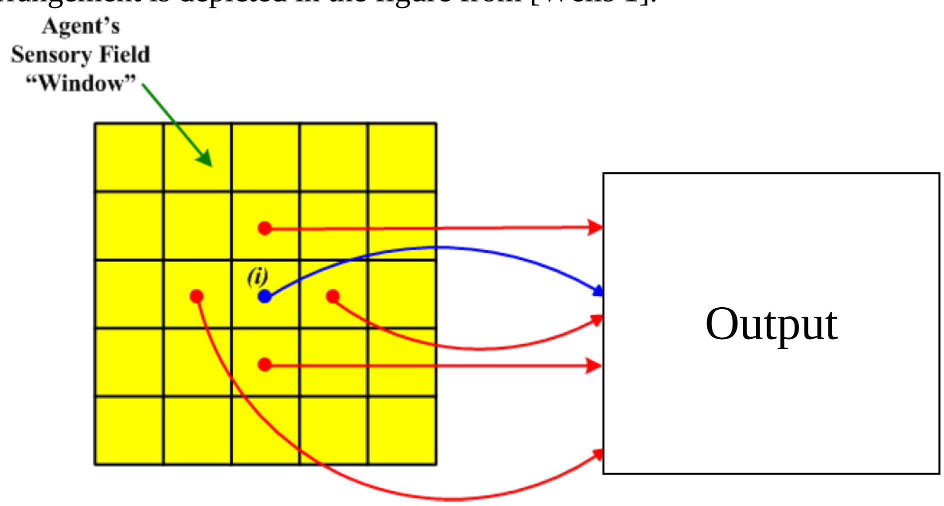
The Potentially Useful Effects of Contrast Enhancement for ART Resonators

By: Quinn MacPherson

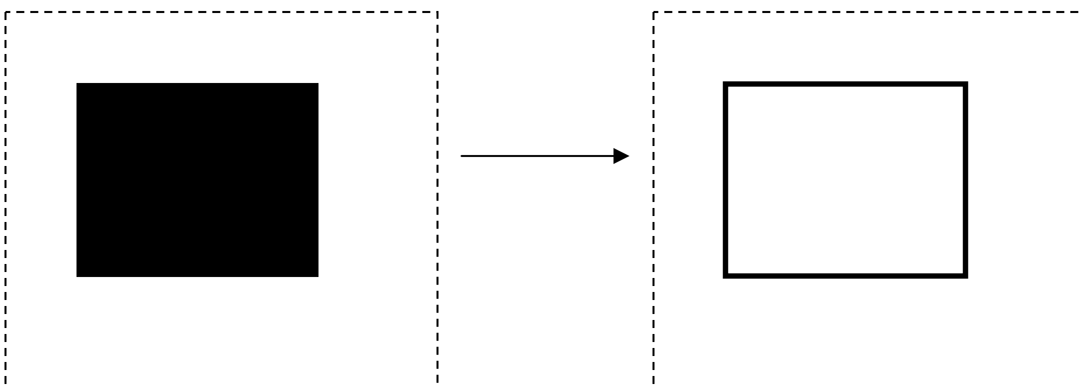
The primary purpose of Grossberg's Adaptive Resonance Theory (ART) networks is to categorize sets of inputs. An ART resonator is a simplified piece of an ART network. Like a complete ART network, an ART resonator's purpose is input classification, that is, pattern recognition. In comparison to a full blown ART network which, as the name implies, is adaptive, an ART resonator has no adaption or "learning" capabilities. The adaptable connection weights that give ART networks their ability to "learn" are simply treated as pre determined constants in an ART resonator. This does not, however, render ART resonators useless for the modeling of human intelligence. After all, much of our nervous system (e.g. the spinal chord) is preprogrammed. Also learning deficient resonators can be useful in the proxy simulation of brain functions other than those being investigated.

This brief paper is a summery of an investigation of the effects that on-center/off-surround contrast enhancement can have on ART resonators. The basic idea of on-center/off-surround contrast enhancement is simple; when nodes have high levels of stimulus they inhibit the stimulus of their neighbors. If we think of the nodes as being part of a simplified optical system, each node would have a corresponding pixel. This is arrangement is depicted in the figure from [Wells 1].

