Pedagogical Evolved Art: An Examination and Results of the Innopolis AI Art Contest

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***Abstract*—Evolutionary Algorithms (EA) capacitate a myriad of possibilities and creativity. Therefore, while teaching evolutionary programming to students of Computer Science, we decided to equip them with the technical details and then let them explore the creative aspects themselves. As part of the introductory course on Artificial Intelligence, an evolutionary generation of art is an assignment. The teaching goals were to inform students of creative aspects of EA as well as invoke critical thinking and analysis in them. The students generated images via EA, and the only restriction was on the pixel size for input. The assignment was well-received, despite its complexity. Students engaged with the art generation and felt confident in expressing their perspectives of creativity and art. The assignment evaluation as a contest allowed for judges from diverse domains such as Computer scientists and artists. The goals of the course are met as the students were trained not only in technical details but also realized the capacity and generative power of algorithms, as they practically simulated and expressed their creative thoughts via this contest. Furthermore, the students engaged with the philosophical foundations of computational creativity effectively by the design process, and a report completed along with the work required them to develop their own artistic exegesis of the algorithm.**

***Index Terms*—Art, Contest, Genetic Algorithms, Education**

I. Introduction

The *Innopolis artificial intelligence art* contest has been initiated with the intention to provide practice and understanding of evolutionary algorithms. Furthermore, the art theme provided students with the opportunity to express and display their artistic and aesthetic preferences. The students have a diverse definition of what is art.

The question as to if a computer can be said to be creative and what exactly is computational creativity is a greatly debated topic [1], with foundations back to exhibitions in London in the 1960s [2]. Some make appeals to the issues of the Chinese room [3] in that computers can build things but not understand what they produce, making humans distinct creative forces. Others make claims based on the Turing test [4] in which emulation should be seen as proving a property as esoteric and subjective as intelligence or creativity, and surely if the computer artwork cannot be told apart from a human creator, either they are both creative, or the concept of creativity has little meaning. Some propose and consider alternative methods, IDEA, and FACE models as better evaluative measures than the Turing test [5].

The philosophical foundations of what is computer art have been contested. The Turing test gives many examples of a computer being asked by an interrogator to produce some manner of artistic expression [4]. In 1966, poets would note the issues inherent in making a creative poem solely though a computer and would pessimistically decide it was not possible [6]. However, poetry is now a well-studied area of computer expression with numerous types of generative methods [7].

Hertzmann [8] presents a series of hurdles which he sees as being essential for the computer artist. One of these hurdles is a need for intent in order to have creativity. Whereas, Mazzone and Elgammal [9], accepts the idea of a computer as a tool in the creation and as a creative force in conjunction with the programmer. As these debates rage, the news media has grasped on to single points and made definitive claims that computers are not of creative stock. It implies that scientific debate can be settled by public press decree. The debate has also entered the news due to the Robbie Barrat scandal in which a creator of an Artificial Neural Network whose work was used, with questionable permissions, by others create a painting which would sell at auction for $432,500 [10].

This paper acts as a more thorough evaluation of the contest entries than the initial contest report in [11]. The evaluation expands on the entries themselves and the student reports produced showing a more significant example of the intent in the design. This human intent in the development of the algorithms and tools agrees with Meazzone and Elgammal and refutes Hertzmann.

This was used as a classroom evaluative assignment. Active learning methods, while found to promote student learning [12], is not seen as substantially in computer science [13]. Innopolis has the goal of using active learning methods inside of classrooms in order to engage students and lead to better learning outcomes [14], and the contest meets with a more creative format of instruction.

The remainder of the is paper is organized as follows: Section II lays out the design of the contest itself commenting on the rules of the systems developed. Section III gives a summary of the methodologies used in order to meet with the objective of the development of an evolutionary art system. In Section IV, the artistic exegesis or rationale provided by the students is expanded upon and examined. Common themes in these reports are the use of polygons, colour palette changes, and the use of fractals to stand in for parts of the target image. The evaluation of the entries and the winners are displayed in Section V. Finally, Section VI concludes the examination and gives suggestions for future contests.

