Experience-dependent Active Vision in an Autonomous Quadruped Robot

Daniel Bulwinkle

Goals

- Model bottom-up process of visual attention.
- Incorporate visual attention into a neural model for learning appetitive and aversive objects.
- Develop theories on how neuroplasticity, behavior, and visual attention interact affect learning.

Background: Bottom-Up

- Primates have ability to interpret complex scenes within fractions of a second
- Itti, Koch, and Niebur propose a modified feature integration theory: saliency map
- In primates, map would be located in posterior parietal cortex and visual maps in pulvinar nuclei of the thalamus

Background: Bottom-Up

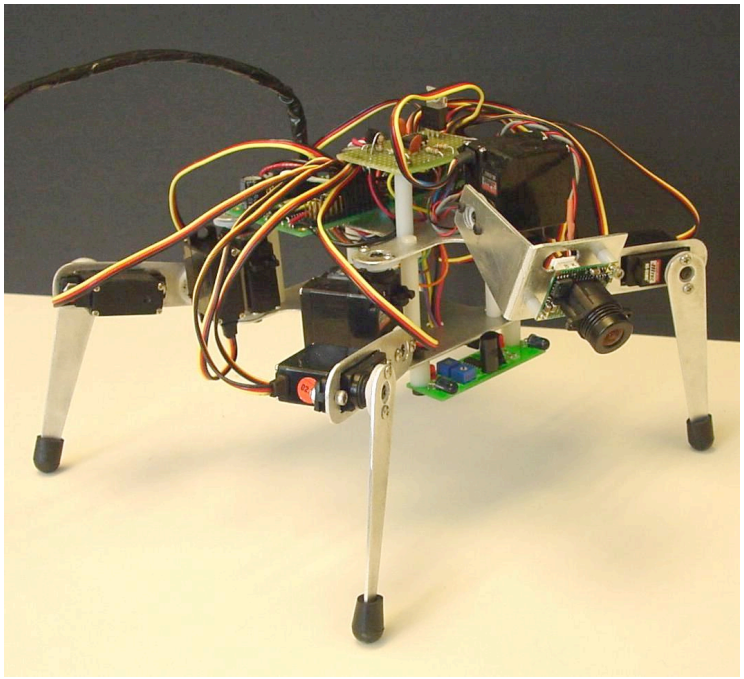
- Inhibition of Return is one method proposed for searching a scene
- Why saliency?
  - Provides simple method for focus of attention
  - Advantageous over exhaustive search: primates find a few interesting targets in milliseconds

Background: Top-Down

- Salient targets are processed by Top-Down methods using trained neural networks.

- Much slower than bottom-up

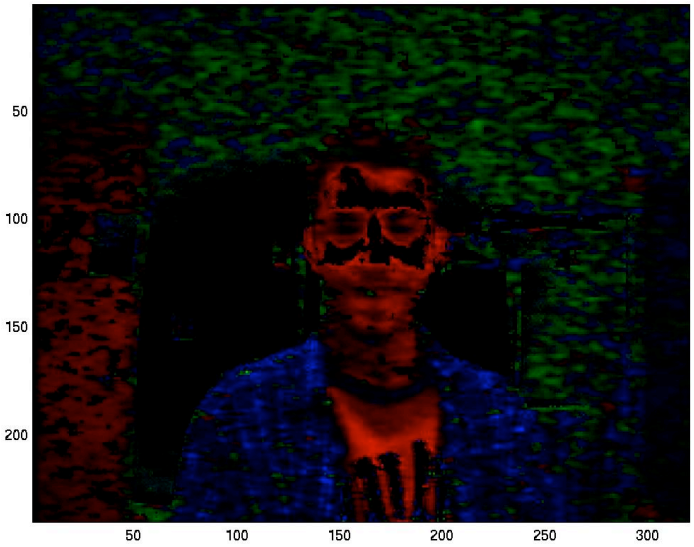
Platform for Attention



Strider is a quadruped with a color CCD camera that has two degrees of freedom. The robot is tethered to a computer where all image processing is done in Matlab

