Pattern Languages: A New Paradigm for Neurocomputation

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-SUMMARY-

Objective
The paper aims to offer an introduction to a new look at neural activity data through the paradigm of pattern languages. Biological examples (e.g., crab stomatogastric nucleus, olfactory bulb) are presented to provide the biological grounding, and an artificial neural network is described to provide a simple example of how to interpret neural activity data in terms of pattern languages.

Context
Many theories about how biological neural systems work emphasize the input / output processing of information in such systems (e.g., Haykin 1994), ignoring the internal processes that transform the data and blend it with a priori knowledge existing within the system. A new computational paradigm emerged recently, the theory of pattern languages (Wolfram 2002), which fits very well to the description and analysis of complex systems and which can be used to highlight the importance of internal processing in neural systems. Examples of complex neural activity patterns, e.g., crab stomatogastric nucleus (Nussbaum and Beenhakker, 2002), olfactory bulb (Freeman 1994), are cases where classic theories were so far not very successful in explaining the behaviour of the neural systems. In these cases the pattern languages approach offers a fresh look at the data with the promise of providing faithful explanations and robust predictions about the behaviour of the neural system.

Methods and results
First, we look at examples of biological neural systems (e.g., crab stomatogastric nucleus, olfactory bulb) which show complex neural activity that is hard to explain using classical models of neural systems. We point out that, while classical models focus on input / output processing, relatively well – known small biological systems indicate that internal processes are very important, and without properly accounting for them the models are likely to fail to provide good explanations and predictions of neural activity.
Second, we briefly introduce the Sierpinski brain (Andras, 2002) and its generalized version. This artificial neural system performs general purpose computation using interacting neural activity patterns. We show how the activity of the Sierpinski brain could be described in terms of classical models, and why these descriptions have low explanatory and predictive power in this particular context. We also show, how the pattern languages approach offers a better description of what is happening in this simple artificial neural system.
Third, we discuss how the paradigm of pattern languages shifts the focus from the input / output processing to the internal processing, how observed complexity can be explained in relatively simple terms using the pattern languages paradigm, and the implications of this paradigm for topics of computational neuroscience. We also point out that the pattern languages approach provides a balanced view of small neural

systems, which takes into account both individual neural activities and activities of larger groups of neurons.

Significance

Understanding simple biological neural systems with complex behaviour is crucial for the understanding of more complicated neural systems. While, classical neural models have only very limited explanatory and predictive power in such cases, the pattern languages paradigm offers a new way to look at these neural systems. By switching from the focus on input / output processing to internal processing, and by having a balanced approach between considering only individual neurons or only large groups of neurons, the pattern languages paradigm is likely to be able to capture to a good extent the behaviour of complex neural system. Consequently it is likely that it can provide better explanations and predictions about such neural systems with complex behaviour.

References

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