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II. The Contest Proposal

For the second assignment for the Introductory Class on AI, a contest was run with the following rules:

1) The process implemented would need to be an Evolutionary Algorithm. This choice was made to make the content of the competition, similar to what was being taught in the lecture.
2) The process implemented should take a 512 by 512-pixel image as input. This was made to allow for a fitness function to be created as a fitness function that requires a definitive input. The rationale for opting for 512 by 512-pixel was that several available test images were generally of this size. During the contest, a set of images would be given as inputs, unknown to the developers.
3) The process implemented should present a 512 by 512-pixel image as output. This was based upon the size of the input image.

Other than these concerns, made primarily due to the available resources and the requirements of the course and curriculum design, no other conditions were set on the images created in the first stage of design. The students could use any set of images for their report; however, for the contest, we limited the set of base images for a generation. This limitation was to ensure a levelled playing field, as a selected input image could inherently be more beautiful than that used by another student. Furthermore, it would focus the design on generating an artistic creation without an assumed input image, meaning the created method would need to be general. The students would select one target image from the set and provide an output into an online collection system. They then were allowed to vote for three images from their fellow students. The images with the most selections would then be sent to a panel of guest judges. The guest judges were selected for their backgrounds in AI, PCG, Art, or a combination of the factors. The judges were presented with six images that had emerged as chosen favourites of the students and provided a ranked ballot.

III. Evolutionary Algorithm Specifications' Summary

The student submissions were analyzed to identify the common features among their implementation as well as unique implementation methods.

A. Representation

The most common representation is circles and polygons (triangles, hexagons). Another(but less common) are texts (letters, numbers, symbols), lines. Other representations include zeroes and ones, 2, using other shapes, as in Figure 3, emoji, texture blocks (from Minecraft). Other pictures or their parts were also used as a brush (examples). Many students decided to use circles because it is considered to be an ideal figure in art. The triangles are used because it has the capacity to represent many shapes.

The genes are coordinates, colour RGB/RGB(A), rotation angle or pixels (as the representation of a brush). Manipulations on an alpha channel are added for more details.

Fig. 1: Original Image approximated with Triangles

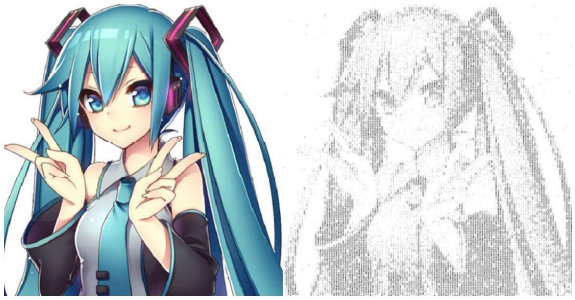

Fig. 2: Original Image approximated with Zeroes and Ones

Furthermore, another technique applied is the use of pixels or a block of pixels. For example, swapping pixels of an image.

The technique of splitting squares (piece-by-piece division) such as diagonal, vertical or horizontal is also adopted by some students. The colours of the resulting segment are either random, from the colour palette, copied from one of the neighbours, from the original picture, and the mean colour of some region or inverted colour, as in Figure 4 . The mosaic effect is produced through the same techniques, Figure 5. An additional parameter of tilt is also introduced. Sometimes horizontal stripes of the picture are used instead of squares. Some students manipulated parts of the picture by shuffling, overlaying or applying some effects on them.

Some manipulated on the channels separately. Another

(a) **(b)** **(c)**

Fig. 3: The flower image in (a) is approximated with water image in (b) resulting in image (c)

Fig. 4: Image created by Colour Inversion

Fig. 5: Image created by Mosaic effect

common technique is fractals, such as Julia set, as in Figure 6, Mandelbrot set. Many pictures were pre-processed or post-processed (black and white, blurred, inverted colours, noise, Sobel edge detection). Some students applied the Genetic Algorithm to parts of the picture and then joined them together.

B. Crossover and Mutation

A few students stated that they could not devise an optimal crossover function, and the selected method would primarily be based off a mutation which would change the current image or which would add another feature by budding off a new branch in a generative tree. Others used a point of a plane separation for crossover. Some decided not to kill the weak ones, but they were given some time to live and improve (to avoid local optimum). For mutation, the majority used some random noise or random shapes appearing on the image, see Figure 7. Students mentioned that it is necessary to choose the right initialization for optimal convergence.

