Complexity and Size of Neural Networks

Comparing Factors for the Emergence of Intelligent Behaviours

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Abstract

It is established that the Encephalization Quotient - i.e. the ratio between brain and body mass - increased during the natural evolution [1]. There are also convincing studies on the relationship between intelligence and brain size. On the contrary, very little has been investigated on brain complexity and its relationship with intelligence: this paper proposes an artificial approach to study this relationship.

The present work is original also because it uses Neural Complexity measures on recursive nets evolved to control autonomous agents. Elman ANN were adopted, with sigmoid activation; the evolutionary processes have been repeated with different sizes of the hidden layer - in order to test the influence of the "brain" size on the agent's intelligence.

The evolution of the nets has been made with a genetic algorithm that coded directly the weights: every generation the best 25 individuals - scored with an automatically estimated fitness - were cloned 8 times, with small random changes of the connection weights.

Four different experiments - in different environments and with tasks of different complexity - have been carried out on a simulated Khepera robot, using the YAKS simulator (http://r2d2.ida.his.se), an open source program whose code has been modified to meet the requirements of the experiments.

Data of the connection weights and neural activations have been saved and then analyzed with different algorithms to estimate various complexity measures, such as Integration, Neural Complexity, Matching Complexity, Wiring Length, Clustering Coefficient and Effective Information - as proposed in various papers by Tononi, Edelman, Sporns and Seth [2][3][4][5][6][7].

All these data then underwent statistical analysis to discover correlations between complexity measures on one hand, and fitness, generation and the number of hidden neurons on the other hand.

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These analysis show significant correlations between the Neural Complexity - computed from the Connection Weights - and both the generation and fitness. This suggests that the same evolutionary drives work in both natural and artificial evolution.
The Neural Complexity computed from the Activations instead negatively correlates (or doesn't correlate at all) with the generation and fitness. This fact may be explained with the hypothesis that in simple environments and for agents with poor sensorial abilities, a high Activation Neural Complexity would bring chaotic behaviours, not suitable for such environments and tasks, that instead require stability.
The other measures don't show significant correlations.
At last, the Estimated Marginal Means of the Neural Complexities show that the different complexities of the tasks bring to different levels of Neural Complexity.

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