

# Experiments in Evolutionary Synthesis of Robotic Neurocontrollers

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*Artificial neural networks* offer an attractive paradigm for the design of behavior and control systems in robots and autonomous agents for a variety of reasons, including: ability to adapt and learn, potential for resistance to noise, faults and component failures, potential for real-time performance in dynamic environments (through massive parallelism and suitable hardware realization) etc.

However, designing a good neurocontroller for a given robotic application is an instance of a difficult multi-criterion optimization problem, requiring complicated trade-offs among different, often competing measures of the network, like performance, cost, complexity etc., which is further compounded by competing objectives in the realization of behavior (e.g., move quickly versus avoid obstacles).

*Evolutionary Algorithms* (EAs), simulated models of natural evolution, have been shown to be effective in searching several vast, complex, multi-modal, and deceptive search spaces. They are therefore viable candidates to employ in the design of neurocontrollers (Balakrishnan & Honavar 1995).

Although this synergy of approaches is not new (see (Balakrishnan & Honavar 1995) for a bibliography), this field still offers many exciting avenues of research. Our recent work has been based on a simulation task that requires a robot to clear an arena by pushing boxes to the enclosing walls. The number of boxes that the robot pushes to the walls, within an allocated time, is taken to be a measure of its fitness. We use *Genetic Algorithms* (GAs) to evolve high-fitness neurocontrollers for this robot.

Our simulation results indicate that *recurrent* networks achieve much higher fitnesses on this task compared to their *feedforward* counterparts. By analysing the evolved networks we have been able to determine that a large, negative, *self-loop* at the output unit that decides the action (move forward or turn), is what gives these networks such an advantage. This recurrent link biases the robot to frequently switch actions

(interleave moves and turns), thereby guarding it from getting into permanently stuck states (e.g., fruitlessly trying to move into the wall), which is a real possibility in this environment (where there is no feedback and the robot does not bounce off walls). With networks that are *initially feedforward* (but capable of evolving recurrent links through mutation), evolution produces high fitness neurocontrollers with 30% (and sometimes even 70%) fewer recurrent links compared to networks fully recurrent from the start (Balakrishnan & Honavar 1996). This suggests a potentially useful approach to the design of networks with near-minimal recurrence.

Through our experiments on *sensor evolution*, we have shown the utility of designing the sensory systems of robots in addition to the usual practice of designing just the neurocontroller. Since real world domains are often noisy and faulty, we are also exploring the evolution of noise and fault-tolerant neurocontrollers. Preliminary results look extremely promising.

Our ongoing research aims to examine the intricate interplay between the environment and the evolutionary processes in determining the structure and function of the resulting neurocontrollers. Our results are suggestive of the possibility that as the constraints are changed, evolution can potentially discover behaviors that are tailored for success within the constraints imposed by the environment.

## References

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