C. Fitness Function

Most of the fitness functions are an average individual or block pixel-by-pixel difference of RGB(a) channels using the distance between pictures such as Manhattan, Euclidian, mean

Fig. 6: Image created using Julia Fractals

Fig. 7: Deviation from the original image via Random Noise

Fig. 8: Generated via Fitness function applying Opacity criteria

squared error, mean average error, root-mean-square, cosine distance (by channel), l1 (absolute value) difference, and least squares, Figure 8 . Sometimes normalized, for example, divided by loss. Student computed and compared histograms of pictures. Some students altered these standard techniques slightly to get a different output or comparing the monochrome version to allow the colour to be unchanged.

Another common strategy is to find the structural similarity index (SSIM), which captures the shape and the essence of the images. However, due to high computational requirements, many students decided to use something simpler such as pixel-by-pixel difference (as mentioned above) or comparing some features of the original picture(colour, edge detection, etc.) that are described as follows.

Students who used polygons would not only compare the colours, but sometimes used information about edges. The edge formation ensures that vertices would lay on edges to resemble the shape. Some would compare only the average colour inside the polygon. For edge detection, Sobel and Laplacian techniques were adopted. Moreover, in some cases, gradients of colours are also computed to find edges. Some students used Dilation and Poisson sampling for edge detection. Others thought about using entropy to compare the amount of information. Another technique applied is the evaluation of symmetry as there is a common opinion that symmetry implies beauty.

Some fitness functions are combining several ideas or modifying existing ones and, for example, using fourth power instead of a square in the distance (for more accurate results), or assigning weight to some genes, like pixels matching the colour and not matching the colour, to avoid full reproduction of the picture. Another interesting idea is using the theory from

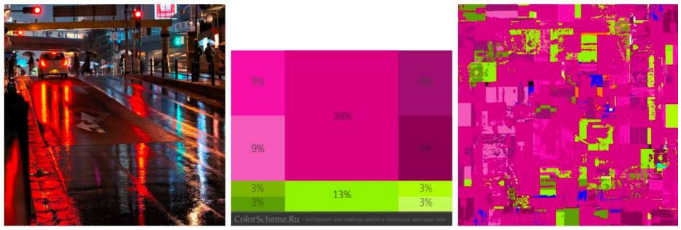

Fig. 9: Palette

Fig. 10: Image created by matching part of pixels

art school, composition, technique, and colour composition as the essence of art. Thus, students chose some nicely looking palettes, like triadic or just using the fact that the colour should be 120 degrees to have a nice match, in other words, evenly spaced around the colour wheel, as in Figure 9. Another approach is to minimize the distance between red and green channels for more details. These methods required some manner of a formula for beauty to be derived, and the difference was computed not only with the picture but also with the edges.

Some students did not want the final image to look like the source image, so it was essential to match only a part of pixels as in Figure 10. Moreover, the idea of fitness is inverted the lower the fitness, the better, to deviate from the source image as much as possible.

IV. Art

The assignment had a mandatory question to answer. The students had to state the rationale behind considering the final image as a piece of art. Since art is a subjective impression, the students had no restriction to justify their preference in any particular way.

1) ***Painting****:* Many students compared the systems with the process of *painting*, such as the computer is a painter, input picture is a sight that it needs to paint and shape/symbol is a brush. Usually, these systems create pictures that resemble some of the art styles the students were inspired. Some students compared this process with painting, considering the programmer, an artist. An algorithm is just a tool, but the ideas are of a human being. Different shapes used were like different brushes – artistic look, an essence without details with short, thick strokes. People make art with hands and mind – just like programmers.

Fig. 11: Pencil Art

2) ***Music****:* Students compared the image generation process with *music* – palette is a melody, fitness is harmony, and the stroke length is a rhythm. One could think of image reproduction as a music cover in this case.

3) ***Mathematics and Programming****:* Some students are inspired by the field of mathematics, for example, by fractals (Koch Snowflake fractal) and algorithms (Xialin Wu line algorithm). Mathematics is considered art and programming is also art. Students explained, such an art reflects a different perception. So, it is an art for computers, not humans, and they commented, it looks beautiful to robots.

