# Ronaldinho's Metal Friends

## 10 Years of Robotic Competitions, with a Look to the Future

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# Outline

- Background
- Robotic Competitions as Benchmarks
- Computer Vision Applications
  - Global Vision
  - Local Vision
- Conclusions

# Background

- 1996, Ph.D., University of Calgary, AI
- 1996 – 2002, Lecturer, University of Auckland, NZ. Robotics
- 2002 – now, University of Manitoba, Winnipeg, Canada. Robotics and Competitions

# Robotic Competitions

- 1992 Soccer by Alan Mackworth as challenge problem for AI
- Two international events started
  - 1996 Prof. Kim Jong-Hwan, KAIST Korea started FIRA
  - 1997 Prof. Kitano, Sony Japan started RoboCup
- Participated since '98
  - Chair FIRA HuroCup and RoboCup Humanoid

# Competitions as Benchmarks

- Real-world applications for intelligent robotics are still lacking
- Competitions serve as benchmarks
- Creating benchmarks is tricky
  - Dhrystones, MIPS, ...
- Must be entertaining, but
- must lead to meaningful research results

# Global Vision

- Use one vision system for the whole team (RC:Small-sized, FIRA:MiroSot)
- Track ball and opponent robots
- Track and identify robots of own team
- Real-time domain (60 fps = 16ms)
- Non-uniform lighting

# Global Vision: Camera Placement

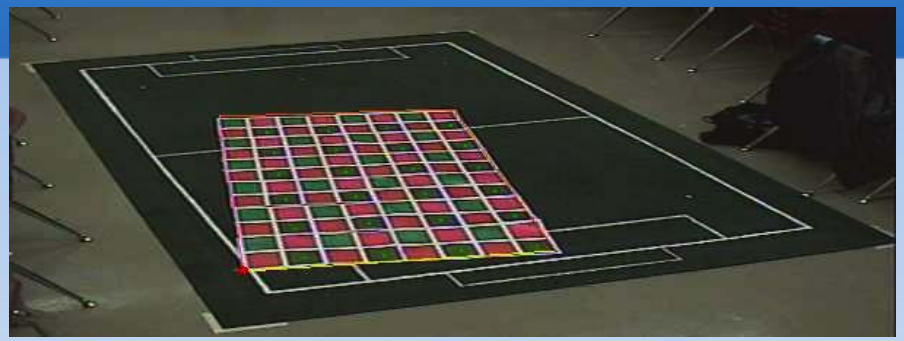
- Camera is mounted straight overhead
  - Simple homopgraphy
  - Occlusion
  - High quality motors, tires, kickers, ...
- Our approach
  - Must be cheap = remote controlled toy cars
  - Low accuracy actuators and sensors

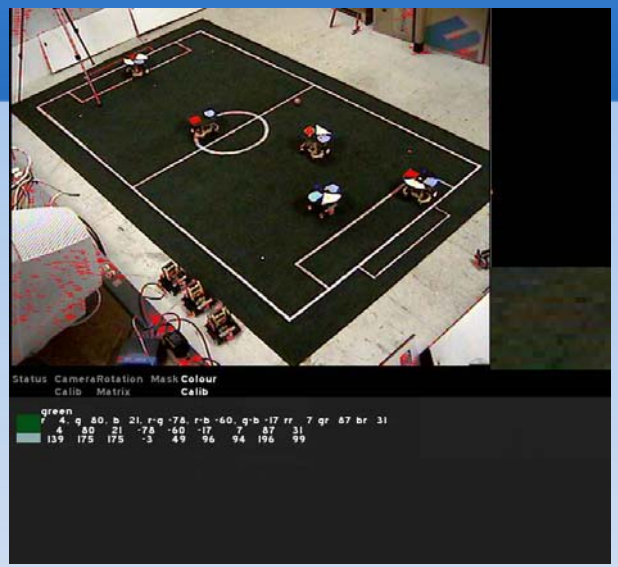
# Global Vision: Camera Placement

# Global Vision: Camera Placement

- Give some RC cars to children
- Tell them to play soccer
- How many will climb?
- Goal: play as well as humans

# Global Vision: Doraemon






- Tsai Camera Calibration, arbitrary angle
- Blob detection
  - efficient colour model mixing RGB and YUV
  - 24 bit colour
- Simple rules for occlusion

