Title: Building a brain: layer by layer.

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Abstract: As natural intelligence is largely dependent on the architecture of living neural networks in the brain, it is remarkable that these networks emerge through a developmental process with self-organization at its core. This feature makes the brain truly unique and different from artificial learning machines, like convolutional neural networks, as they rely extensively on heuristic hand-programmed architectures to perform tasks with high accuracy. This fundamental limitation of artificial learning machines motivates our paper, as we attempt to endow computational devices with the capability of ”growing” from scratch without any human intervention, similar to how a single cell grows to form a functioning brain. In this paper, we grow a layered neural network and propose a developmental algorithm that allows for robust self-organization of inter-layer connections to mimic a key constituent of convolutional neural networks, namely the convolutional pooling layer. This developmental algorithm was abstracted from the early visual system, where spatiotemporal activity waves tiling the retina enforce connections between spatial patches of retinal ganglion cells (RGC’s) and neurons in the lateral geniculate nucleus (LGN). We implement this algorithm through mathematical models and show that activity waves driven by noise in the first layer is sufficient to organize a diffuse network of connections between the two layers into a set of pooled nodes in the first layer connected to units in the second layer. We have successfully grown and self-organized pooling layers for a wide-range of inputlayer geometries, tuned the size and shape of the pooling layer by altering the properties of the emergent spatiotemporal wave in the first layer and have demonstrated that this system is robust to malfunctioning units in the first layer. Broadly, our work shows that biologically inspired developmental algorithms can be applied to autonomously ”grow” artificial computational devices.