4) ***Inspiration Sources****:* Students are inspired by previous works on art generation by computer scientists, artists or works of art. Most of the students are inspired by style of art such as minimalism (which is neglecting small details and extracting just the necessary part), oil paintings, abstractionism (Mark Rothko, Jackson Pollock, Piet Mondrian), avant-garde, impressionism, suprematism (Kazimir Malevich, Piet Mondrian), see Figure 9, pixel art, modern art, black and white vintage photos, pointillism (divisionism, Georges Seurat, Paul Bignac, VanGogh, Picasso, Kandinsky), semi-cubism, realism (Sandro Boticelli), classicism, cyberpunk, fauvism, pencil art, shown in Figure 11. Glitch art (noise for aesthetic purposes) was also mentioned, as in Figure 12. Some students are also inspired by the drawings made by children and Pop art, Figure 13.

Art galleries are also mentioned as sources of inspiration: Uffizi Gallery in Florence, Sistine Chapel in the Vatican, and Hermitage Museum in Saint Petersburg. Another common inspiration is various handcrafting, art techniques such as decoupage (gluing coloured paper cutouts), engravings, origami, mosaic, tinsel art (pictures made of sparkles), as shown in Figure 1, Delanau triangulation, see Figure 14, Polygon art, and kaleidoscopes.

Students find inspiration in informatics. For example, inspiration by image compression. Human eyes care about some colours more than others, so the colours are reduced to make the size smaller. The students decided to use the same principle for their algorithms. Another student is inspired by competitive programming. With the same perspective, abstraction was sometimes used for inspiration, as an example, abstraction of how a computer would describe a picture to another computer.

Those who had arts education in the past are inspired by the concepts of composition and representation that were learnt in

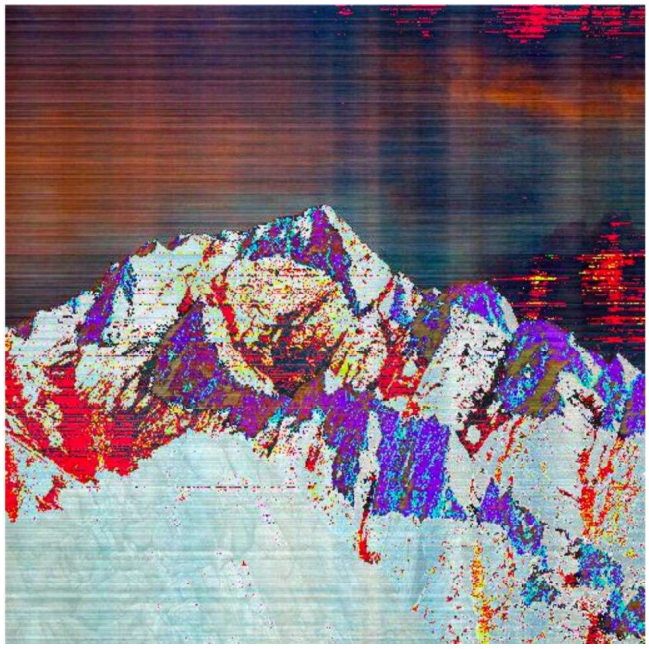

Fig. 12: Glitch Art

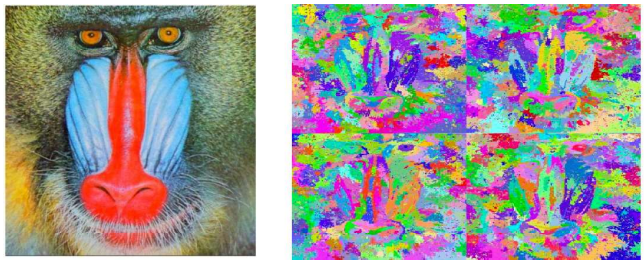

Fig. 13: Pop Art

art school. Besides pixel art, there were some quite specific sources of inspiration, such as Minecraft. Another impressive inspiration is Conways Game of Life. Sources of inspiration of the students also included human eyes and Bible stories such as *Adam and Eve*.

