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Co-Evolving Robot Soccer Behavior

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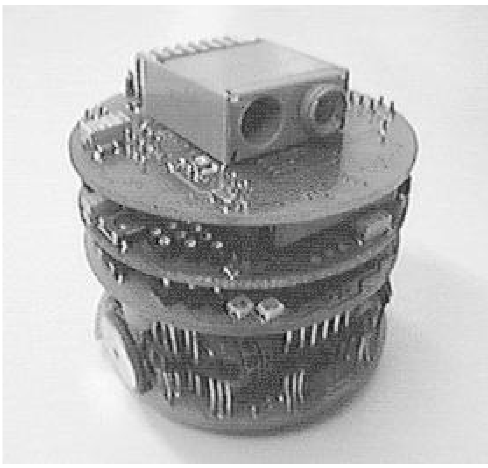

Figure 1: The Khepera Robot, about 5.5 cm in diameter.

1 Introduction

Robot soccer is a complex competitive task. Deciding on which strategy to implement when constructing the robot controller is hard, and no methodology exist for finding the best controller. The task lends itself to co-evolution due to its inherent competitive nature. We present a system that uses competitive co-evolution to develop robot controllers for the task, and show that the evolved controllers are capable competing with hand-coded robots.

In a Khepera robot soccer match two Khepera robots (figure 1) are pitted against each other in an arena, shown in figure 2.

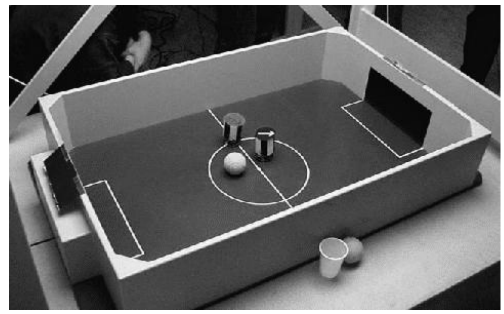

Figure 2: A picture of the football arena.

2 The Implemented System

We use an off-line evolutionary system, as shown in figure 3. The evolutionary algorithm works on gene strings, which are translated into a controller. The controller is tested in a simulator, and the performance of the controller is fed back to the evolutionary algorithm. After a pre-specified number of generations, the best performing controller is translated into a binary file that can be executed on a Khepera soccer player. Co-evolutionary is implemented as two separate populations. Individuals from the same population are never pitted against each other, and there is no exchange of gene information between the two populations.

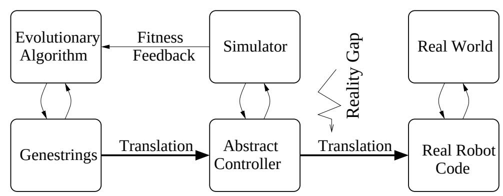

Figure 3: The components of the system.

2.1 Behavior Representation

Behavior is represented in a fixed-structure tree of arbitrators and primitives, shown in figure 4. The size

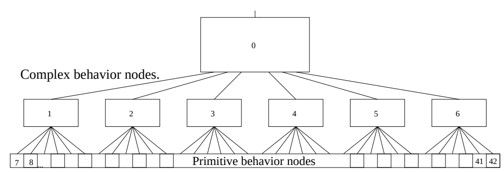

Figure 4: The structure of the behavior tree.

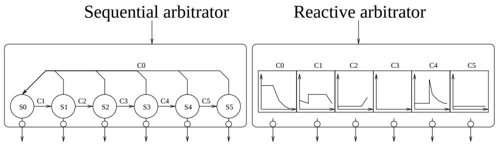

Figure 5: The two types of arbitration nodes. Control is propagated down to a sub module. In the sequential case, control is transferred to the sub module corresponding to the state of a finite state automaton. In the "reactive" arbitrator case, control is transferred to the submodule corresponding to the leaky integrator with highest activation.

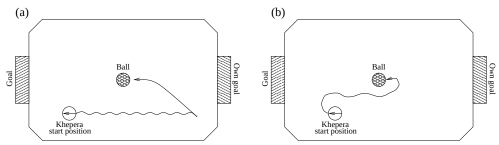

Figure 6: Different evolved football strategies.

and structure of this tree is based on an estimate. Modules 0-6 are arbitrator modules, and modules 7-42 are primitive actions. At each 100 ms time step, control is propagated down through the tree to one of the 36 primitives, which will then have full control of the robot for the duration of the time step. Two types of arbitrators were implemented; sequential and "reactive" arbitration, illustrated in figure 5. This approach is based on the task decomposition approach described by W. Lee, J. Hallam and H. H. Lund in [LHL97].

2.2 The Simulator

A hybrid between the minimal simulation approach, suggested by Nick Jacobi [Jac98], and a geometric mathematical model is used. Basically everything that relatively easily could be modeled geometrical is modeled geometrically, and then the rest is made *unreliable* by adding noise. The world is only modeled in two dimensions, since the third dimension, the height, does not seem relevant for the task at hand.

As stated in [HCH92], producing simulations of visual sensing is a very time-consuming task, both for the programmer when building the simulator, and for the computer during simulation. Instead of simulating the camera pixel by pixel, a filter returning the centroid and with of the ball in the image is simulated. Similar methods were used for the IR sensors and the wheel incremental encoders.

3 Performance

Two distinct strategies for approaching the ball were observed in the evolved robots. The two types are shown in figure 6 (a) and (b). The system was really put to

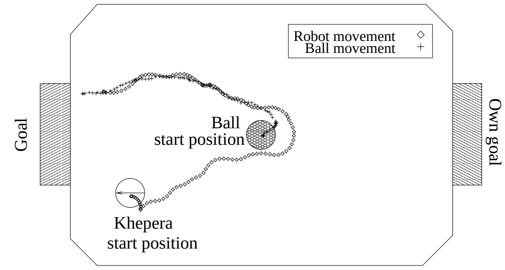

Figure 7: The plotted position of the robot *Brute Force* and the ball in the simulator. The ball starts to move when *Brute Force* pushes the ball.

the test, when an evolved robot controller participated in the Danish Robot Football Competition, Dec. 1999 under the name *Brute Force*. Videos from this event can be found on the home page of this paper[1], and is the main source of documentation for the real robot performance. In the preliminary matches, *Brute Force* won two times and had one draw, which was enough to qualify for the semi finals. In the semi final *Brute Force* won 1-0 without much difficulties, but lost in the final against *KITT*, partly due to a dead battery in the second round. *Brute Force*'s behavior in the simulator is shown in figure 7. By observation, this behavior corresponds to the behavior in the real world.

4 Conclusion

The objective of the work was to explore the co-evolutionary robotics approach and to test whether it could be used to evolve behavior for the Khepera robot soccer task. This seems to be the case. However, existing theories still need further development in several areas to reduce the amount of intuition required to build such a system. Especially the problem with writing complex simulators seems to be difficult to overcome.

References

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[Jac98] Nick Jacobi. The minimal simulation approach to evolutionary robotics. In Takashi Gomi, editor, *Evolutionary Robotics, Volume II*, 1998.

[LHL97] Wei-Po Lee, John Hallam, and Henrik Hautop Lund. Learning complex robot behaviours by evolutionary approaches. *6th European Workshop on Learning Robots, EWLR-6*, aug 1997.

[1] http://www.mip.sdu.dk/~esben/EvoRobSoc