

# Evolutionary Non Photo–Realistic Animations with Triangular Brushstrokes

Ashkan Izadi<sup>1</sup>, Vic Ciesielski<sup>1</sup>, and Marsha Berry<sup>2</sup>

<sup>1</sup> School of Computer Science and Information Technology

<sup>2</sup> School of Media and Communication,

RMIT University,

Melbourne, 3000, VIC, Australia

**Abstract.** We have developed a method for generating non photorealistic animations of a target image. The animations start as a random collection of triangular strokes on a canvas and the target gradually emerges as the animation proceeds. We use genetic programming to evolve programs that draw the brushstrokes. A measure of similarity to the target is used as the fitness function. The best individual in a generation becomes a frame of the animation. We have experimented with *open* and *filled triangles*. Both kinds of triangles resulted in animations that our artist collaborators found engaging and interesting. In particular, the use of filled triangles generated animations that exhibited a novel immersive quality. The evolutionary approach requires artistic judgment in selecting the target images and values for the various parameters and provides a rich environment for exploring novel non photo–realistic renderings.

**Keywords:** Artificial intelligence, Computer graphic, Evolutionary art, Evolutionary computation, Genetic programming.

## 1 Introduction

It has been claimed that one of the major benefits of using evolutionary computing to solve an art or design problem is that the evolutionary process can generate novel, unlikely combinations that a human designer or artist would not think of [4]. Non photorealistic rendering (NPR) is an area in which artists are continually seeking novel, creative and unusual kinds of renderings. Our motivation for the work presented in this paper is to investigate whether it might be possible to find a new style of non photorealistic rendering using a form of evolutionary computing.

Non photorealistic rendering is a developing art-form where the goal is to show an image in some more interesting way than as a photograph. Some examples of non photorealistic renderings include pencil sketches, oil paintings, watercolour paintings and photomosaics. Traditionally non photorealistic renderings are still images. However, the use of evolutionary techniques provides an opportunity to add the time dimension. In an evolutionary run the best individual in a generation gets fitter and fitter as the generations increase. If the measure of fitness is similarity to a target image, then the best individual will become more and

more like the target image as the generations increase. We have found that the best individuals can be combined into an engaging movie that holds the viewer's interest as a recognisable subject slowly emerges from a random collection of strokes.

Current evolutionary algorithms are primarily designed for optimisation problems where the aim is to find the optimal solution as quickly as possible with minimal use of resources. These algorithms need some modification for the art domain where the aim is to find interesting images and animations. For example, an animation that reveals the target too quickly in the first few generations will not be very engaging and a rendering that has optimal fitness will be an exact match to the target and not very interesting as a non photorealistic rendering.

The work presented in this paper is based on the work of Barile and et al. [3]. This work was limited to brushstrokes that were simple grey level lines and stroke placement was limited to blending pixel values when two strokes crossed. Nevertheless the system was able to produce animations and still images that excited our collaborating artists. We build on the work of Barile et al. in three ways: (1) We use color brush strokes, not just grey scale, (2) We use more complex triangular brush strokes, not just lines, (3) We explore a wider range of options when a new stroke will overwrite a pixel already drawn by a previous stroke, not just blending. The new options are *partial stroke* where the new stroke is immediately terminated if it will overwrite a previously drawn pixel, and *no stroke* where the new stroke is not drawn at all if it would overwrite a previously drawn pixel. Our overall goal in this work is to explore a range of brush strokes and placement strategies and determine whether they can be used to produce engaging and interesting animations. In particular, our research questions are:

1. How can we construct a system for non photorealistic rendering with triangular brushstrokes using genetic programming?
2. What are the differences between using open and filled triangular strokes?
3. How do the different placement modes (*blend*, *partial stroke*, *no stroke*) affect the evolved animations?

Where it is necessary to make aesthetic judgments about evolved artworks we will seek the views our collaborating artists.<sup>1</sup>

## 2 Related Work

### 2.1 Evolutionary Art

Dawkins was one of the first researchers to show how evolution on a computer could be combined with the aesthetic preferences of a user to produce pleasing or interesting forms in 1986 [5]. In 1991, Sims [11] produced his animation Panspermia which was about forests of synthetic 3D plant structures. He employed artificial evolution to evolve the growth rules of plants, for example, how

---

<sup>1</sup> We thank Karen Trist, from Media and Communication, RMIT, for her comments.

fast branches of a plant can grow. In Turbulence and a number of follow up works, McCormack [8] used an evolutionary approach to generate a series of artworks of an imaginary natural world.