Several students mentioned website ostagram.me as their inspiration. This website shows the result of merging two pictures. Some students stated that their project is inspired by works of other scientists, such as Roger Johansson's EvoLiza, AlteredQualia, works of scientists such as Joseph Alexander Brown and Daniel Ashlock [15], [16], Trist et al. [17], and John F Canny [18].

Fig. 14: Image created with Delanau Triangulation

*5) **Other Perspectives**:* Many students asked the Google Images engine and got an answer that their picture is a painting, visual art, an illustration, or modern art.

The student claimed that it is exciting to wake up in the morning to see the output of the algorithm –new run – new result. The images would be creative mainly to randomness and unexpected output. Thus, it also provoked some emotions. Some are related to the images generated because it felt like that students have drawn them themselves. This was particularly found by those who did not take drawing courses.

As they informed, these pictures convey mood and express ideas, mainly via colouring. Also, vividness, simultaneous contrast and silhouette were claimed to be a part of the art. It is meaningful for the creator and can be interpreted in multiple ways. This is something that makes me think. It evokes aesthetic feelings in a person.

Art is not something created easily. In the same way, it is a struggle to design a program and wait for the output. An interesting perspective was that those systems could express ideas of how people with glasses see the world without them. It is an enjoyable process for many students. They provided feedback informally and expressed happiness with such an assignment. Generally, students commented, these assignments bring joy, provokes creativity and allows them to work on their favourite things.

It is also mentioned that we live in times of information overload, where it is so hard to create something new. Humans can not easily create new things, and the computer has more capabilities. The computers can be creative using randomness and unexpected output. Besides, they can reach perfection easier because they can draw the same shapes with precision and accuracy.

Some argued that it is based on some other piece of art, as they quoted the expression, *"new is well forgotten old"*. Socrates defines art as imitation, attempts to approach the ideal. Furthermore, it is easier for computers to reach an ideal, as it was mentioned before. The algorithm tries to maximize fitness to get closer to the image. Digital pictures, such as made in Adobe Illustrator, is an example of art. Artists can use many tools, which are unavailable to classical painters. Genetic algorithms are even more advanced. They would pass a Turing test because often one can not tell if a human or a computer makes a picture.

V. Entry Evaluation

The process of selection has been made in two processes, and the first stage was to create a set of finalists via a student-driven selection in which each student could place three votes against the set of all images. Secondly, a group of guest judges with backgrounds in the arts and computer science were tasked with providing a ranked ballot vote. In order to further ensure the fairness of the testing being based on the accomplishments of the algorithm and no single student

(a) (b) (c) (d) (e)

Fig. 15: Provided Five Target Images for the Participants

Judge	Country	Field	Gender	POC	Local
#1	USA/CANADA	CS	M	N	N
#2	UK	CS	M	N	N
#3	UK	A	O	N	N
#4	RUSSIA	A	M	N	Y
#5	CANADA	CS	M	N	N
#6	PAKISTAN	CS	M	Y	Y
#7	UK	A	F	N	N

TABLE I: The Guest Judges

selecting a better input image and therefore getting a better output image, the input images were common between all submissions and were only released to everyone after their algorithmic process was decided and programmed. Students took three days to run their algorithms against the chosen target and submit their juried images.

The target images provided to the class for evolutionary art generation are in Figure 15. The top three placing images and the runners up are in Figure 16.

A. Student Vote

The student vote allowed each student to select their top three candidates on a ranked ballot - scoring three points for their first down to one point for their third. This first round limited the set of pictures to be sent to the judges to six highly ranked images by the students.

B. The Guest Judges

The goal of the selection of judges was to ensure diversity in the fields represented in skill sets and cultural experiences, as shown in Table I. Further, the aim was to bias the judging from outside groups from the University. We were able to meet these ends in terms of the division of the computer science and artistic/media fields. Though unfortunately, the distribution in terms of countries, gender, and ethnic background is less than ideal. The outcome of the images was extremely close in the ranked ballot from the judges, again made in the same manner as the students, and only one point separated the rankings of the top three images.