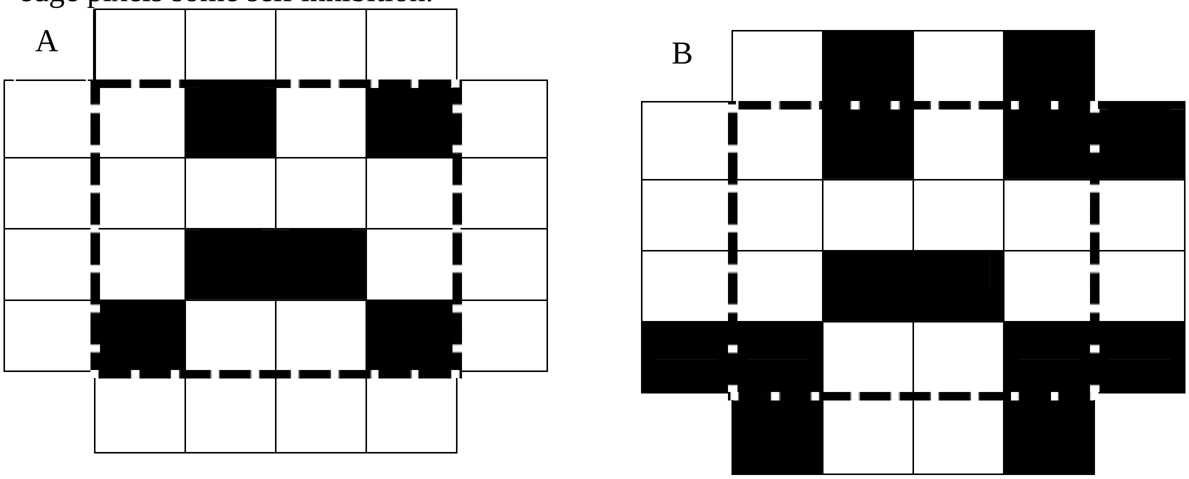


In this way the output from pixel (i) depends positively on the input from what is being seen in pixel (i) and negatively on what is being seen by its neighbors. If this is done to each of the pixels in the window an output window can be constructed that has the same number of pixels as the agent's original sensory window.

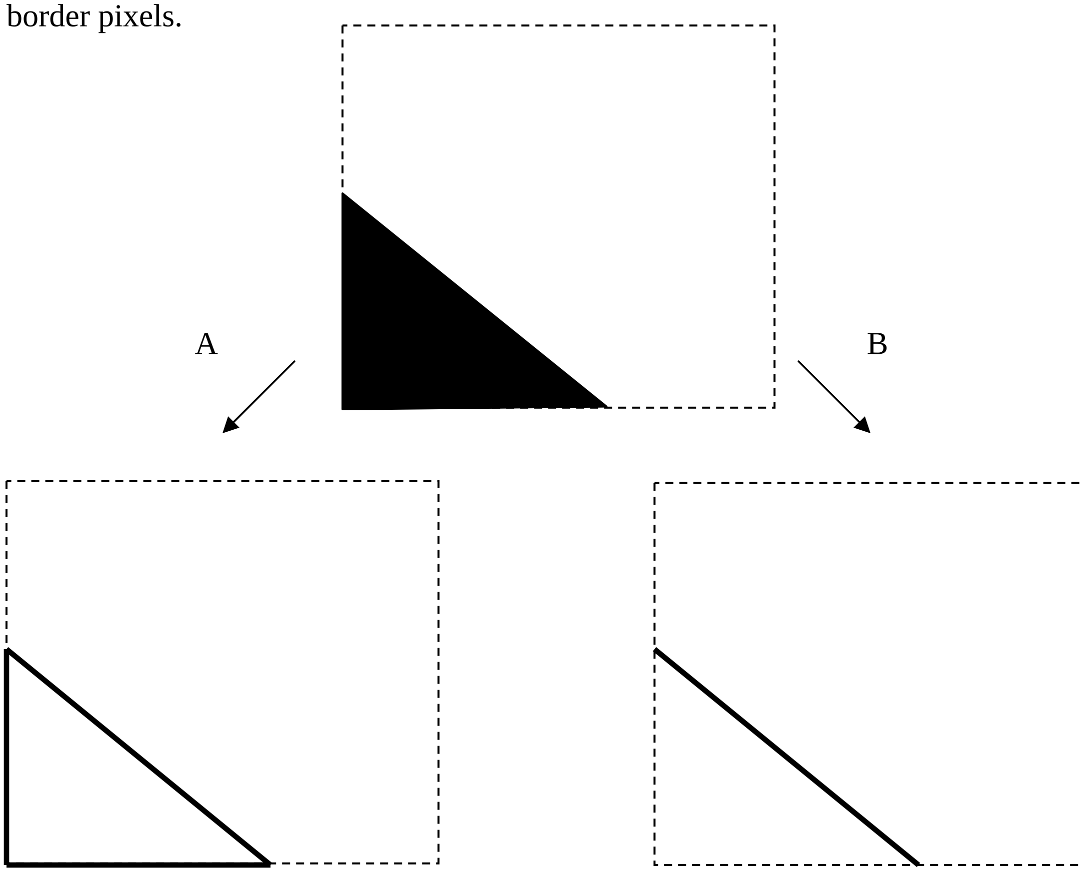
The affect of this contrasting enhancing is that it turns solid figures into solids.