## 2.2 Non Photo-Realistic Rendering

Gooch et al. [6] identify two main approaches to image painting and drawing in NPR. The first approach uses user-assisted painting programs to place brushstrokes on the canvas manually. The second approach uses automated programs to place brushstrokes on the canvas and the stroke positions are calculated without using any user interaction. The automated approach is divided to two different categories. The first category uses standard computer-graphics rendering without any evolutionary computing technique. The second simulates painting with an evolutionary computing techniques.

**Evolutionary Approach:** Various evolutionary techniques have been used for NPR. For example, Aupetit et al. [1] used an interactive genetic algorithm to evolve parameters for ant paintings. Samet et al. [10] have designed an NPR system based on ant colony optimisation that can navigate and sense the environment of a target image. They generated painterly and pencil sketch renderings. In 2008, Neufeld et al. [9] introduced a system that can replace the user evaluation interaction. This system can produce non photo-realistic image filters as well as normal evolved images. Neufeld et al. employed genetic programming with multi-objective optimization. Barile et al. [2,3] used simple grey line strokes to generate a non photo-realistic rendering by genetic programming.

## 3 Configuration of Genetic Programming

An overview of the evolutionary process is shown in algorithm 1. Our programs are evolved according to the grammar shown in figure 1. To draw a brushstroke

---

### Algorithm 1. Genetic Programming for Non Photorealistic Rendering

---

```

Initialise population with four random individuals
while Maximum number of generations is not reached OR pixel differences are too
big (fitness) do
  Generate an image from each individual
  Compute sum of pixel differences with target (fitness)
  If the new best is better than previous best, write frame of movie
  Copy the best individual to new population (elitism)
  Select two individuals for crossover
  Place the children in the new population
  Select one individual for mutation
  Place child in the new population
end while
Compose a movie from individual frames

```

---



types of triangular strokes, empty and filled. An empty triangle can be drawn by knowing two lines and the angle between them, and then applying basic geometric calculations for the third line.

### 3.2 Different Stroke Placement Strategies

There are a number of considerations when placing a stroke on the canvas. Firstly, what to do if the new stroke will write over a pixel that was already written in a previous stroke (placement mode), and secondly whether to use any information from the target image in drawing the stroke (guided or unguided search).

**Placement Mode:** We have experimented with three different modes for dealing with the situation where a new brushstroke would overwrite a pixel already drawn on the canvas by a previous stroke: *blending*, *partial stroke*, *no stroke*. In *blending* mode, if two strokes cross, a new pixel value will be the average of the canvas pixel and the brush pixel. In *partial stroke* mode, the new stroke is drawn until a previously drawn pixel is encountered at which point drawing ceases. In *no stroke* mode, the new stroke is not drawn at all if it would overwrite a previously drawn pixel. In these last two modes, once a pixel has been drawn there is no possibility of improvement with a later brushstrokes.

**Guided and Unguided Search:** Using information from the target image in placing a stroke can enable accelerated convergence. In *guided search* mode a pixel in the evolved image is only changed if its new value brings it closer to the corresponding target pixel. In *unguided search*, a pixel in the evolved image is unconditionally updated by a brush stroke. In some situations of guided search the acceleration is too fast and the target is evident far too early in the first few generations.

## 4 Experimental Results

We have experimented<sup>2</sup> with many different images and five to twenty runs for each image. We have explored a large number of combinations of values for selection, population size, elitism, crossover and mutation rates. The best configuration is shown in table 1. Surprisingly, small populations are best for this problem domain.

### 4.1 Open vs. Closed Triangular Brushstrokes

Figure 3 shows a comparison of filled and unfilled triangle brush strokes for the same target image. Figure 4 shows the progression of fitness values during the course of the evaluations for one run. Low fitness values indicate closer resemblance to the target. Not surprisingly, filled triangles have better fitness and converge towards a solution faster than the empty triangular brush strokes. This is because drawing more pixels in a stroke gives more opportunity to be closer to the target.

