JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Evolving Images By Analyzing Genome

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Abstract: In order to use a genetic algorithm to solve a problem, a method is required of converting a string of numbers (or symbols) into possible solutions to the problem. Gray scale images can be taken for starting application. This allows solutions to be mutated by changing symbols at random. Importantly, every possible string of symbols must generate a valid solution. Images are widely used in media contexts such as web design, games and video animation. In doing so, the user is also able to control various settings and parameters as suggested by [1], [2], [3], [4], [5] & [6].

In this paper it is described that an interactive image generation tool based on genetic algorithm can be used to create novel, surprising, and sometimes stunning images. The system permits the user to progressively evaluate and generate new images from previous sets of images. For each run of evolution, the number of circles is fixed. The reason being that the more circles an image has, the more able it will be to mimic the target image, so it is figured out that the number of circles would keep increasing. It will be interesting to allow the number of circles to change, but have a penalty for each circle, thus tending to select images made of the fewest circles.

Each circle has six parameters:

- an x-coordinate (0 to the image's width)
- a y-coordinate (0 to the image's height)
- a z-coordinate, which determines the order in which circles are drawn
- a diameter (from 0 to a third of the image's height)
- a grey scale color (0 to 255, corresponding to black to white)
- a transparency (0 to 255, corresponding to completely transparent to completely opaque)
- The z-coordinate does not have a value as such, but is represented by the order of the circles in the genome. Circles are drawn in the order they appear in the genome onto a white background that has the same dimensions as the target image. Mutations in the z-coordinate therefore require the genome to be rearranged, allowing a circle from the back to be brought to the front. With 128 circles, a genome therefore consists of 6400 numbers.

Keywords: **Genetic Algorithms, Genome, Fitness measure, Mutation**

1. Introduction

Images are widely used in media contexts such as web design, games and video animation. The process of creating interesting images can be enjoyable if a useful tool is involved. In this paper, we describe an interactive image generation tool based on genetic programming, which can be used to create novel, surprising, and sometimes stunning images. The system permits the user to progressively evaluate and generate new images from previous sets of images. In doing so, the user is also able to control various settings and parameters. From a user perspective, the system has the following qualities which make generating images entertaining: appealing images arise at random, different styles of images can be created by choosing different function settings and families of images which have common characteristics between parents and children can be generated. A general principle of evolving images by great Darwin is in figure 1.

Figure 1

2. The fitness measure

The fitness of the genome is measured by comparing each pixel of the generated image with the corresponding pixel in the target image. For grey scale images, each pixel has a value 0 corresponding to pure black and 255 corresponding to pure white. For each pixel I square the difference between the value from the target image and the generated image. I can therefore calculate the difference between two images by summing the squared difference of all the pixels. The lower this value is, the closer the two images are, and the ‘fitter’ the genome. In the subsequent updates I use this distance value (which I call *d*), though I've divided it by one million to make it more manageable. In general, a random genome have a *d* value around 200-300, and a highly evolved image have a *d* value around 8-12. Initial results is shown in figure 2.

Figure 2

It was decided to experiment with changing the parameters for the program so a standard image was required. It was wished to start with a grey scale image to keep things simple at first so famous photo of Charles Darwin is taken, which seemed appropriate. The picture was first cropped with 152 x 200 pixels version to speed up computation. There are two images evolved over 150,000 generations; one image is made up of 128 circles, the other from 256 circles. The images are far from exact replicas of the original, though one can hardly think they are recognizable as Darwin. Both images are almost indistinguishable from the original. The overall shape and shading of the evolved images is approximately right, while the details are missing. As it may be expected, the image built from 256 circles has more details (specifically the eyes and nose) than the image built from 128 circles.

