Learning Complex Structures of Images Through Recursive Independent Component Analysis

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It has long been hypothesized that the functional role of perception is to capture the statistical structure of the sensory stimuli such that corresponding actions could be taken to maximize the chances of survival (see [1] for a brief review). Attneave [2] pointed out that such statistical structure was measured by the redundancy in the sensory inputs. Barlow [3] further hypothesized that for a neural system one possible way of capturing the statistical structure was to remove the redundancy in the sensory outputs. Linear implementations of this hypothesis, such as Independent Component Analysis (ICA), has been used to explain the functional role of simple cells in the primary visual cortex [4, 5].

However, since ICA is intrinsically a linear method, there are inevitably some structures that cannot be captured by a linear ICA. This is reflected in the fact that there is residual redundancy in the ICA outputs when it is applied on natural image patches [6]. Residual Redundancy Reduction studies how to capture the structures not captured by a linear ICA. In this work, we propose to apply another layer of ICA to reduce the residual redundancy. This was inspired by the idea that different areas of cortex share similar anatomical structures and likely use similar computational learning principles. Also, by doing so we transformed a new and hard problem into an easier and previously solved problem. We derived a nonlinear activation function between layers which allows the higher layer of ICA to work efficiently. As a result, we get to a hierarchical recognition model in which the higher layers capture more complicated structures of images by pooling the simple structures learned at the lower layer.

Acknowledgments
We thank Eric Wiewiora and other GURU members for helpful discussions.

References