<sup>2</sup> Some of our animations can be found at <http://evol-art.cs.rmit.edu.au/ai10>

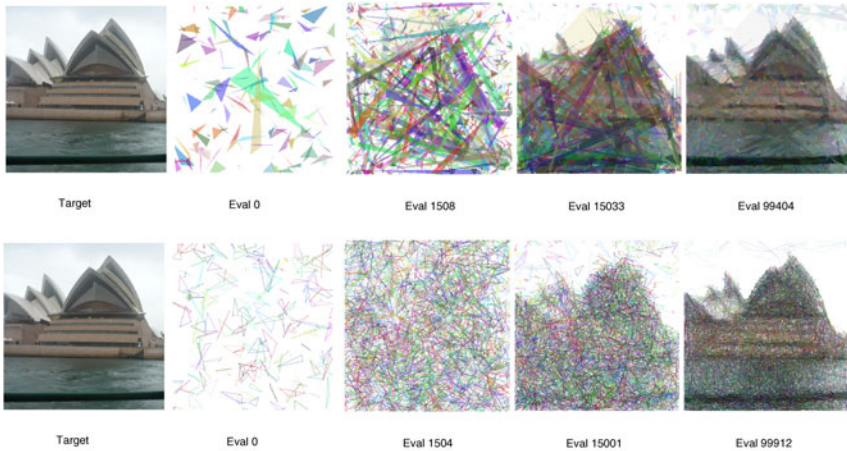
**Table 1.** Common GP parameters for our experiments

Functions	<i>program3,4</i> and <i>triangle</i>
Terminals	float numbers
Maximum evaluations	80000–100,000
Max Tree size	8
Min Tree size	3
Population	4
Crossover	50%
Mutation	25%
Elitism	25%
Selection	Roulette Wheel
Termination	Max. generation reached
Stroke mode	<i>Blending, partial stroke, no stroke</i>
Target information	<i>Guided</i> and <i>unguided search</i>

**Artists Evaluations:** Our collaborating artists have examined a number of evolutionary runs with filled and unfilled triangles for a variety of target images. They conclude that “The filled triangles provide an extension to the application in a way that the empty triangles do not. The filled triangles offer more possibilities for experimenting with perspective and figure and ground relations”.

### 4.2 Different Size of Triangles

The size of triangles can directly influence the look of evolved images. An example is shown in figure 5. In this figure, small triangles have been rendered by two small line lengths ( $L1 = 20$  and  $L2 = 30$ ) and large triangles have been



**Fig. 3.** Sequence of rendered images with the filled triangle (top) and empty triangle (bottom) brushstrokes, blending mode, guided search

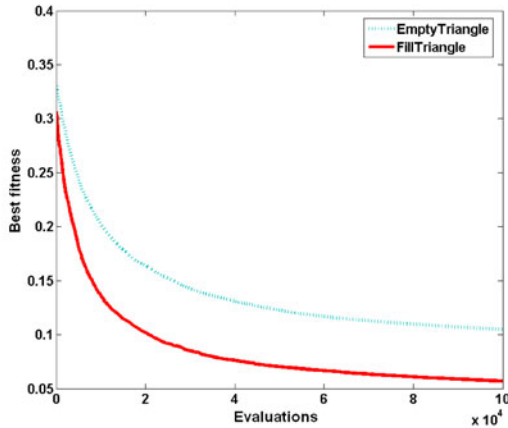


Fig. 4. Fitness progression for the runs of figure 3 for 100,000 evaluations

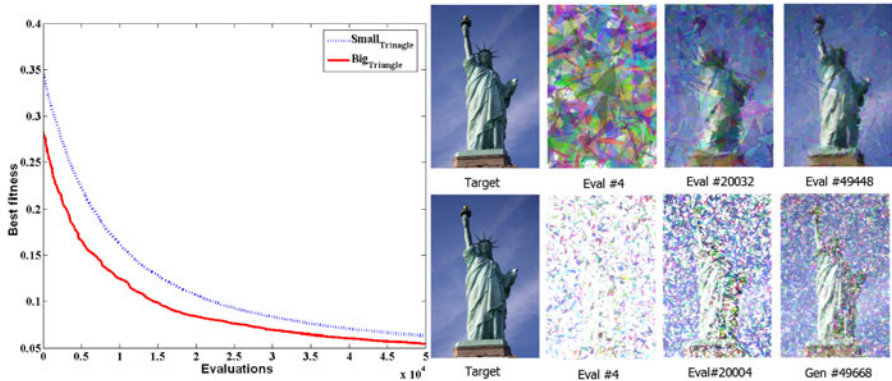


Fig. 5. Left: Fitness for small and large triangles. Right: Rendered images for large and small triangles.