As you may have guessed, a slight problem is encountered on the edges of the sensory window where pixels lack the usual number of neighbors. I have experimented with two ways of avoiding this problem. A: Making an extra layer of zeros around the outside of the sensory window and B: filling the outside with the edge pixel itself. That is, giving edge pixels some self inhibition.



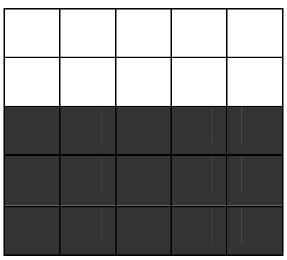
When sent through the contrast enhancers, these two different methods have markedly different results. Method A will produce "extra" lines were positive input is on the border pixels.

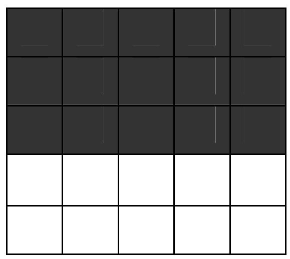


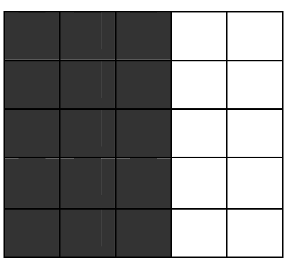
Not only are there two ways to do an on-center/off--surround contrast enhancement there are also two places to apply this contrast enhancement to the ART resonator. Remember that ART resonators use pre-determined weights to recognize patterns it is presented. Contrast enhancement can be used when creating these weights and/or when presenting it these inputs. So in total there are nine different was to use and apply on-center/off-center. So as not to bore you I will not cover all 9 of these possible situations.

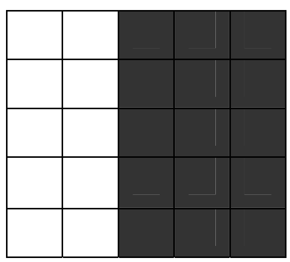
No enhancement weights 1 No enhancement patterns	Enhancement A weights 4 No enhancement patterns	Enhancement B weights 7 No enhancement patterns
No enhancement weights 2 Enhancement A patterns	Enhancement A weights 5 Enhancement A patterns	Enhancement B weights 8 Enhancement A patterns
No enhancement weights 3 Enhancement B patterns	Enhancement A weights 6 Enhancement B patterns	Enhancement B weights 9 Enhancement B patterns

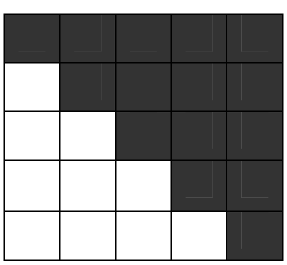
To establish a control group, we will first take a look at no enhancement (1). For the purposes of the current investigation, the ART resonator was given weights that allow to recognize six different patterns.