# Global Vision: Doraemon

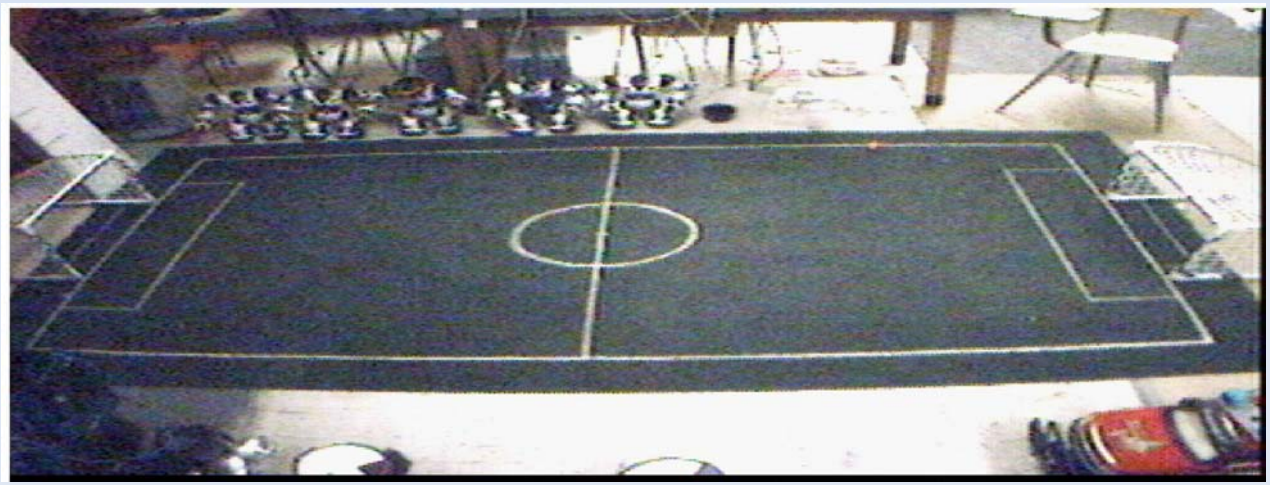
- Simple race track
  - Video 1: AuckIndy
- Extended to 3D Environments:
  - Video 2: Wages of Fear

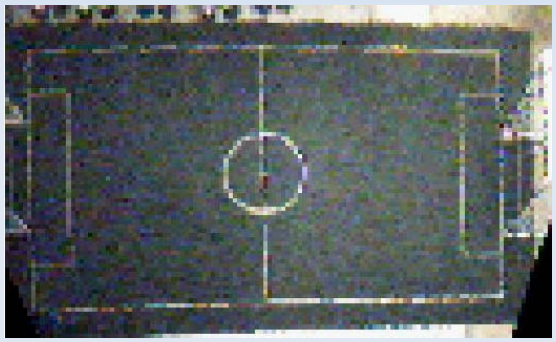
# Global Vision: Ergo

- Doraemon's colour calibration was time consuming
- Use motion and shape information
- Only use colour in the last instance
- More processing power available

# Global Vision: Ergo

- Shape information is dependent on view point
- Interpolate overhead view
  - Computational efficiency
  - 640x240 -> 125x76





# Global Vision: Ergo

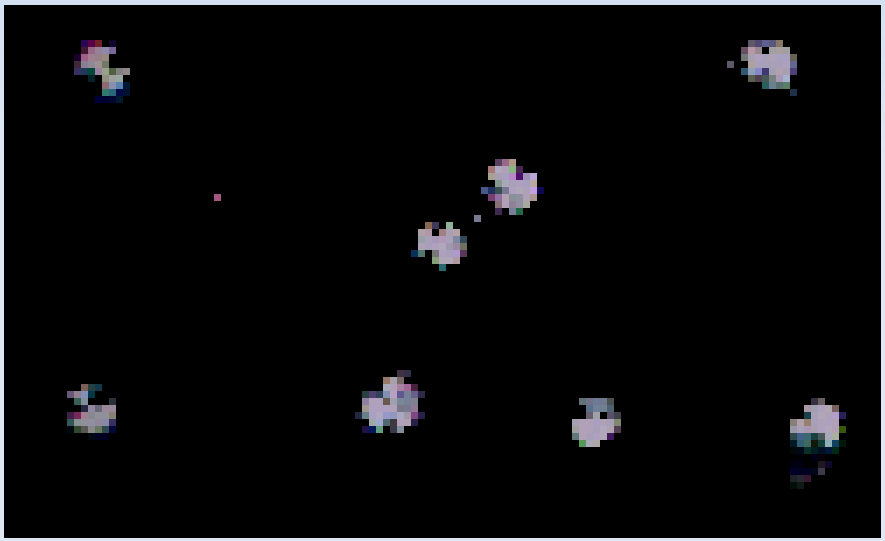
- Noisy camera make background removal more difficult
- But ball is only 1 – 9 pixels
- Estimate variance using counter algorithm
- Predict position of objects and prioritize in search

