

## **Can Deep Learning Learn to Count? on cognitive deficit of the current state of deep learning**

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Subitizing, or the sense of small natural numbers, is an innate cognitive function of humans and primates; it responds to visual stimuli prior to the development of any symbolic skills, language or arithmetic. Given successes of deep learning (DL) in tasks of visual intelligence and given the primitivity of number sense, a tantalizing question is whether DL can comprehend numbers and perform subitizing. But somewhat disappointingly, extensive experiments of the type of cognitive psychology demonstrate that the examples-driven black box DL cannot see through superficial variations in visual representations and distill the abstract notion of natural number, a task that children perform with high accuracy and confidence. The failure is apparently due to the learning method not the connectionist CNN machinery itself. A recurrent neural network capable of subitizing does exist, which we construct by encoding a mechanism of mathematical morphology into the CNN convolutional kernels. Also, we investigate, using subitizing as a test bed, the ways to aid the black box DL by cognitive priors derived from human insight. Our findings are mixed and interesting, pointing to both cognitive deficit of pure DL, and some measured successes of boosting DL by predetermined cognitive implements. This case study of DL in cognitive computing is meaningful as visual numerosity represents a minimum level of human intelligence.

Bio Sketch: Xiaolin Wu, Ph.D. in computer science, University of Calgary, Canada, 1988. Dr. Wu started his academic career in 1988, and has since been on the faculty of Western University, New York Polytechnic University (NYU Poly), and currently McMaster University. He holds the NSERC senior industrial research chair in Digital Cinema. His research interests include image processing, computer vision multimedia signal coding and communication, joint source-channel coding, multiple description coding, and network-aware visual communication. He has published over two hundred-sixty research papers and holds five patents in these fields. Dr. Wu is an IEEE fellow, McMaster Distinguished Engineering Professor, an associated editor of IEEE Transactions on Image Processing, and served on the technical committees of many IEEE international conferences/workshops. Dr. Wu received numerous international awards and honors.