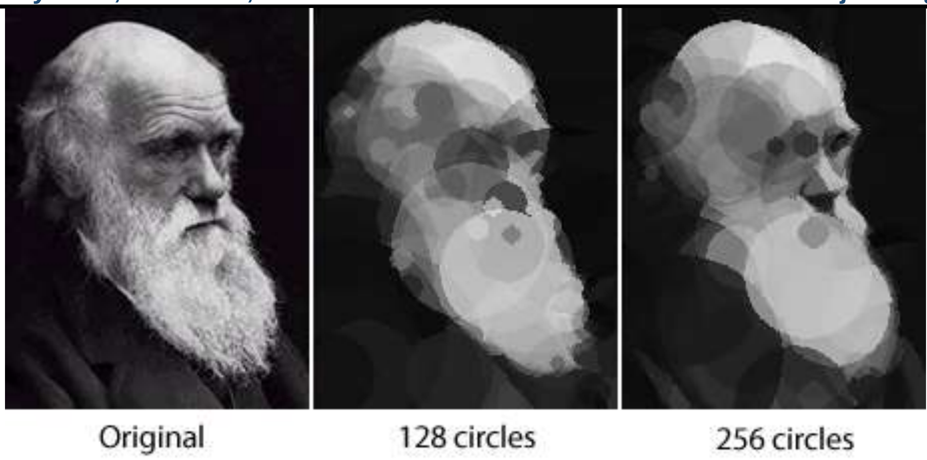

Figure 3

In the first runs through evolutionary search for an approximation of Darwin, It had no way of saving the result. Later it is started to record every genome that was more successful, i.e. its predecessor. As a result it can be re-executed an evolution path at an accelerated rate. In one run of evolving 256 circles for ~150,000 generations, 3010 daughter genomes were 'fitter' (i.e. less distant from the image of Charles Darwin), than the preceding genome. All were generated and saved the 3010 images corresponding to each of these genomes as PNG files, then imported them into Image as an Image Sequence. This created a huge stack of images, which was saved as a QuickTime movie, showing 24 images per second.
Analyzing an evolutionary trajectory:

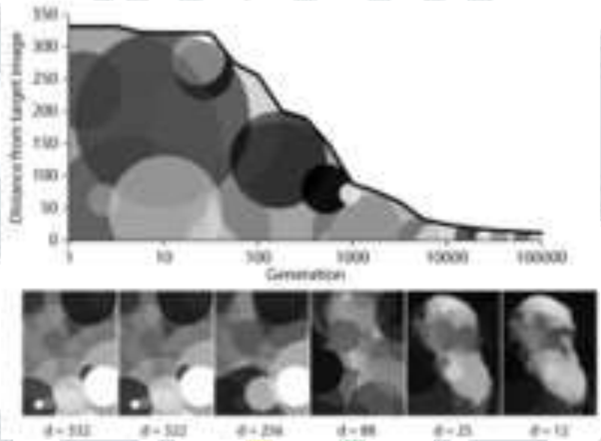

Figure 4

Now it had to re-execute the evolution of an image Darwin using 128 circles, this time recording the genome and the distance the resulting image is from the true image (which is the inverse of a genome's fitness) for every generation in which an improvement is found. Below is a graph showing how the evolved images become a closer and closer match to the true image. Also example images from generations 1, 10, 100, 1000, 10000 and 100000 were also added with their corresponding measure of distance (d, in arbitrary units).
As a side note, the graph is only an approximation of the full set of results, based on the values from 21 evenly spread (on a log scale) generations. The reason for this is that it was drawn the graph in Adobe Illustrator, to see what its graph-drawing function was like. Though it is obviously quite limited, Illustrator does let us draw distracting circles in the background.
The graph shows that largest decrease in the distance value (and therefore the largest increase in fitness) occurs approximately between generations 100 and 1000. However, I would say that the biggest increase in subjective image quality is between generations 1000 and 10000. There is relatively little change between the images of the first 100 generations, suggesting that not much improvement can be seen on that timescale. By generation 1000, the distance value has decreased significantly, but the most we can say about the image is that there is a general area of lightness in the centre with darker regions at the periphery. By generation 10000, the general shape of Darwin’s head is in place, and by generation 100000, the outline is sharpened and some of the details, such as the nose and mouth can be seen. It can be expected how close the image could get by the millionth generation.

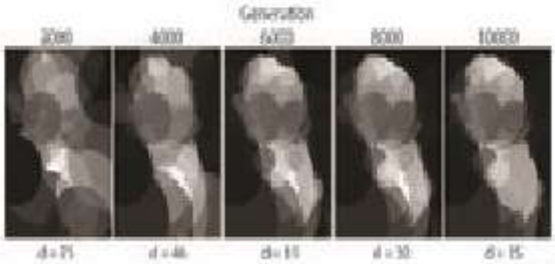

Figure 5

Figure 5 images are from generations 2000 to 10000 with their distance values. This looks like the time when Darwin's image begins to take shape.

3. Genetic analysis

A little more in-depth analysis was done of an evolution with 128 circles, looking at individual mutations. It was identified the mutation that caused the largest improvement in fitness (that is to say, the largest (in absolute and relative terms) decrease in distance between the evolved image and the target image). The mutation occurred in the 36th generation and caused the distance value to decrease by 42 units, or 13%. The result of the mutation was to swap gene 10 with gene 115, and the effect of the image can be seen below in figure 6.

