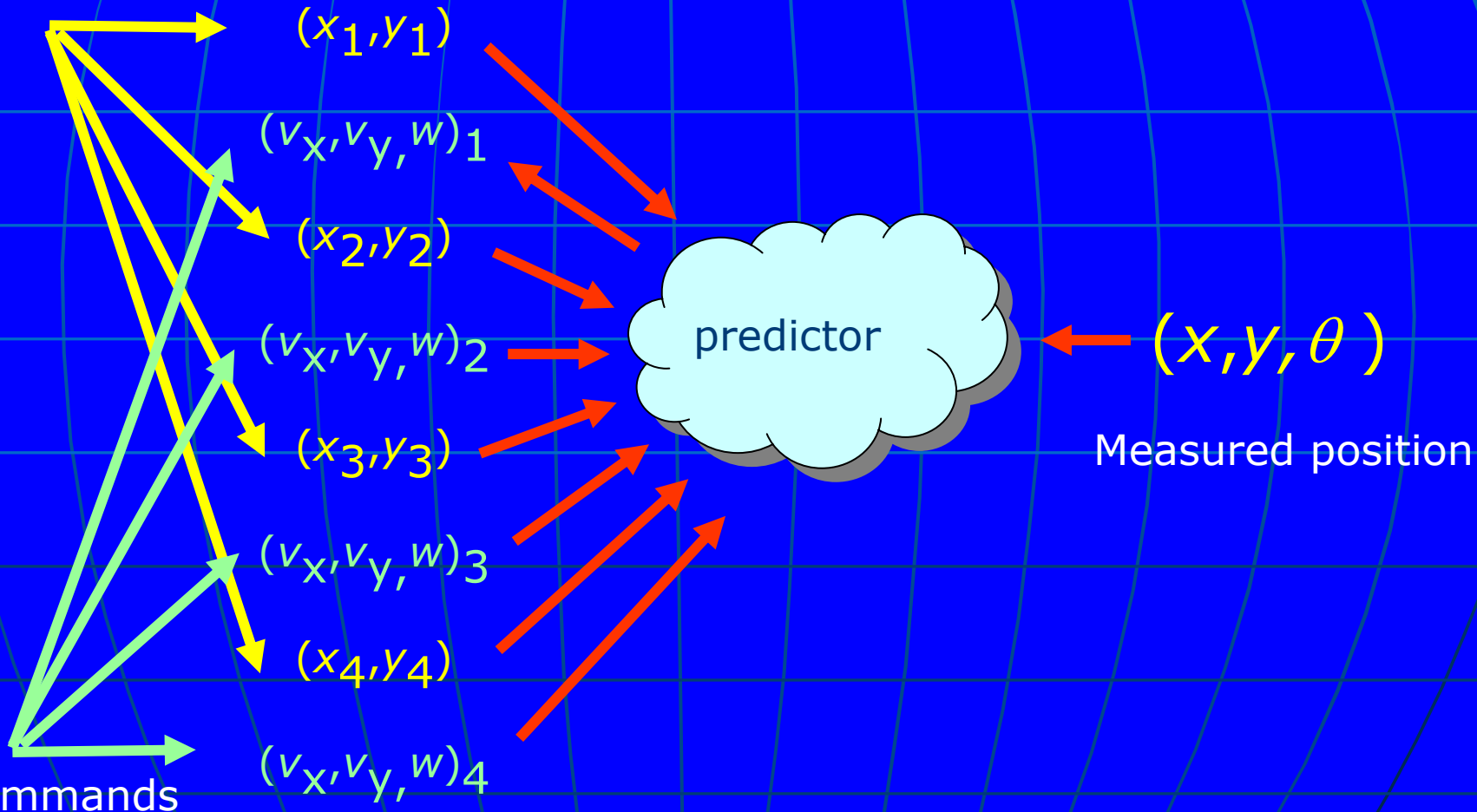
$(v_x, v_y, w)_4$

predictor

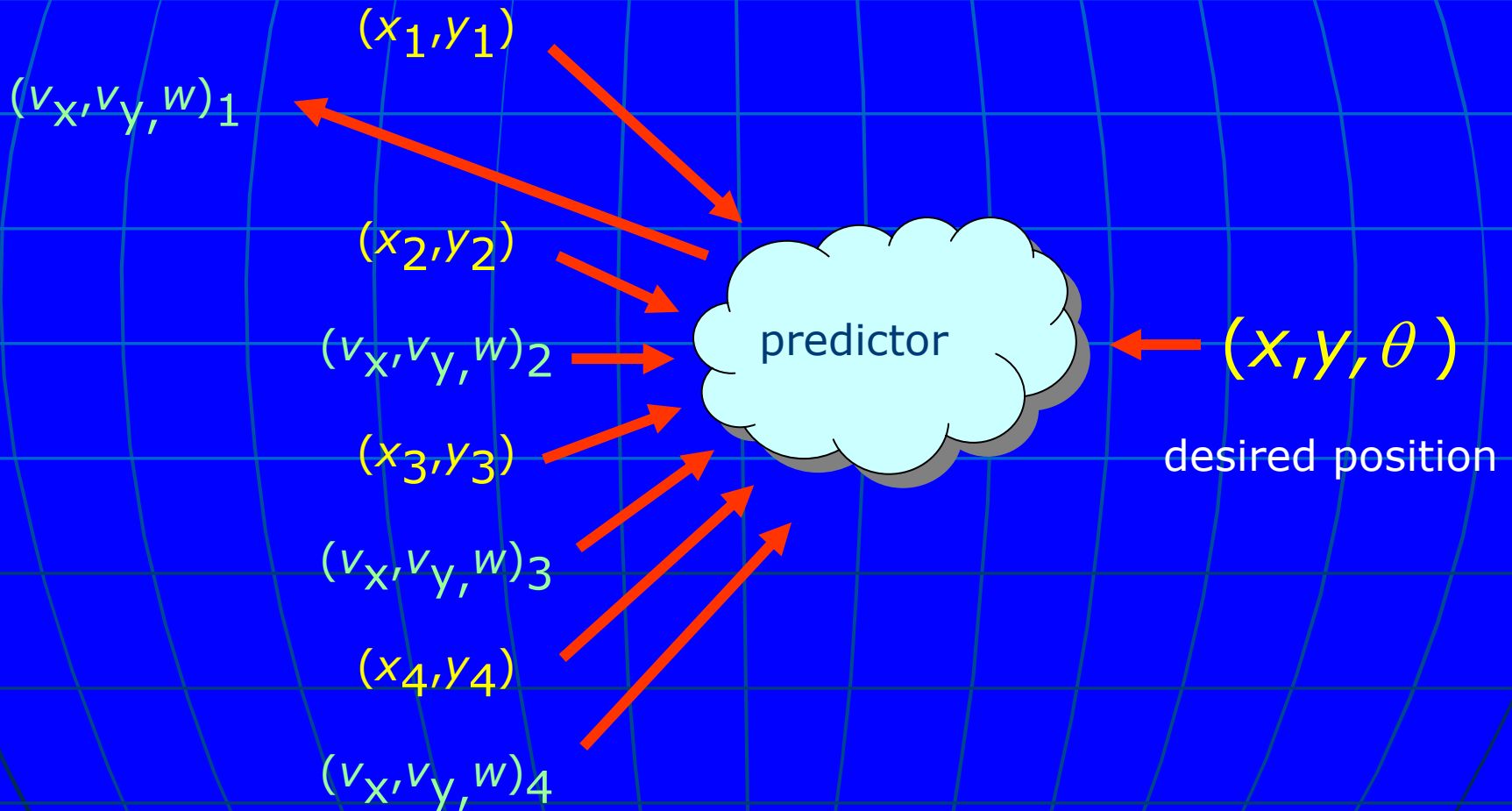
(x, y, θ)

Measured position

commands

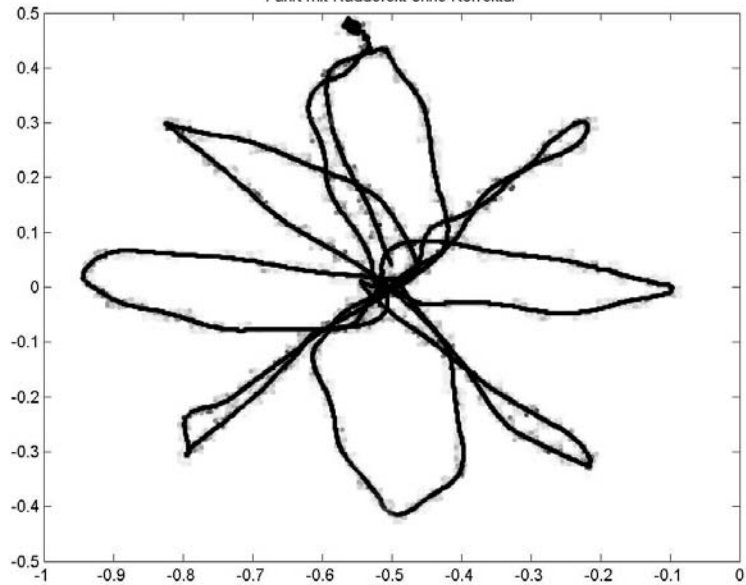