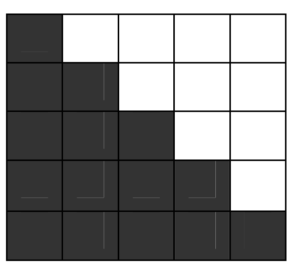

HB


HT

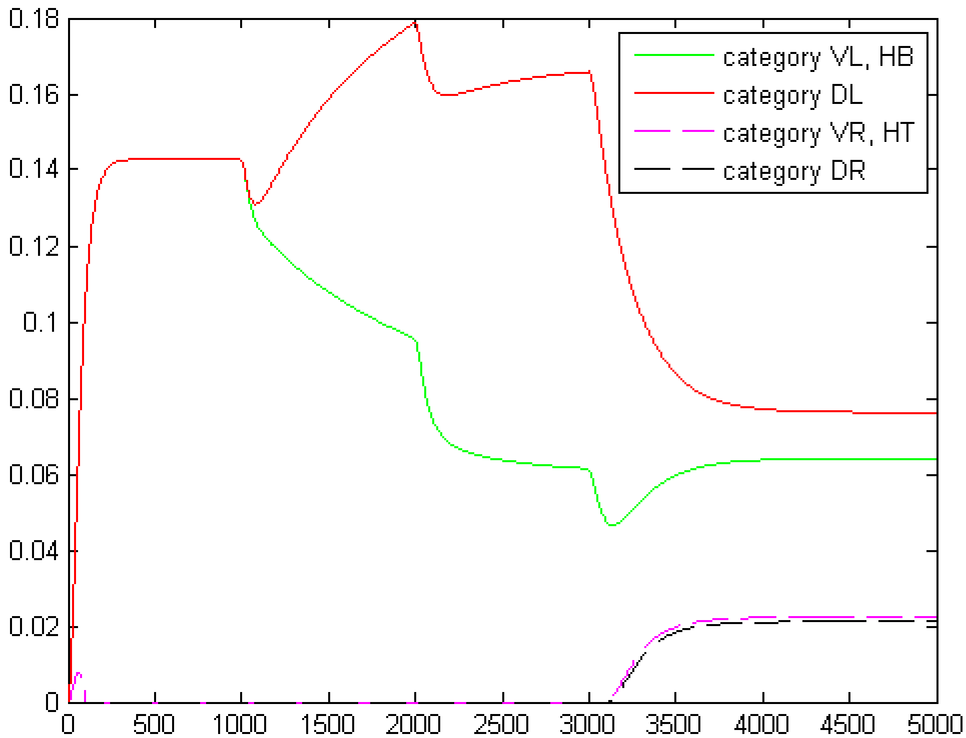

VL


VR


DR

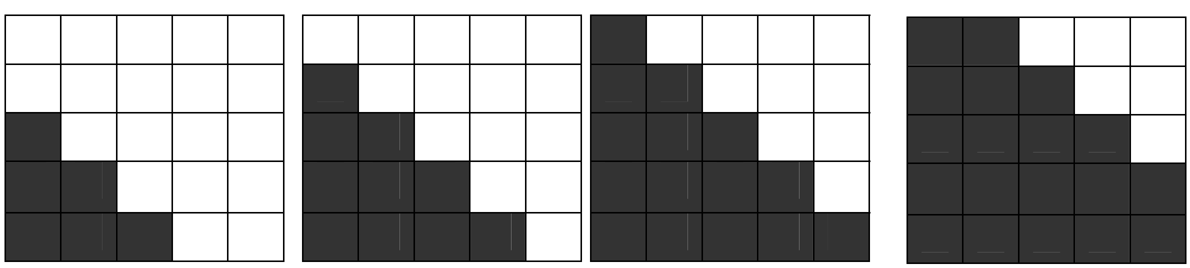

DL

In ART resonators (as in full ART networks) there is a "node" for each of these six patterns that the ART is trying to recognize (they are referred to as Field 2 nodes). In the following figure, level of stimulus in each of these nodes is tracked as the ART resonator is presented a different pattern to recognize every 1000 time units.