# Global Vision: Ergo

- Background removal

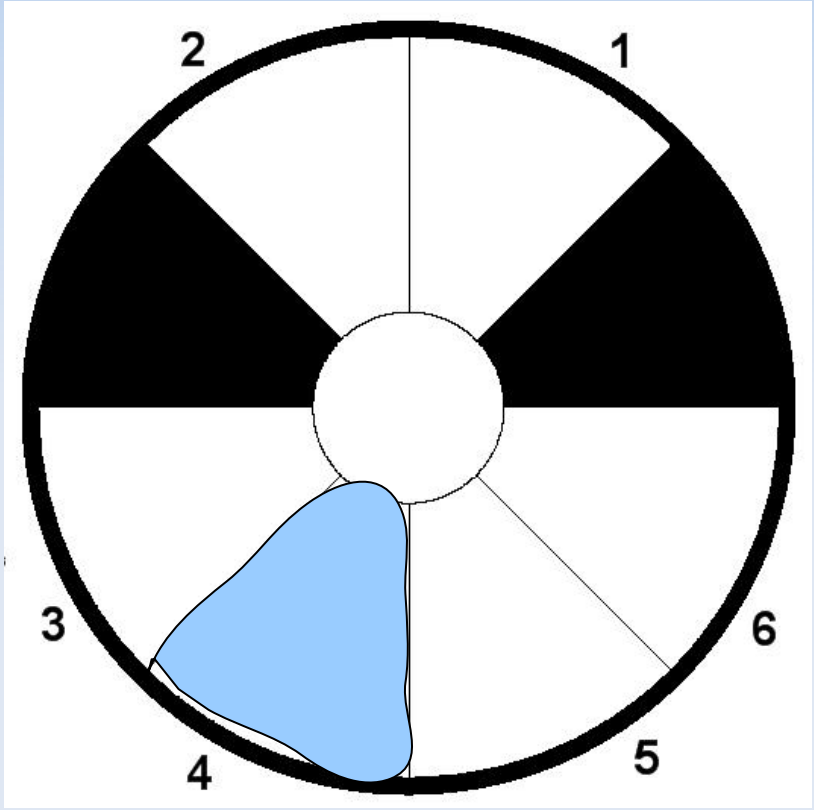
Reconstructed Frame

Motion Image



# Global Vision: Ergo

- Robot identification
- Novel pattern design allows 62 robots
- No colours
  - white, black, other

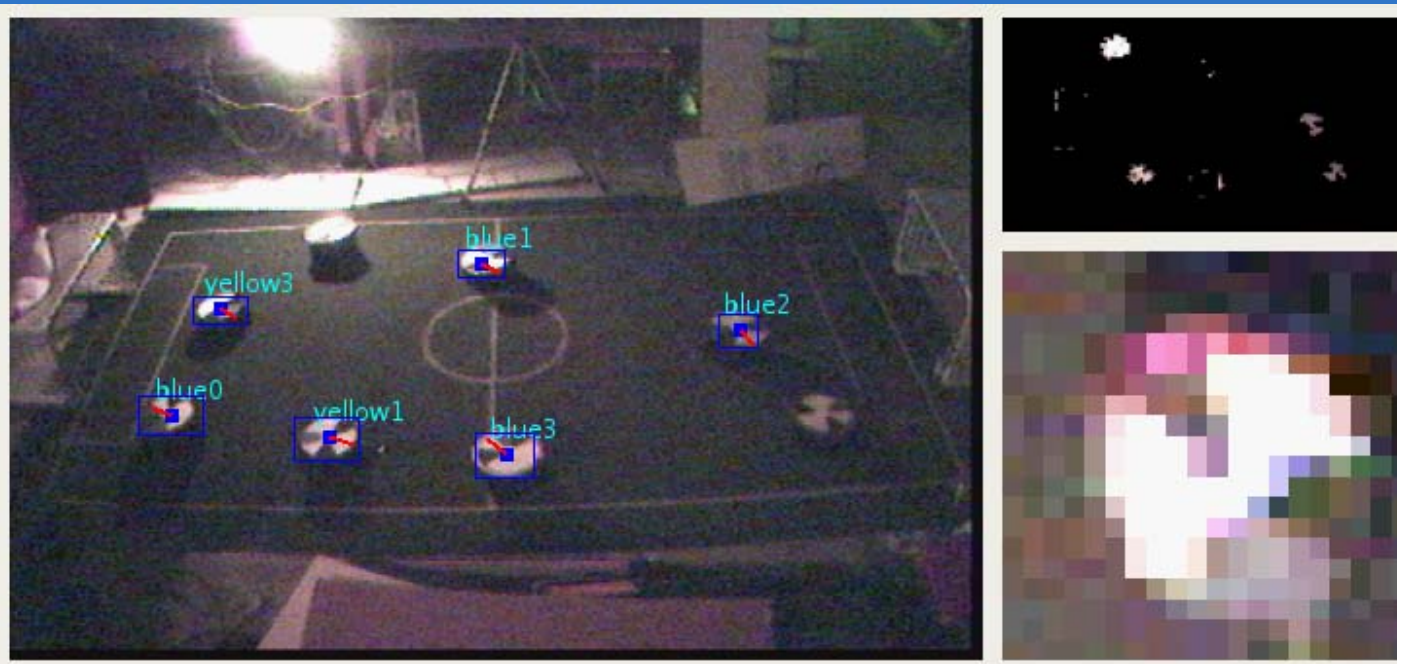


# Global Vision: Ergo

- Robot Identification
  - Approximate centre of pattern
  - Interpolate a high-resolution strip around the center
  - Median filter
  - Calculate local thresholds for Sobel Edge-detection to find white-to-black and black-to-white transitions
  - Two black wedges = robot's orientation
  - Histogram of strip to seperate white and other = robot's code