rendered by two large line lengths ( $L1 = 150$  and  $L2 = 100$ ). As can be seen from the graph of figure 5, large triangles tend to give faster convergence by providing better fitness values. As can be seen from figure 5 at 50,000 evaluations, using *blending*, the fitness values are close to each other. However, the final rendered images are quite different. Smaller triangles can give more photorealism, but larger triangles give a more interesting rendering. However, for the *partial stroke* and *no stroke* modes small triangles tend to give faster convergence.

**Artists Evaluations:** Artists comment that “If the aim is to create an immersive experience that engages the emotions transporting the viewer to an imaginary world as well as an intellectual response, then large triangles with gradients are more likely to satisfy this aim. However, if the intention is to engage analytical

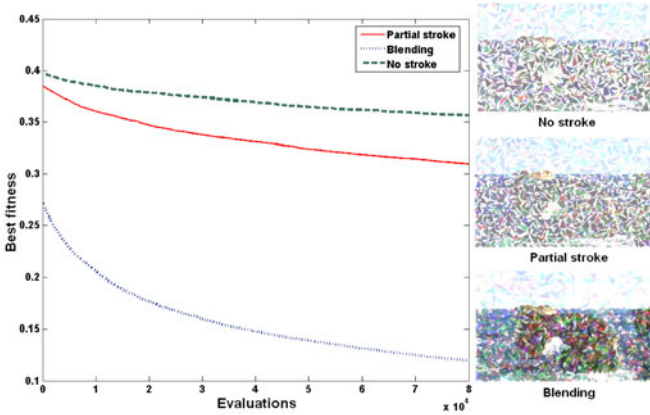


Fig. 6. Comparison of placement modes, unguided search

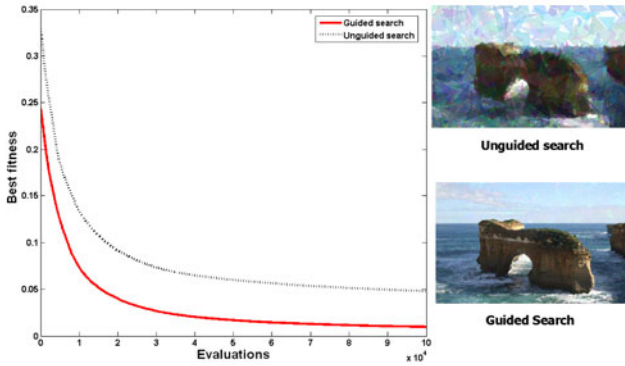


Fig. 7. Left: Fitness differences between guided search and unguided search; Right: unguided search (generation= 45, 589), guided search (generation= 45, 528)

thinking about the image, than smaller triangles may be more appropriate.” Also “there is always correlation between thought and feeling and we cannot think without any feeling. Rendering images using a big triangle size causes the images to have a greater affective impact than images made up of small triangles”.

### 4.3 Different Stroke Placement Modes

**Unguided Search.** Figure 6 shows examples of the three different modes of stroke placement *blending*, *partial stroke*, *no stroke*. As can be seen from figure 6, the blending mode converges towards the target much faster than the two other modes. We need more generations to get close to the target with the

“*partial stroke*” and “*no stroke*” modes. However these two new modes provide different styles of animations and this gives artist users more creative opportunities.

**Guided Search.** Figure 7 shows the fitness differences between the “*guided search*” and “*unguided search*” approaches. By using *guided search*, the system is able to reach to the target very closely, in some cases, even at the initial generation. *Guided search* over many generations can achieve a high degree of photo-realism. The artist needs to terminate the evolution when the desired degree of photo-realism is achieved.

One current drawback of our algorithms is that they can be slow. A run with guided search for a relatively small target can be done in minutes, while a run with unguided search and a large target can take several days.

