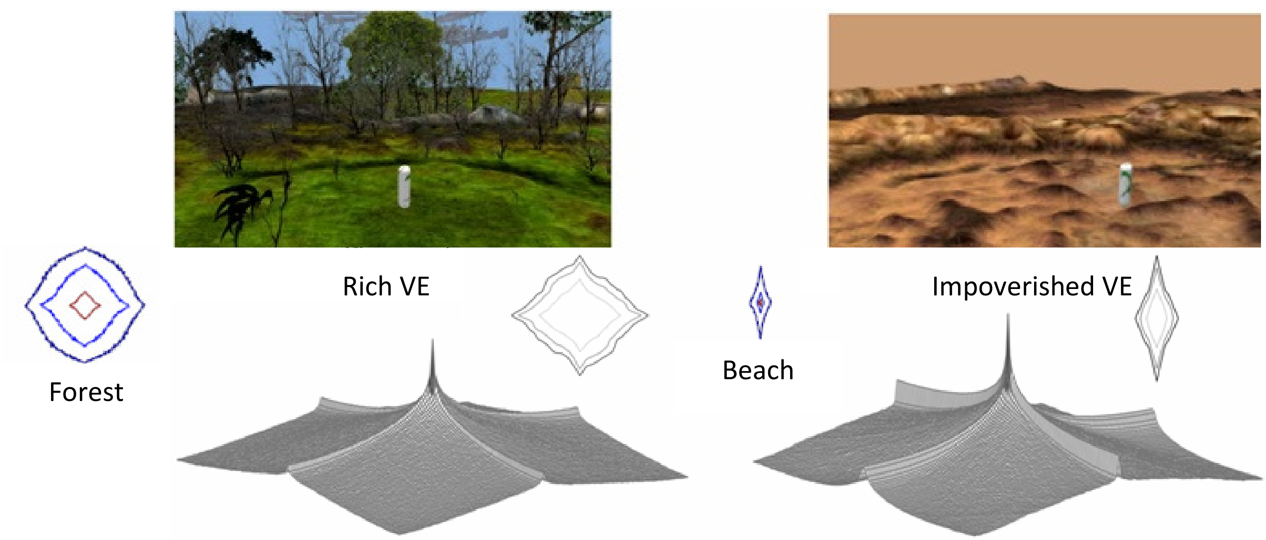
Modeling Early Visual Plasticity in a Realistic Virtual World

Gennady Livitz, Jasmin Léveillé, Heather Ames, Anatoli Gorchetchnikov, Massimiliano Versace, Ben Chandler, Richard Carter, Hisham Abdalla, Ennio Mingolla, Greg Snider.

Progress in developing adaptive computational models of vision is often hampered by limitations in computing infrastructure and in how a given model interacts with the outside world. To address these problems, we combine high-performance computing with 3D graphics to embed a neural model in an autonomous agent (animat). This approach affords a high degree of control in designing simulations, testing, and prototyping while varying model parameters. Here, we show a model of early visual pathways in an animat whose visual system develops orientation selectivity maps as it wanders in a realistic virtual world.

This work demonstrates the capabilities of the *Cog Ex Machina* (*Cog*) computational platform for neural modeling (Snider et al., 2011). Cog supports scalable parallel neural network implementations and allows formulating neural models in terms of algebraic transformations of tensor fields that represent cell populations. Cog is jointly developed by Boston University's Neuromorphics Lab and Hewlett Packard Laboratories.

The model includes retinal cone cells and center-surround LGN cells organized in chromatic and achromatic pathways, as well as V1 cells whose synaptic connections are modified according to BCM theory (Bienenstock et al, 1982). Competition in the last layer ensures that cells learn different components of the visual input. Simulations show the formation of stable orientation selectivity maps in both chromatic and achromatic pathways. Map formation is studied in two different types of environments (rich and impoverished), and for various wandering patterns. Spatiotemporal statistics of the visual input under various wandering patterns are matched to corresponding data from a cat in its natural habitat. We demonstrate that these maps reproduce characteristics of the average power spectrum of the visual input sampled by the wandering animat. Our simulations show how environment type and animat motion patterns combine to influence learning and go beyond typical "natural image" simulations.



The above figure shows the distribution of oriented edges for rich and impoverished visual environments (VE). These statistics are similar to the edge statistics found in natural scenes (forest and beach, Torralba and Oliva, 2003). Other factors that influence the formation of orientation sensitive cells in our simulations are the patterns of body and eye movements, the distribution of luminance contrast and the way color and luminance channels feed their input to orientation-selective cells. Our experience suggests that realistic, 3D virtual environments can be key in developing neural models of vision characterized by a high degree of neural plasticity.