Strider's Bottom-Up

Color Feature Map



- Opponent-Colors

$r` = r_n - (g_n + b_n) / 2$

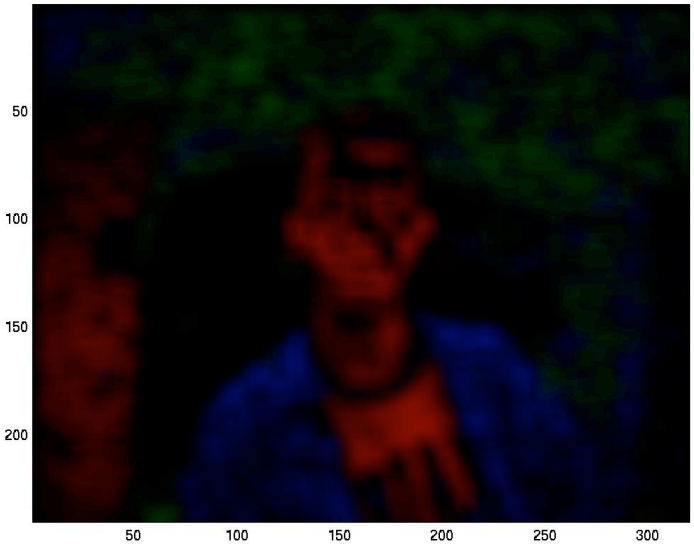
$g` = g_n - (r_n + b_n) / 2$

$b` = b_n - (r_n + g_n) / 2$

$y` = (r_n + g_n) / 2 - b_n - ||r_n - b_n||$

Strider's Bottom-Up

Color Feature Map



- Smoothing
- 11x11 pixel smoothing matrix
- Removes pixel noise

Strider's Bottom-Up

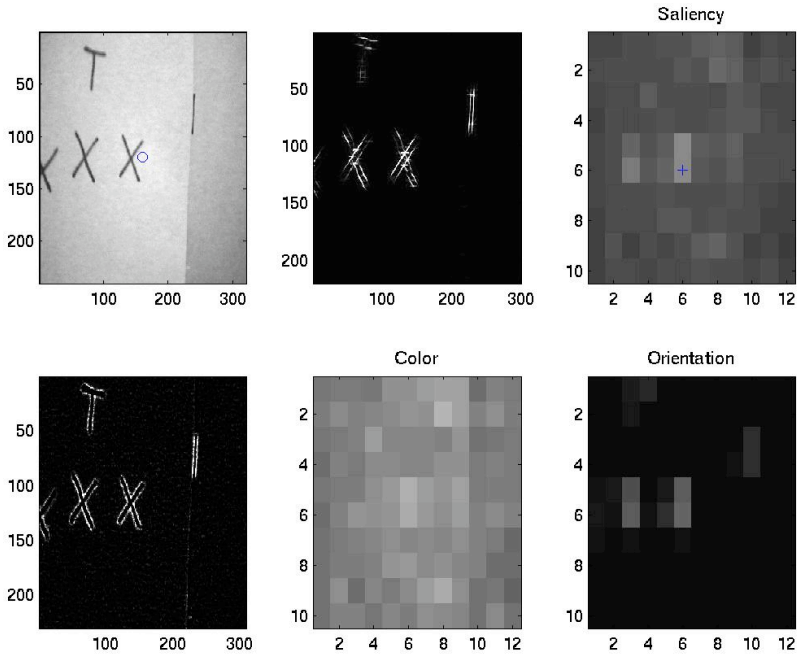
Orientation Feature Map

- Gaussian filter used to detect edges in *n* orientations.
- Biological analog to edge detection is the lateral geniculate nucleus.

Strider's Bottom-Up

Feature Maps & Saliency Map

Images undergo their respective filter and then are fit to 10x12 grayscale feature maps. The saliency map is created by adding the weighted values of each feature map.



Behavior: Walking

- Gait is based on biological quadrupeds providing Strider with a biomimetic touch.
- A sinusoidal function controls the gait.
- Parameters of amplitude and frequency make it possible for Strider to gallop or stride, walk or run, and veer left and right.

Behavior: Tasting

- As Strider approaches an object, gait becomes smaller yielding cautious behavior.
- By positioning its head directly down, Strider indicates that it has tasted salient object.

Neuromodulation

- Strider's model for learning involves the use of catecholamines.
- Dopamine is theorized to play an important role in learning, specifically the time during learning at which dopamine is released.
- Strider's model is an abstraction of the midbrain neuronal cluster.

Neuromodulation

- Approaching an object for the first time, Strider `tastes' and associates the features of the object with either an appetitive or aversive object (if dopamine is released at the appropriate interval).
- Subsequent trials yield that learning has taken place when, simply upon seeing a salient object, Strider classifies the object as appetitive or aversive and behaves.

Behavioral Inquiries

- Now that all of the components are in place, how is the relationship between all of the components relevant to learning?
- What modifications can be done to test the reliability of the models (e.g. add distracting background to objects)?
- In what ways does the quadruped model differ from Khepera; what does that tell us about the relevance of anatomical structure (i.e. body)?

Summary

- Saliency is a model for instantaneously determining interesting objects in a scene.
- Strider incorporates a biologically-based model for walking and visual attention using saliency.
- Current studies are being done to determine the relation between learning and visual attention, neuroplasticity, and behavior.

The End…

… of the beginning.