Final Report

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Abstract

The final lab within Nonlinear Dynamics focuses on the idea of convolutional neural networks and introduces their concepts. We study this by coding a convolutional processes and analyze it's actions on images and animations.

1 Introduction

Convolutional processes are often used in deep learning within neuroscience. It is a class of deep neural networks and is most often used in visual analysis systems. In this lab we apply a convolutional process to analyze several different types of images. This involves defining a convolutional kernal, the number of input and output channels, as well as the depth of the convolutional filter of the input feature map.

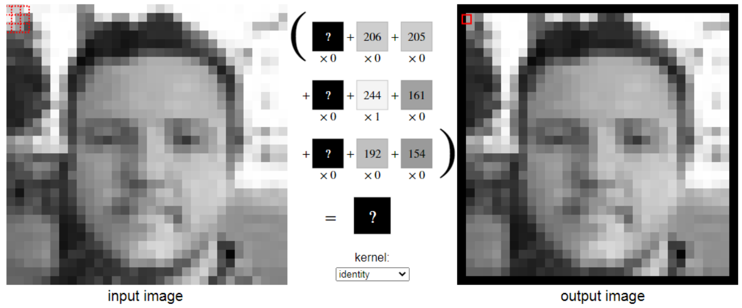
1.1 Convolution through Kernals

The kernal within a convolutional processes is a filter that extracts features of the image inputs. The kernal does this by performing a dot product over each area of the input data, sub-region by sub-region, and then outputs a matrix of said dot products. This can be used to detect edges on a simple scale, but this can be expanded to detect categories of images.

Kernals can also be changed to manipulate an image output. This is done by creating a matrix of pixels and manipulating each pixel within that matrix. This is done for each pixel within the image and the output changes the original image by a certain property.

This concept is very similar to the first lab we did in this class. It introduces the concept that one pixel is defined by those around it. This is very similar except that it changes the output image and ultimately the way the network defines the input.

For example:



Above is an image input and output after convolution has been made by a kernal. The kernal however makes no change in the output because the kernal is telling each pixel within the image to have the same dot product as it's output.
However, if we change this to a predetermined kernal, named "blur" in this example, we see the following manipulation done:

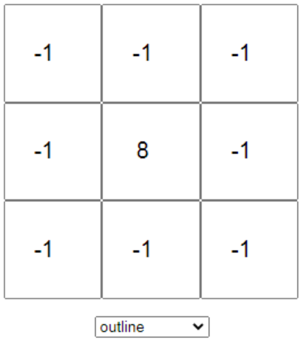
2 Theory

Kernals can be used to manipulate virtually any aspect of an image:

- color
- grayscale
- sharpness
- gain
- embossing the image
- blur

Virtually every aspect of the picture can be manipulated by changing one number within the kernal's dot product.

Below is another example with a picture that had a much denser pixel input.

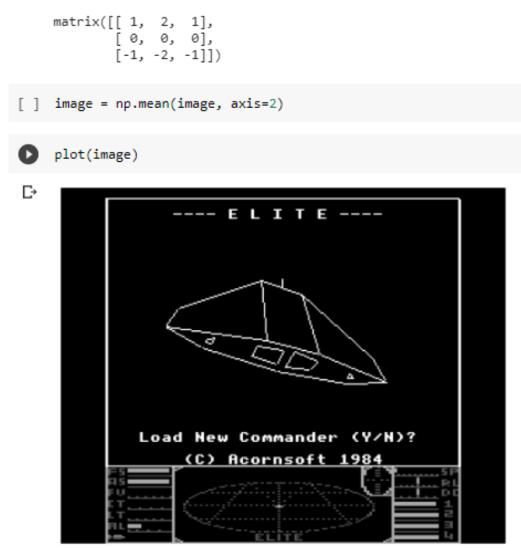


3 Methods

In our lab we introduced some basic predetermined kernals such as our first matrix below:

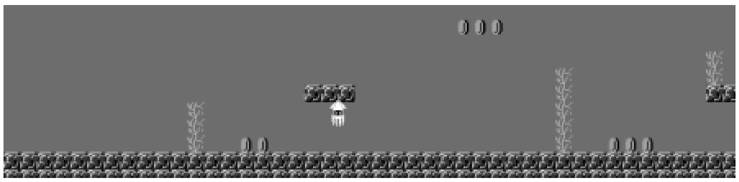
$$a = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

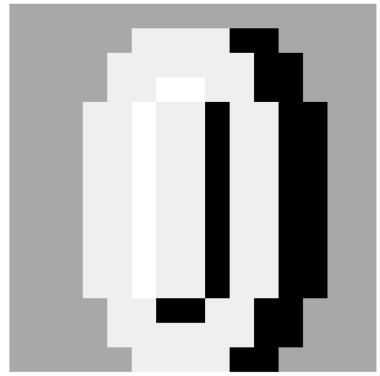
This is a predefined matrix that creates a stronger grayscale output based on the values above and below it.

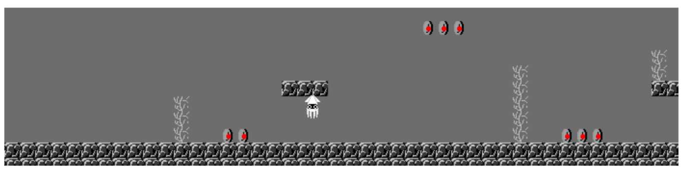


We continue to iterate this process with different matrices to visualize the different outputs and possibilities using kernals.

This idea is expanded upon by assigning a name to a certain arrangement of pixels in the image. This is done with a "coin" in an image of the game Super Mario Bros. Using this coins are able to be identified by the algorithm and within the image.







Following this, several animations of automata are introduced fairly breifly. These include the Game of Life, a model of Surface Tension, Nonlinear Waves, the Wireworld Wire and Oscillator, the Fitzhugh-Nagumo Reaction Diffusion, and Gray Scott Reaction Diffusion. These are all models used to study different dynamical systems like cellular multiplication, fire, waves, oscillators, etc. The animations are very interesting to watch and manipulating areas of the code can be used to study the effects without affecting the natural environment.

4 Conclusions

Convolutional networks are complex tools used by many scientists, including computational neuroscientists, to model systems networks and study their progression. It's a useful tool because it allows one to study the iterative processes of natural systems without affecting environments or participants that would otherwise be involved.
A real life example of this that comes to mind is the Tuskegee Experiment that inhumanely withheld the treatment for syphilis from african americans in order to study the progression of the disease. It was a horrible experiment that resulted in pain and death for over 400 african americans. One can imagine that in the future, convolutional networks can be created to model the progression of different diseases and they could be studied without harming others in order to develop different treatment options.