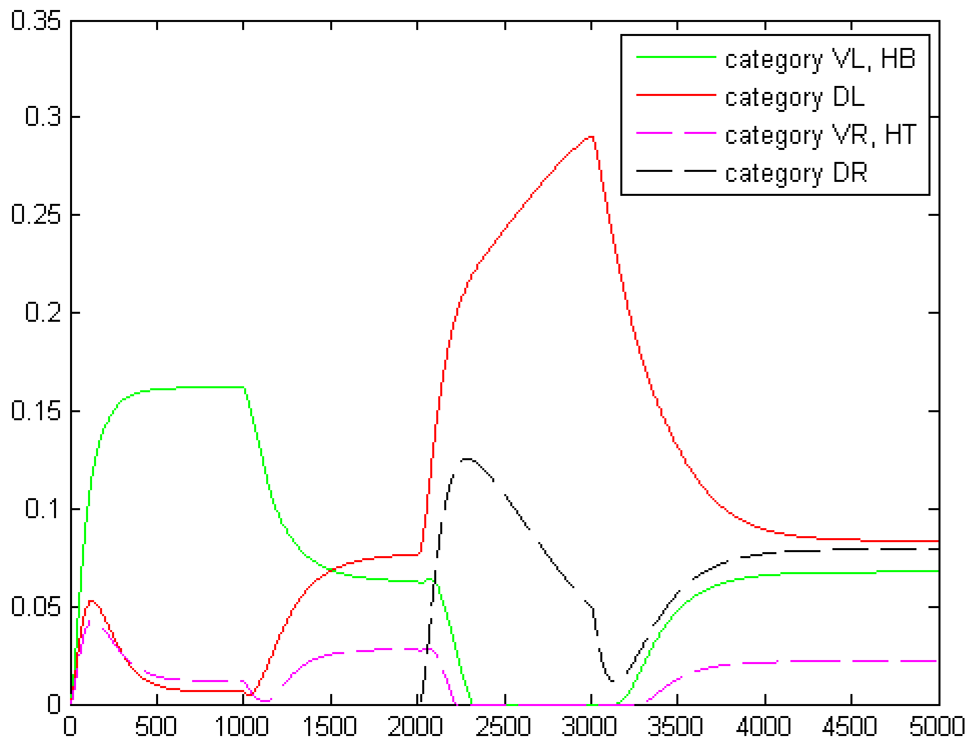
As you can see, throughout the course of the simulation the ART resonator is primarily recognizing DL (diagonal left). This is not surprising because the patterns presented it were as follows:

Time: 0-999 1000-1999 2000-3999 4000-5000



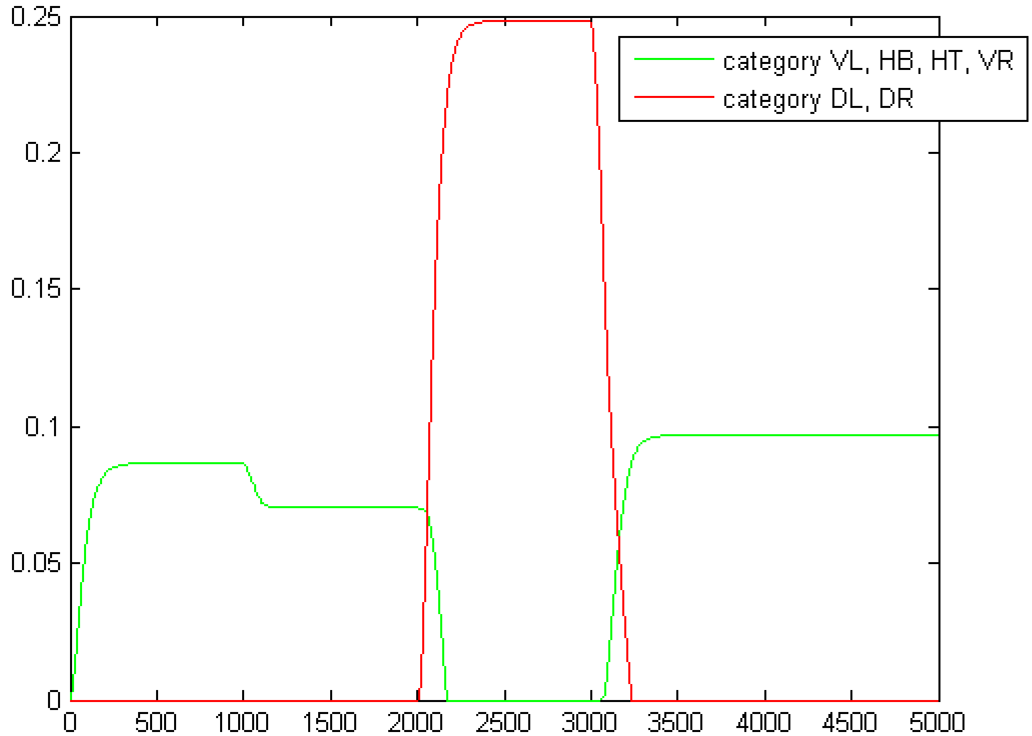
Notice how for the first 1000 time units DL, VL (vertical left), and HB (horizontal bottom) are all equal. This is because the first pattern presented the ART resonator has only six squares and all six of these squares have corresponding squares in the DL, VL, and HB patterns used to set the weights. Once the second pattern is presented, VL and HB begin to "lose" in comparison to DL. Part of what is driving down VL, and HB is that each of the six nodes for the output patterns in the ART resonator has an inhibitory connection to all others. So as DL becomes dominate it begins to drive down VL, HB.

If we add on-center/off-surround contrast enhancement and fill the outside layer with zeros on both our weights and patterns (situation 5) the simulation changes dramatically.

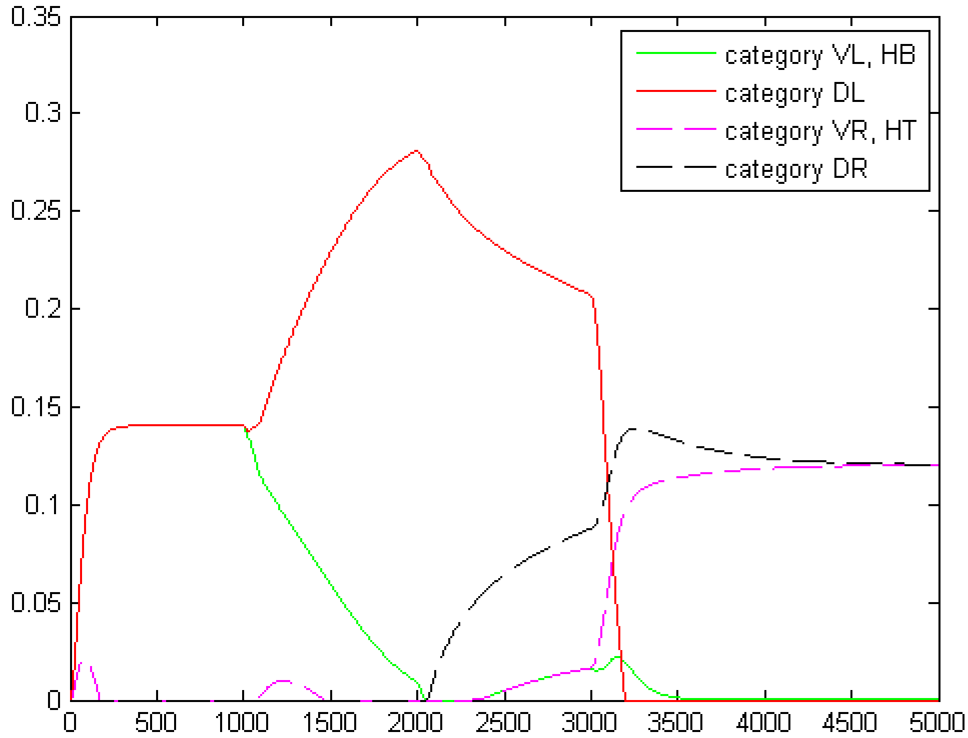


As you can see, the result is a bit sporadic. It only definitively recognizes the pattern it is presented as DL when the pattern is exactly the same was the example pattern (2000-3000).