## 5 Conclusion

Our overall goal in this work was to explore a range of brush strokes and placement strategies and determine whether they can be used to produce engaging and interesting animations. We have discovered a number of combinations of triangular brush strokes and placement strategies that can produce animations that artists find interesting, in particular large closed strokes in blending mode. While we cannot claim to have discovered a new style of non photorealistic rendering, we believe that the combination of large triangles and blending is one that a human artist is unlikely to think of.

With respect to our specific research questions, we have shown how to employ genetic programming to generate engaging non photo-realistic animations. This can be done with tree based genetic programming with a *triangle* draw function and two gluing functions, *program3* and *program4*. We found that a population size four with 50% crossover, 25% mutation and 25% elitism was the best configuration. This is consistent with Barile and et al. [2]. We found that runs with closed triangular brushstrokes converged towards a target faster than open triangular brushstrokes. Our artist collaborators commented that closed triangular brushstrokes create an immersive experience that is more engaging than open triangular brush strokes and that open triangular strokes evoke analytical thinking but filled triangular brushstrokes are more affective. Different modes of stroke placement provide different kinds of renderings. With the *blending* mode, we reach the target quicker and generate a more engaging rendering than with the *partial stroke* and *no stroke* modes. By using information from the target image (guided search), we have shown that fitness is improved around 100% compared with not using any information from the target image (unguided search). Guided search provides better resolution of the final image than unguided search, and images resembling the target are evolved earlier, too early in some cases.

**Comments From Our Artist Collaborators:** Our artist collaborators made the following comments while working with our programs: (1) “Triangular brush

strokes create some good visual illusions”, (2) “Visual illusions made by triangular brush strokes, especially filled triangles, cause an emotional, or affective, response in a viewer. This is a good thing”, (3) “I like to have control over variables to create specific effects I have in mind”. These comments suggest that our programs are capable of rendering images and animations that are conceptually strong.

**Future Work:** In future work, we plan to optimize the fitness calculation to speed up the runs, to explore different kinds of brush strokes and to investigate special purpose genetic operators for these kinds of rendering tasks.

## References

1. Aupetit, S., Bordeau, V., Monmarche, N., Slimane, M., Venturini, G.: Interactive evolution of ant paintings. In: *The 2003 Congress on Evolutionary Computation, CEC 2003*, vol. 2, pp. 1376–1383 (8-12, 2003)
2. Barile, P., Ciesielski, V., Berry, M., Trist, K.: Animated drawings rendered by genetic programming. In: *GECCO 2009: Proceedings of the 11th Annual Conference on Genetic and Evolutionary Computation*, pp. 939–946. ACM Press, New York (2009)
3. Barile, P., Ciesielski, V., Trist, K.: Non-photorealistic rendering using genetic programming. In: Li, X., Kirley, M., Zhang, M., Green, D., Ciesielski, V., Abbass, H.A., Michalewicz, Z., Hendtlass, T., Deb, K., Tan, K.C., Branke, J., Shi, Y. (eds.) *SEAL 2008*. LNCS, vol. 5361, pp. 299–308. Springer, Heidelberg (2008)
4. Bentley, P., Corne, D.: *Creative evolutionary systems*. Morgan Kaufmann Pub., San Francisco (2001)
5. Dawkins, R.: *The Blind Watchmaker*. Longman Scientific & Technical, New York (1986)
6. Gooch, B., Gooch, A.: *Non-photorealistic rendering*, ch. 4,5,9. AK Peters Wellesley, MA (2001)
7. Koza, J.: *Genetic programming: on the programming of computers by means of natural selection*. MIT Press, Cambridge (1992)
8. McCormack, J.: *Impossible nature: the art of Jon McCormack*. Australian Centre for the Moving Image (2004)
9. Neufeld, C., Ross, B.J., Ralph, W.: The evolution of artistic filters. In: *The Art of Artificial Evolution*, pp. 335–356. Springer, Heidelberg (2008)
10. Semet, Y.O., Reilly, U.M., Durand, F.: An Interactive Artificial Ant Approach to Non-photorealistic Rendering. In: Deb, K., et al. (eds.) *GECCO 2004*. LNCS, vol. 3102, pp. 188–200. Springer, Heidelberg (2004)
11. Sims, K.: Artificial evolution for computer graphics. *Computer Graphics*, 319–328 (1991)