# Global Vision: Ergo

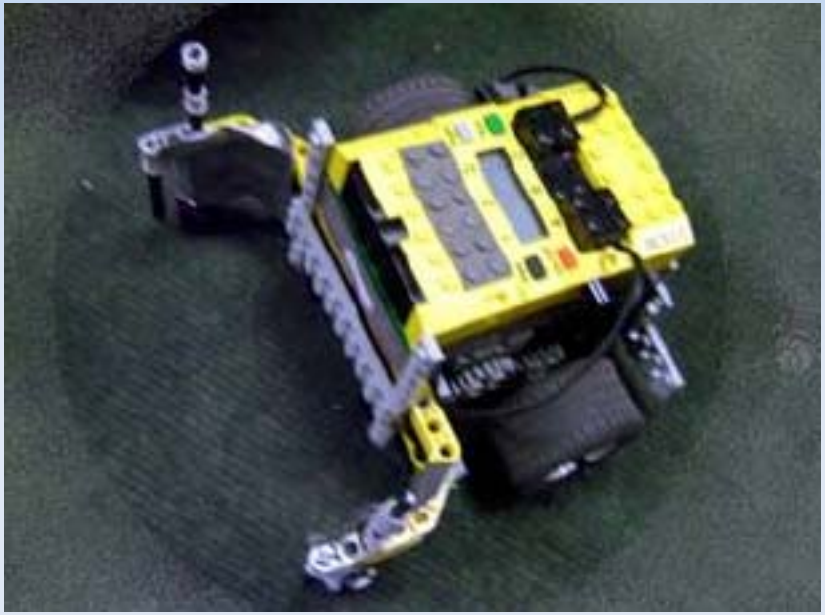
- 10 parameters
- Works with hostile lighting
- > 25 FPS for 8 robots




| | Name | Type | x | y | dx | dy | theta | Found |
|---|---|---|---|---|---|---|---|---|
| 1 | blue0 | Robot::6 | 310.73 | 394.00 | -0.04 | -0.03 | 2.72 | 100% |
| 2 | blue1 | Robot::4 | 1280.95 | 1172.71 | 0.01 | 0.00 | -0.76 | 100% |
| 3 | blue2 | Robot::3 | 2149.56 | 729.63 | -0.00 | -0.00 | -1.26 | 95% |
| 4 | blue3 | Robot::1 | 1373.85 | 210.70 | -0.00 | -0.00 | 2.25 | 100% |
| 5 | yellow0 | Robot::8 | 2330.39 | 320.82 | 0.02 | 0.02 | -2.32 | |
| 6 | yellow1 | Robot::1 | 843.32 | 293.47 | -0.00 | 0.00 | -0.33 | 94% |
| 7 | yellow2 | Robot::1 | 2320.83 | 309.00 | 0.01 | -0.00 | -2.29 | |
| 8 | yellow3 | Robot::3 | 342.03 | 933.63 | 0.00 | 0.00 | -0.69 | 100% |

# Global Vision: Ergo

- Video
  - E-League Final



# Global Vision: Mixed Reality

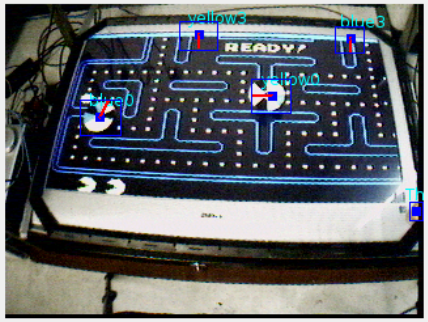
- Reduced size of robots using IR controlled toy tanks (4cm)
- Citizen robots (1cm)
- Added 40 inch TV set
- Mixed reality
  - TV produces environment
- Sensing, actions are real