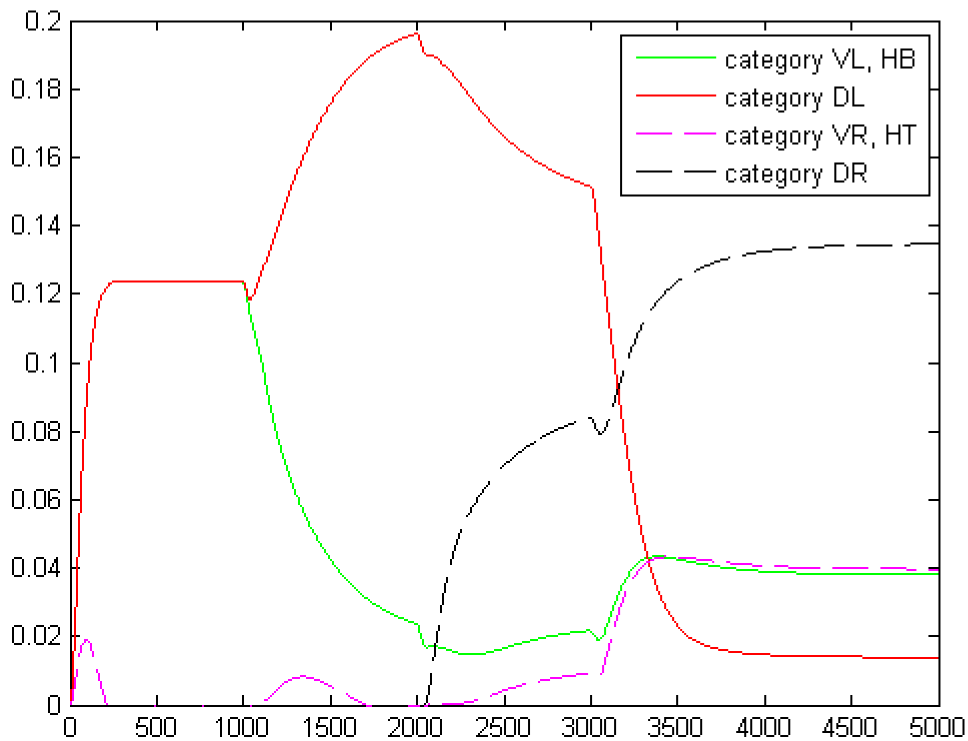
If we change the contrast enhancement to type B (situation 9) we once again see a major change.



This contrast only recognizes the left and right diagonals when it is given the exact pattern it was looking for. Oddly, for the rest of the time it recognizes the all other inputs equally while keeping the diagonal nodes low. Although this contrast enhancing method could have its uses, for the problems we are looking at it is insufficient. If we instead only contrast enhance the patterns presented it while still using the unenhanced patterns when making the weights the results are as follows:
(With contrast type A, that is (situation 2))



(With contrast type B, that is (situation 3))



The potential property of these two results that could make them useful is that they could be used to center a window on an edge. Suppose each output were hooked to a muscle that moves the window in its direction. E.g. HL would pull the window left and DR would pull the window up and to the right. The interesting result that allows this to work is that the when the edge of the diagonal pattern moves into the upper right of the window (3000 and onwards) the DL and DR swap positions as the dominate result (especially in type B). This did not occur with an unenhanced simulation.

The fact that the ART resonator is also returning some recognitions other than the dominate diagonal results is not necessarily a bad thing. As you can see, these secondary results will also tend to drive the window to center on the edge. For example, when, at time 0, the pattern presented the ART resonator is in the lower left of the window there are strong responses from not only the DL, but also the VL and HB. Each of these subordinate responses is driving the window in a general direction that will bring the contrasted edge to the center of the screen. These subordinate responses will sometimes result in taking a less than optimal path, which could be analogues to groping.