**Overview**

- Hardware
- Software
  - Framework
  - Image Processing
  - World Modeling / Self-Localization
  - Behavior and Skill Architecture
  - Reinforcement Learning
  - Teamplay
- Current Projects
  - OpenTribot
- Future Work

**Brainstormers / Tribots**

- 2003 – 2009 Project Group at Uni Dortmund, then Osnabrück
- 2 times Robocup Mid-Size World Champions (2006 & 2007)
- 4 times RoboCup Mid-Size German Open Champions

**Brainstormers-Tribots / openTribot**

**Hardware of a Tribot Soccer Robot**

- Custom 3-wheel Omnidirectional Base and Omnidirectional Firewire Camera
- Small Notebook running Linux
- Can-Bus Interface for Robot Motor Control
- Pneumatic Kicking Device
- Wi-Fi for Communication
Hardware of a Tribot Soccer Robot

Software Framework

- Worldmodel / Decision / Robot Control units
- Module based, Framework allows replacement of hand-written parts through learned / ai based parts
- Ability to act as a team (via wireless communication)

Image Processing / Omnicam

- Light on a robocup field is very inconsistent.
- Automatic White Balance/ Exposure to automatically adapt to changing Light

Image Processing / Omnicam

- Automatic Mask Generation to prevent misinterpreting the robot for obstacles
- Omni Directional Distance Calibration to make it possible to measure distances on the ground
**Image Processing / Omnicam**

- Omnidirectional Vision Debug Image

**Stereo Camera Configuration**

- Goalkeeper needs to detect chip kicks, the need for 3d ball detection arises
- Stacked mechanical setup
- Stereo basis ca. 28 cm

- Completely different images due to
  - Different camera types
  - Fields of view
  - Distortion
  - Resolution
  - Limited computation time

- Incomplete data problem while tracking ball
- Approach: CM Completion / Maximization, Regression
Pan Tilt Stereo Camera

- Possible Future Camera Configuration?

Software – World Model

- Sensor Fusion & Models used in the World-Model
- Self-localization
- Ball-model (robust regression / multiple hypothesis checking)
- Self-model (robust regression / MLP)
- Teammate / Opponent-Model (shared WM, robust regression)

World Model

- Sensors, old State, Communication

Software – Self-localization

- Line transitions from the omni camera have been converted to real distances

- An error metric for matching the lines to the field model can be calculated
Software – Self-localization

- Minimization using gradient descent with R-Prop

Example of Goalie Arbitration

- Goalie “Stack”

Goalie

- BGGameStopped
- BGoaliePenalty
- BGoalieGetAwayFromGoalPosts
- BGoaliePositioningChipKick
- BGoalieRaisedBall
- BGoalieFetchBallNearGoalPost
- BGoalieAttackBall
- BGoalieFetchBall
- BGoaliePositioning
- BGoaliePatrol

Robot Behaviors and Skills

- Robot behavior is defined by using a class
- Framework oriented on the BDI approach (Belief / Desire / Intention)
- Complicated Graph-based state machines are avoided using arbitration

FSM / BDI Comparison
Some Important Skills

- Get the ball!
  - Must always work faster than the enemy robot ;)
  - Rolling ball must be no disadvantage
  - Must work everywhere on the field
- Dribble the ball
  - Move to a position not losing the ball on the way
  - The ball could roll away
- Shoot if the chance to score is high
  - Don't dribble too much in front of the enemy goal

Skill Implementation

EXAMPLE 1
Static ball, approach from different positions dependent of goal direction

EXAMPLE 2
Moving ball

Necessary data:
- relative ball position
- relative ball speed
Skill Implementation

**EXAMPLE 3**
Dribbling to a position / goal

**EXAMPLE 4**
Trajectory Planning

- Trajectories are planned based on a geometric analysis of the configuration of the field and the dynamic properties of the robot.
- We do not generate whole trajectories but only way-points.
- The trajectory is replanned every 33 ms to cope with the dynamic environment.

Skill Implementation

**EXAMPLE 5**
Shooting at the goal looking for a free spot

- Approach some more, aim at right goal post...
- Shoot !!!!

Learning on a real system

- Using real hardware for Learning presents challenges
  - Testing is a lot of work => Algorithms that learn fast are needed.
  - Delays make the state non markovian
Learning on a real system

- Approach: Prediction of the state

Model-free Reinforcement Learning without a simulation is possible!

Reinforcement Learning

- Catching a passed Ball
  (Keeping the ball from jumping away)
- Keep the Ball from rolling away while Dribbling and Moving Omnidirectionally
- Omnidirectional Motor Control
- Learned Skills were actually used during Robocup Tournaments
**Teamplay / Cooperation**

- Hard to implement Useful Robot Cooperation
- Implicit Cooperation through Knowledge / Explicit Cooperation through Communication
- Dynamic Role Change
- Defense Rotation
- Subteams
- Passing
- Dynamic Chain of Command

**Example: Pass**

**Current Project: openTribot**

- DFG funded Project
- Open Source Hardware / Software Platform for the Robotcup MidSize League
- Designed in Cooperation with Harting KgaA

**openTribot Hardware**

- Custom 3- wheel omni-drive, with powerful brushless motors, strong lipo batteries (5 m/s)
- Omnidirectional USB camera
- Netbook w/ Linux
- Can-Bus, high Pressure Kicking device, 6-dof IMU
- Modular design
Prototype Hardware

- Custom CNC milled chassis

Future Projects

- Making the Robot intelligent enough to play in a mixed team with other Robots
- Optimize Robot performance
- Elaborate on the Learning aspect
- Making the Setup easy
- Rent-A-Robot
- Technical Challenges in Robocup

Videos online

- Check our site http://ml.informatik.uni-freiburg.de for links to videos
- or search Tribots Robocup in Google Videos!

Thank you for your attention!

- If you are interested you are welcome to get involved in our projects!
- Please come by my office on Thursdays if you like! (Building 79, Room 0 00 06)
- Feel free to join the Robocup AG Mid-Size in the next semester.
  
  http://ml.informatik.uni-freiburg.de/people/welker/info