# Global Vision: Mixed Reality

- Mixed reality
  - Obstacle run
  - Pac-Man

# Global Vision: Mixed Reality

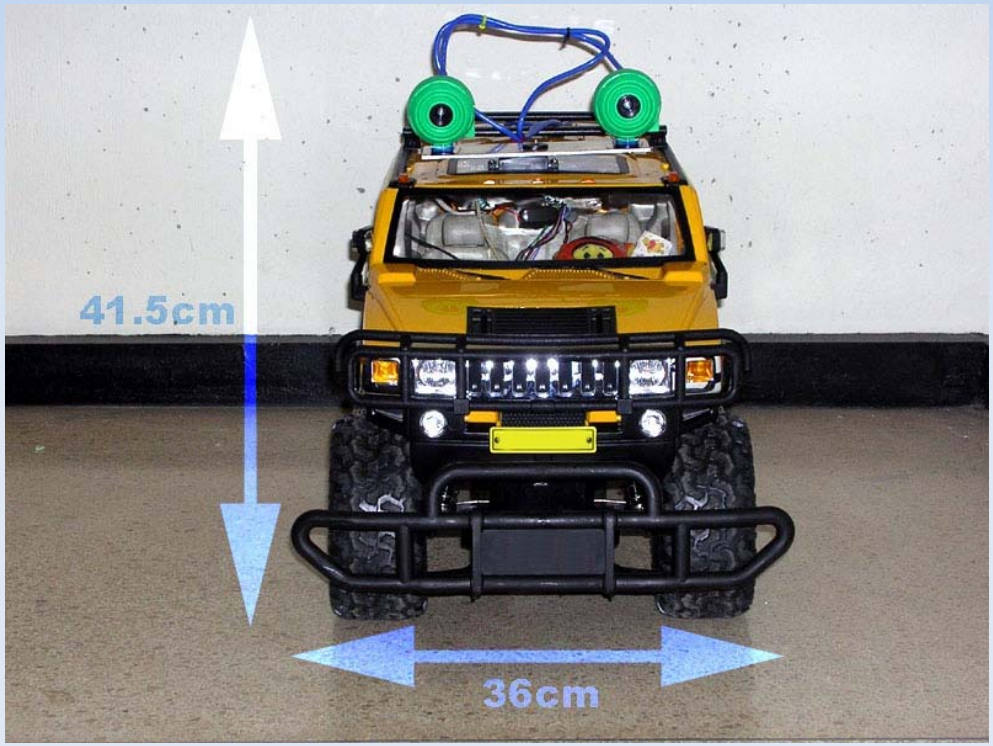

Tracking | Motion | Geometry | Calibration | V4L2 Control | Debug | Colours




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | TheBall | Ball::-1 | 916.26 | -22.36 | 0.09 | 0.00 | 0.00 | 99% |
| 2 | blue0 | Robot::6 | 109.46 | 192.51 | 0.13 | 0.00 | 1.44 | 94% |
| 3 | blue1 | Robot::4 | 571.23 | 262.52 | 0.00 | -0.00 | -1.70 | 0% |
| 4 | blue2 | Robot::32 | 202.32 | 464.71 | 0.00 | 0.00 | -1.64 | 0% |
| 5 | blue3 | Robot::1 | 786.92 | 464.26 | -0.09 | -0.09 | -1.58 | 10% |
| 6 | yellow0 | Robot::8 | 559.40 | 268.60 | 0.08 | -0.00 | -3.12 | 46% |
| 7 | yellow1 | Robot::16 | | | | | | 0% |
| 8 | yellow2 | Robot::12 | 490.89 | -1.87 | 0.01 | -0.03 | 2.97 | 0% |
| 9 | yellow3 | Robot::3 | 787.70 | 466.56 | -0.01 | -0.00 | -1.69 | 25% |

# Local Vision

- Started moving into local vision systems
- Robot gallery: Wheeled



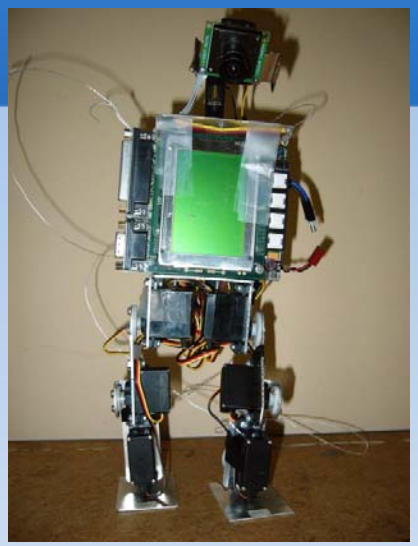
# Local Vision Processing

- Convert image into scanlines with avg. colour of the line
- Break scan if difference between pixels is greater than threshold
- Flood fill region with avg. colour as seed
- Check bounding box, aspect ratio, compactness of region
- Check avg. colour of region
- Update threshold based on inter scan diff.