Invert the prediction

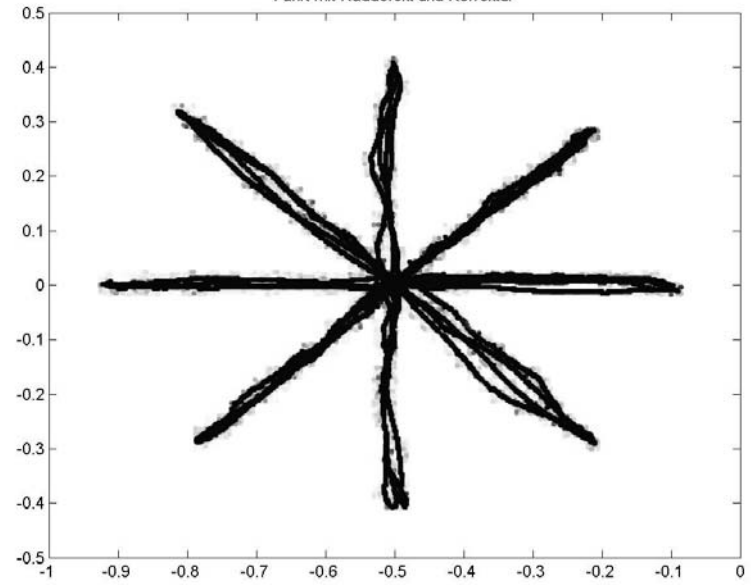


One burnt motor

Fahrt mit Raddefekt ohne Korrektur



Fahrt mit Raddefekt und Korrektur





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



