Relating Neural Network Performance to Morphological Differences in Embodied Agents

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In the study of embodied Artificial Intelligence (Pfeifer & Scheier 1999), all aspects of an agent or robot (body shape and size, sensor and motor distribution, and material properties) are considered important for the construction of intelligent behaviour, not just the choices made about the neural controller. As such, recent research in our group has focussed on attributing specific morphological characteristics of an agent to its behaviour (Bongard & Pfeifer 2002). This is done by evolving neural controllers for agents in a three-dimensional, physics-based simulation. This allows artificial evolution to exploit the dynamics of an agent's body, the external environment, and the interactions between them.

In this paper, we evolve neural controllers for nine different simulated, legged agents. The agents have different body shapes, and differing numbers of legs. In this study we used one tripedal agent, four quadrupedal agents, two agents with five and seven points of contact with the ground plane, a salamander-type agent with nine points of contact, and two segmented agents with 10 points of contact. Despite the differing morphologies, each agent contains the same number of sensors and motors, and identical neural architectures.

By randomizing the output values of the single hidden neurons from evolved neural controllers, it was found that for some agents, sensor-motor mappings are distributed evenly across the hidden layer, but that for other agents the distribution was less even. This trend was found to hold for evolved neural networks with hidden layers containing both three and five neurons (see Fig. 1). This suggests that particular morphological aspects (in this case, number of legs) have an effect on how sensor-motor mappings are distributed across a neural network when the weight space is evolved. This research is a first attempt to elucidate how evolved behaviours cause (or fail to cause) the centralization of neural structure.

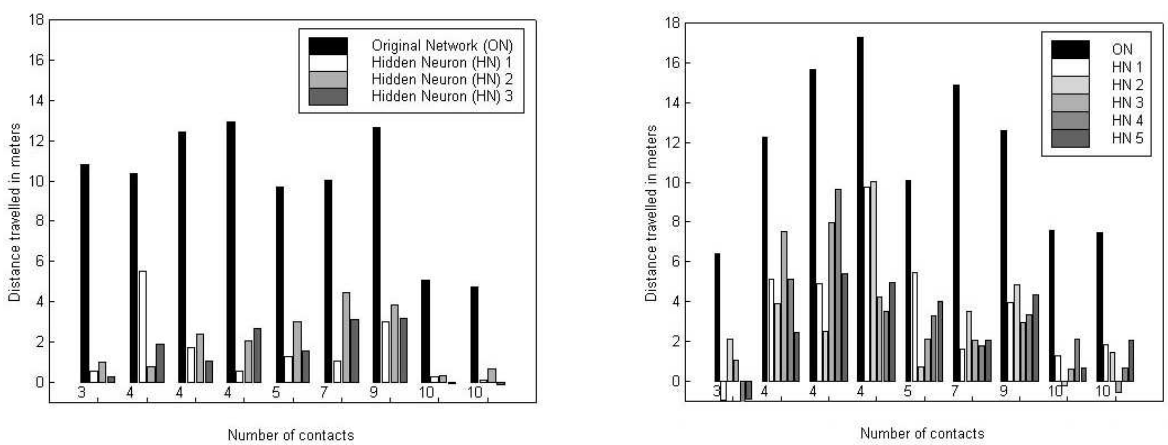

Fig 1. Effect of randomization of hidden neurons. The left-hand panel shows the fitness (distance travelled in meters) for each of the nine agents with the best evolved neural network (black bars). The white and gray bars indicate the distance travelled by the agent when each of the three hidden neurons, in turn, output random activations. The right-hand panel shows the performances for the nine agents using their best evolved neural networks, with five neurons in the hidden layer. The white and gray bars indicate the performances when each of the five hidden neurons, in turn, emit random activations.

References

- Pfeifer, R. and C. Scheier (1999). *Understanding Intelligence*. Cambridge, MA: MIT Press
- Bongard, J. and R. Pfeifer (2002). A Method for Isolating Morphological Effects on Evolved Behaviour. Submitted to: *Proceedings of the Seventh International Conference on the Simulation of Adaptive Behaviour*, Edinburgh, UK.