Each of the top three was presented with a framed copy of their work printed on high-quality, acid-free paper and framed, and the winner would be given a t-shirt with their own design. The guest judges provided feedback on the images. It informed us of the perceptions and different ways an image can be appreciated and evaluated. A judge informed about the third image , Figure 16(c) [sic],

> "A classic kind of image filter, almost. At first I thought that it was okay, pretty nice, but then I was walking back into the room with it on my screen, and I saw it from a distance, and I really like how the image looks drastically different based on how far away you are. Very subtle."

Another Judge commented on the same image as [sic],

> "Has the feeling of a photoshop-esque filter but the cross-hatching effect is very sympathetic to the suburban image it adds to that slightly end of last century feel. I especially like the pink of the road that accentuates the greens of the foliage. I like that the turquoise bleeds into white of the house."

About the second image Figure 16 (b), a judge informed[sic],

> "Feels like an object rather than an image and that appeals to me. It seems solid, and calls out to be rotated. The two white plains disrupt the form and Im left wondering if there is a significance to them. Im searching for the patterns, the shadow just below the midline doesnt quite make sense because if it feels like a form, an object, than makes me wonder how that could possibly be created, the shadows around the edge suggest an object lit from the front. So my eye wanders looking for meaning and understanding, I want to linger here a while so if this were a huge print in a gallery that is exactly what I would do."

The different ideas on generating evolutionary art as well as ways of seeing it has made us realize that art indeed occupies horizons of possibilities for its generation and associated perceptions of beauty.

VI. Conclusions

The Evolutionary algorithm art contest had been beneficial from various aspects. In the course of artificial intelligence, it is necessary to enlighten students about creative and critical thinking. The goal was not to just teach but provide an opportunity to reflect on a problem statement and generate a solution. From this perspective, an art assignment was

chosen and students had the freedom to generate the image from any technique they appreciate. The students, through this assignment, were not only overwhelmed with the joy of creating their own art but developed a perspective about what art is when it comes to using artificial intelligence.

We received diverse and profound definitions of art from students. As teachers, our understanding of students' perception is enhanced. Mathematics, music, and randomness etc. are the inspiration behind students' drawings. From this fulfilling experience, we propose instructors of Artificial Intelligence and such courses include such assignments in the classroom. The results are far-reaching in terms of students' learning, developing a perspective about artificial intelligence and art generation and being confident about having the ability to generate art themselves. For future work, we would encourage novelty as part of the fitness function and examine how creativity is demonstrated.