# Humanoid Robots

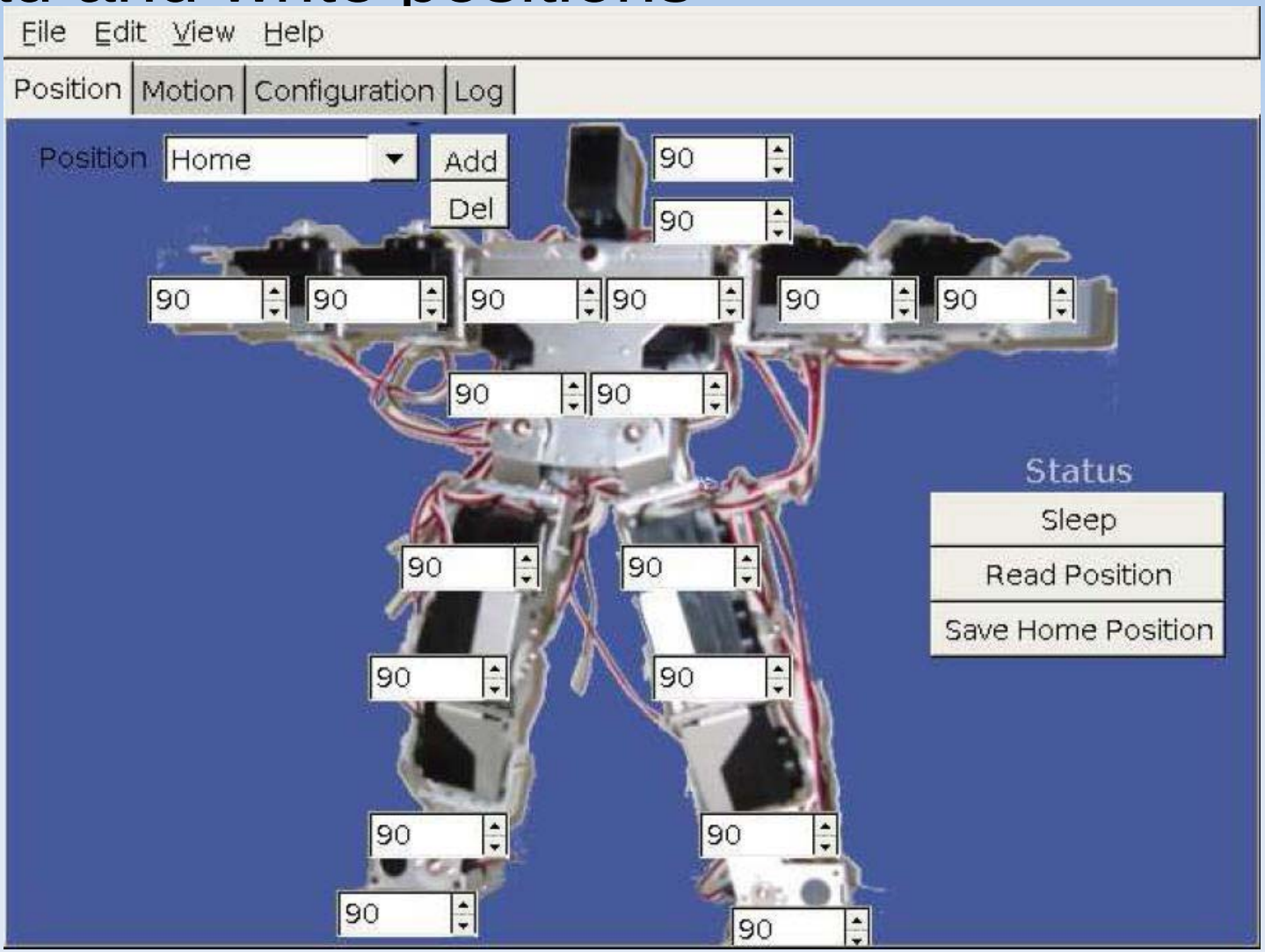
- Local vision processing

  mostly independent of robot platform
- In 2002, started research on humanoid robots
- Developed several humanoid robots
  - Tao-Pie-Pie
  - Dao-Dan