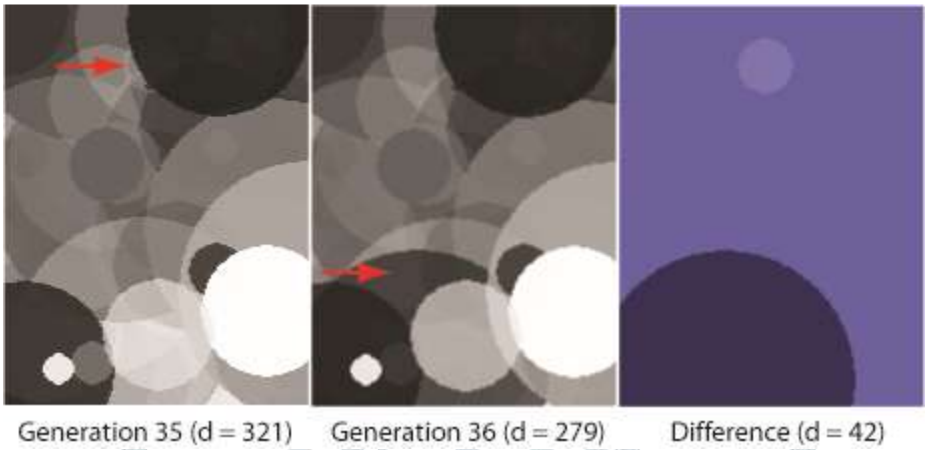

Figure 6

In generation 35, gene 10 encoded a large dark circle towards the bottom of the screen and gene 115 encoded a very transparent circle near the top of the screen. The two circles are shown in the third image above (on a blue background so the transparent, light grey circle is visible), which I made when I tired of playing spot-the-difference. Because gene 10 is one of the earliest genes, it was covered by many other circles, which happened to be lighter. In generation 36, the large dark circle towards the bottom of the screen was now gene 115, so was drawn later, over some of the lighter circles. The result is that the bottom of the screen is darker, and so more similar to the target image. If you look at the previous post, you can see that this circle is basically unchanged at generation 100.

4. Result

This analysis shows that even the most successful mutation in evolutionary history makes a relatively modest difference to the overall image. All of the largest (successful) mutations occurred in the first few hundred generations as the large regions of shading were becoming settled. It seems that this single gene analysis is unlikely to be informative, but one has the tools to compare genomes so comparing genomes from more distance generations can be tried.

Re-executing evolution

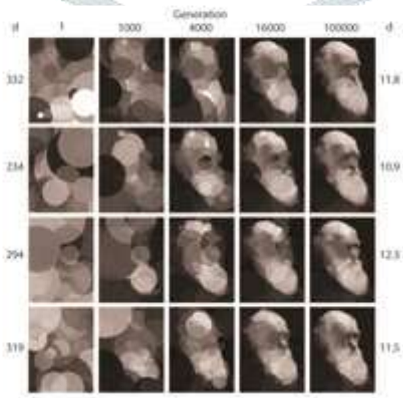

Figure 7

It was re-executed the evolution of Darwin's image using 128 circles four time now. Below is a graph in figure 8 showing the decrease in distance between the evolved and target image over time for each of the runs (the darkest line is the first run). The initial distance value varies quite a lot between the four different runs, but by about 1000 generations, the values are approximately the same. It was planned to compare this rate of evolution with the rate of evolution when there are more circles or a different rate of mutations.

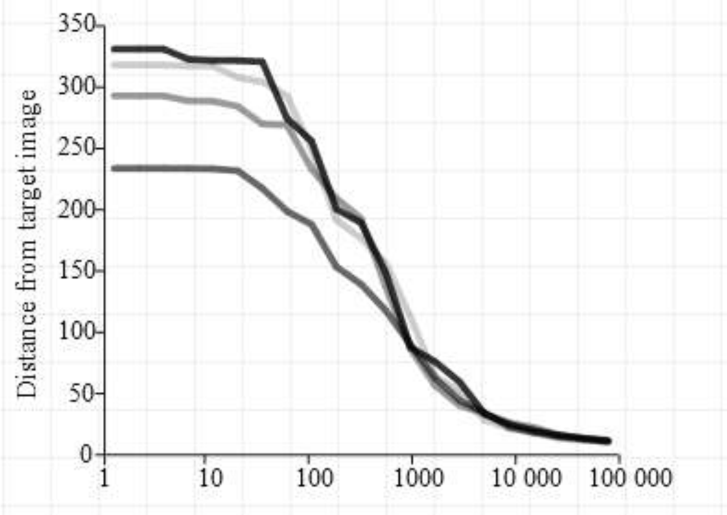

Figure 8

Increasing the number of circles some images of Darwin is shown in Figure – 9

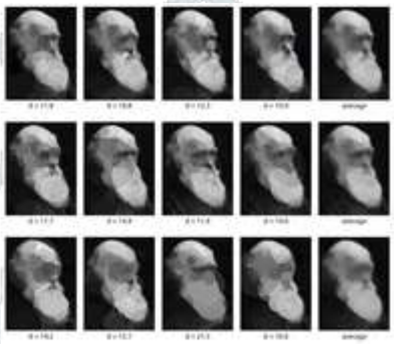

Figure 9

5. Conclusion:

The more circles the image has, the slower it evolves. This is what one would expect because the circles that make the most difference to the distance from the target image are those on top. The more circles there are, the less chance there is that a mutation will affect one of the more important circles. However, it would be expected that while evolution is slower when there are more circles, the rate at which evolution slows should also be slower, such at that, at some point, the images with more circles will overtake those with fewer circles.

Figure 10

It appears that by 100000 generations, the 256-circle Darwins are beginning to catch up with the 128-circle Darwins. To see whether they will eventually 'overtake' the 128-circle Darwins (figure 10), evolution was continued.

6. References:

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