III. Approach: We provide a generic set of basic CV-operators as well as complex, parameterized CV-algorithms. Evolutionary Algorithms (EA) are used to construct and optimize candidates (programs), that possible may solve this task. Each candidate consists of a computer vision sublayer (operators and parameters are subject to the evolutionary process) and a Multilayer Perceptron. The performance of the trained MLP yields the fitness of the candidate.

V. Present and Future work:
A) Transfer to episodic tasks: Enrich encoded state to contain information about changes, use Reinforcement Learning (RL) sublayer, knowledge transfer to descendents via batch RL methods
B) Speed up optimization of vision sublayer: rate every feature individually (e.g. using relevance learning methods like GRLVQ), - Exploit knowledge about the structure of the learning problem

1. Real-time computer vision
The developed computer vision system is able to robustly detect the ball, lines, goals, robots and obstacles in virtually no time (less than 10ms).

2. Behavior Framework
We developed a new hierarchical behavior framework for our robots that brings together both reactive and deliberative modules. The architecture basically is a fusion of ideas from the BDI and Subsumption architecture and allows us to integrated learned submodules as well as „classical“ submodules.

3. Reinforcement Learning on the real robot
With the help of a new batch mode Reinforcement Learning algorithms (NFQ) we were able to learn yet simple but effective strategies directly on the real robot (e.g. stop precisely on a position)

4. Cooperative defensive behavior
Some X and O’s for the robots: Implementation of a cooperative team strategy for defending the goal using the above mentioned framework: Used classical AI methods, relying on implicit coordination as well as explicit contracting via communication; failsafe.

I. Classical approach: (Manual) extraction and selection of features that are then feed into a learning algorithm in order to learn a task (e.g. object classification). The construction and optimization of the computer vision subsystem is not integrated into the learning procedure but done by hand for each different task.

II. Goal: Automatize the development of the computer vision (CV) subsystem: Integrate the feature extraction and selection into the learning procedure and learn the original task directly on the images. Apply this to Reinforcement Learning (RL) tasks.

IV. Up to now: Applied this algorithm successfully to several different supervised learning tasks (set of training images with expected output) like object classification, object counting and simple robot navigation tasks (target ball, go to position, approach ball). Learning restricted to single images.

Contributions to the Soccer Robots

Fig. 2: Steps of the evolution process

Low-Level-Vision subsystem

High-Level-Vision a.
control

Fig. 3: Evolved programs have two sublayers: CV and MLP

Fig. 4: Real-time classification of robots using PCA and SVMs

Fig. 5: Arbitration in the hierarchical behavior framework

Fig. 6: Defense strategy of the Tribots