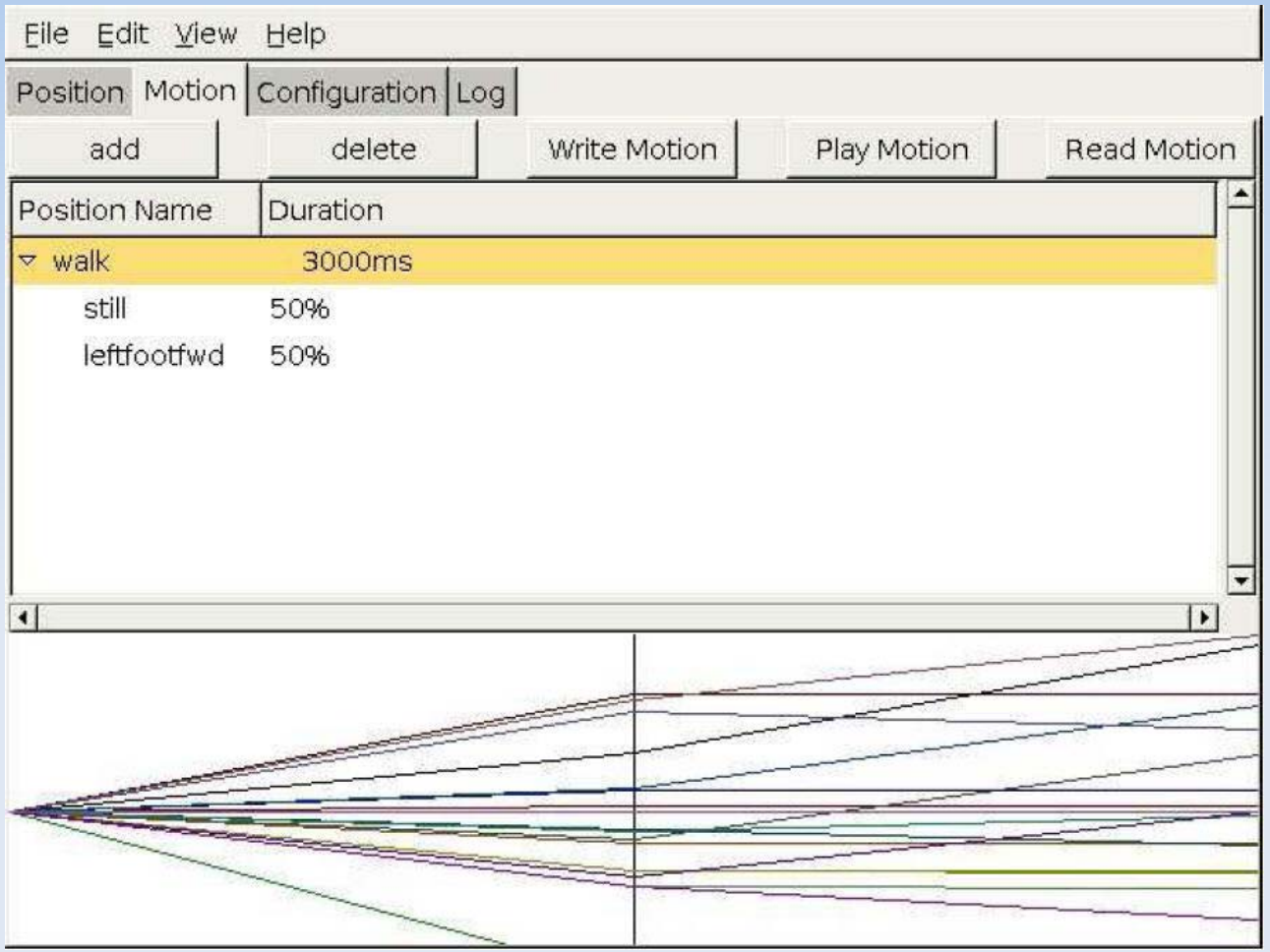
# Motion Development

- Read and write positions



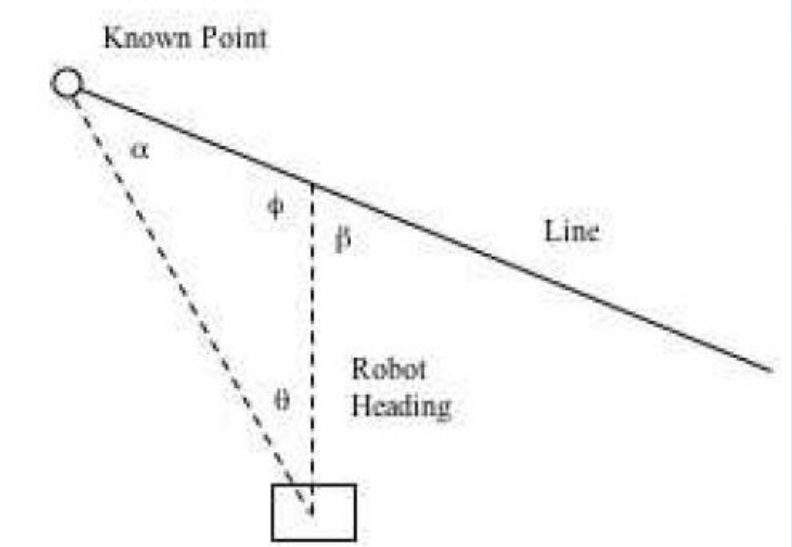
# Motion Development

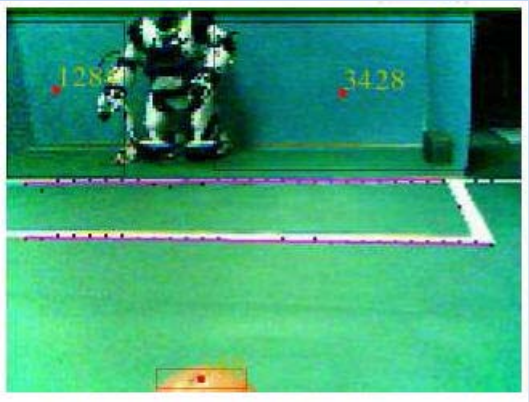
- Positions are combined into motions

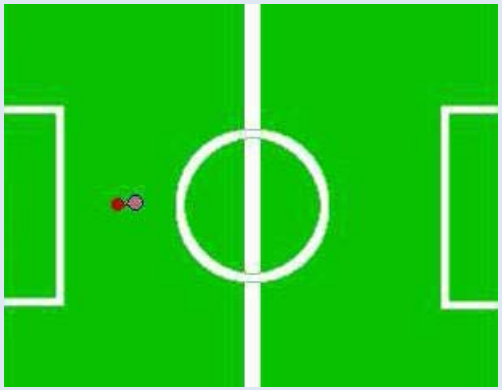


# Localization

- Based on line segments
- Particle filters to fuse different observations
- Optical flow to augment motion model





# Behaviour Trees

- High level behaviour is described as a tree of behaviours
- A behaviour is a finite state machine which includes primitive actions or other behaviours
- Development is error prone

