The Beobot Platform for Embedded Real-Time Neuromorphic Vision

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Animals demonstrate unparalleled abilities to interact with their natural visual environment, a task which remains embarrassingly problematic to machines. Obviously, vision is computationally expensive, with a million distinct nerve fibers composing each optic nerve, and approximately half of the mammalian brain dedicated more or less closely to vision. Thus, for long, the poor real-time performance of machine vision systems could be attributed to limitations in computer processing power. With the recent availability of low-cost supercomputers, such as so-called "Beowulf" clusters of standard interconnected personal computers, however, this excuse is rapidly losing credibility. What could then be the reason for the dramatic discrepancy between animal and machine vision? Too often computer vision algorithms are designed with a specific goal and setting in mind, e.g., detecting traffic signs by matching geometric and colorimetric models of specific signs to image features. Consequently, dedicated tuning or algorithmic alterations are typically required to accommodate for novel environments, targets or tasks. For example, an algorithm to detect traffic signs from images acquired by a vehicle-mounted camera will typically not be trivially applicable to the detection of military vehicles in overhead imagery.

Much progress has been made in the field of visual neuroscience, using techniques such as single neuron electrophysiology, psychophysics and functional neuroimaging. These advances have set the basis for a deeper understanding of biological vision. Computational modeling has also seen recent advances, and fairly accurate software models of specific parts or properties of the primate visual system are now available, which show great promise of unparalleled robustness, versatility and adaptability. A common shortcoming of computational neuroscience models, however, is that they are not readily applicable to real images. Neuromorphic engineering proposes to address this problem by establishing a bridge between computational neuroscience and machine vision. An example of neuromorphic algorithm is our model of bottom-up, saliency-based visual attention, which has demonstrated strong ability at quickly locating not only traffic signs in 512x384 video frames from a vehicle-mounted camera, but also — without any modification or parameter tuning — artificial targets in psychophysical visual search arrays, soda cans, emergency triangles, faces and people, military vehicles in 6144x4096 overhead imagery, and many other types of targets.

We demonstrate a new mobile robotics platform designed for the implementation and testing of neuromorphic vision algorithms in unconstrained outdoors environments. It is being developed by a team of undergraduate students with graduate supervision and help. Its distinctive features include significant computational power (four 1.4GHz CPUs with gigabit interconnect), high-speed four-wheel-drive chassis, standard Linux operating system, and a comprehensive toolkit of C++ vision classes. The robot is designed with two major goals in mind: real-time operation of sophisticated neuromorphic vision algorithms, and off-the-shelf components to ensure rapid technological evolvability. A preliminary embedded neuromorphic vision architecture that includes attentional, gist/layout, object recognition, and high-level decision subsystems is showcased (see `http://iLab.usc.edu/beobots/` for additional information).

Just like Beowulf clusters have revolutionized the world of high-performance computing, replacing costly and slowly-evolving custom supercomputer hardware by assemblies of inexpensive, mass-produced personal computers, we hope that Beobots (a Beowulf cluster on a mobile robot) will lead the way towards a new generation of robotics systems that are inexpensive, rapidly evolving, built from standard mass-produced components, and armed with sufficient computational power to run real-time neuromorphic vision algorithms.

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