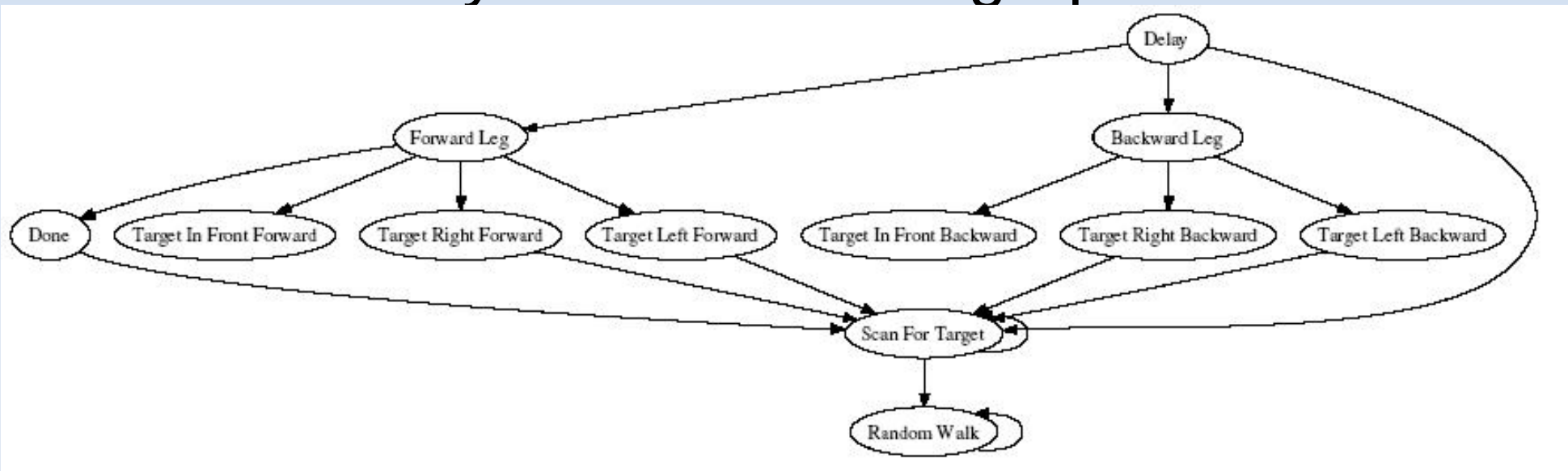
# Behaviour Specification

```
<State id="Scan For Target" >
<Enter>
%%v(angle) = 0;
if ( previousState == %%State("Target Right Forward") )
    {
      %%v(newAngle) = 20; /* Turn 20 degrees first */
      %%v(angleAdjust) = +10;
    }
 else
    {
      %%v(newAngle) = - 20; /* Turn 20 degrees first */
      %%v(angleAdjust) = -10;
    }
</Enter>
<Process>
  if ( ( %%v(newAngle) >= -190 ) &&
       ( %%v(newAngle) <= 190 ) )
    {
      if  (%%v(angle) != %%v(newAngle) )
        {
           turn( (%%v(angleAdjust) * TEN_DEGREE) / 10 );
           %%v(angle) = %%v(angle) + %%v(angleAdjust);
        }
      else
        {
           %%v(newAngle) = - %%v(newAngle) - 40;
           %%v(angleAdjust) = - %%v(angleAdjust);
        }
    }
  else
    {
      %%Transition("Random Walk");
    }
</Process>
</State>
```

- XML based
- Entry/exit statements
- Example: sweeping for a target
- Markup for state, variables, transitions

# Behaviour Specification

- XML specification is converted into C
  - Used on embedded systems, phones, ...
- Check semantics of behaviour tree
- Automatically converted into graph



# FIRA HuroCup Competition

- Humanoid robotic competition at http://www.fira.net
- Humanoid robotics as a benchmark problem
  - Single robot – multiple tasks
  - Humanoid robotic issues
    - balancing
    - complex motion planning
    - human robot interaction

# The Difference

- Academy awards
- www.oscar.com


- Sundance Film Fest.
- www.sundance.org

# HuroCup 2008

- Robot dash
- Marathon
- Obstacle run
- Lift and carry
- Weight lifting
- Basketball
- Penalty kick
- Climbing wall (new)

# EUROBY 2008

- HuroCup competition
  - June 15 – 18, Zurich, Switzerland
  - June 19 – 23, Linz, Austria
  - co-located with 5th Computational Intelligence, Robotics, and Autonomous Systems (CIRAS), Paper submission: Aprill 21st 2008
- Travel support
- Contact: jacky@cs.umanitoba.ca

# RoboCup 2007 Final

- Video
- Team Nimbro (University of Freiburg, Germany) vs Team Osaka (VisiOn, Osaka, Japan)

# Conclusions

- Robotic competitions provide a rich and rewarding environment for computer vision research
- Colour is highly overrated
- Next Frontier: Textures
- Human performance

# Human Performance

- Video: human performance
- Video: collision