VII. Acknowledgements

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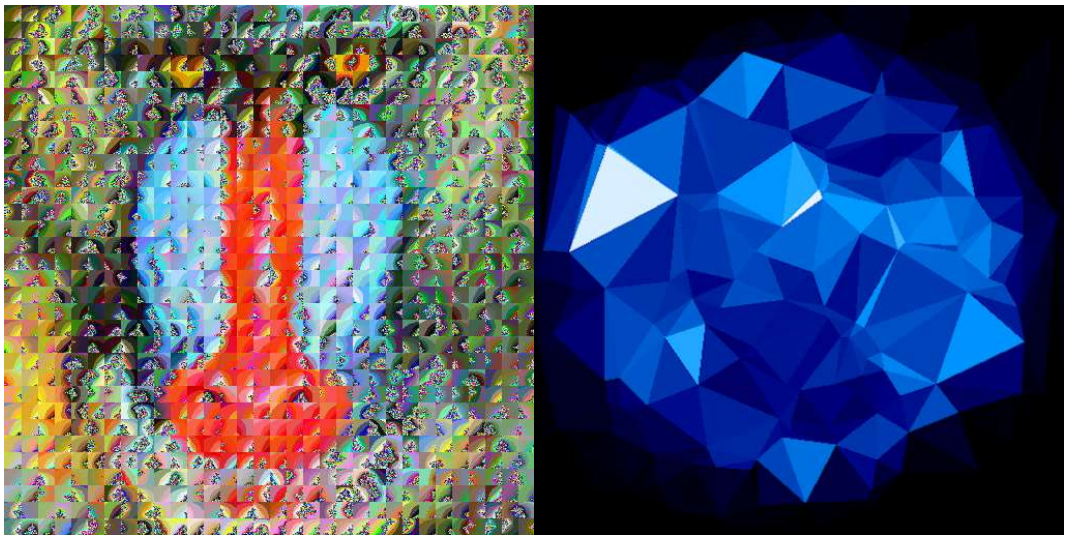
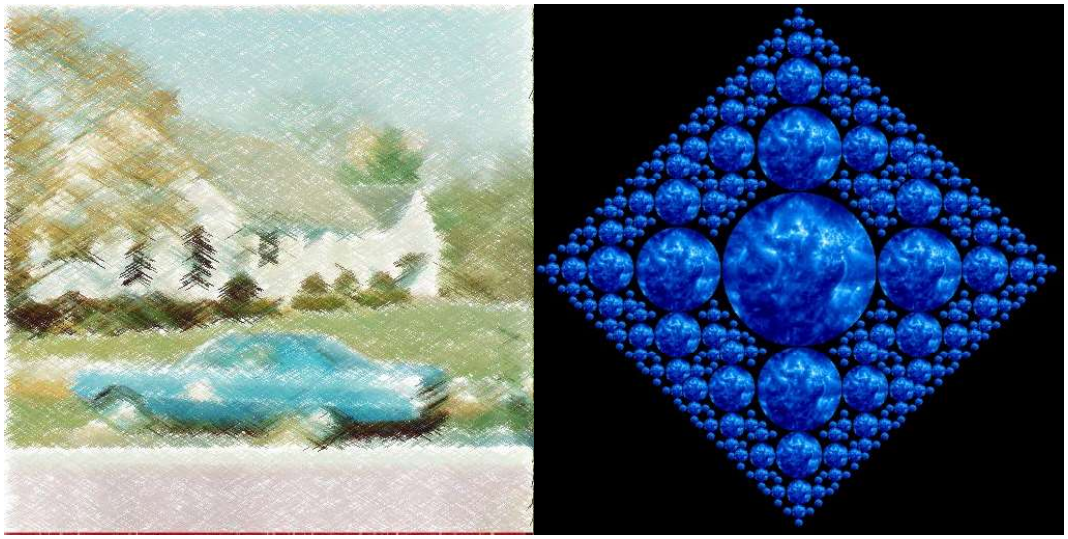
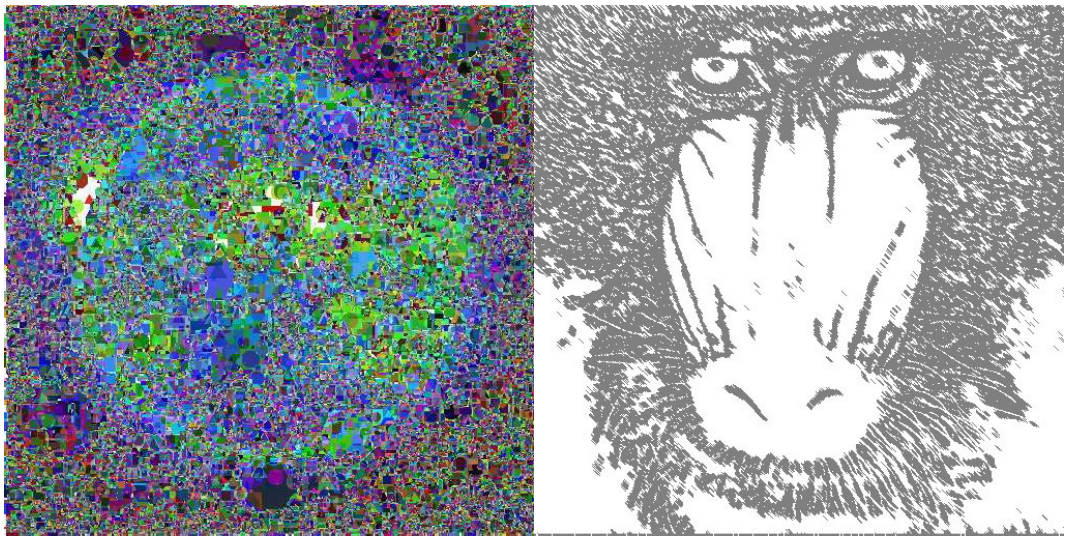


(a) First **(b)** Second



(c) Third **(d)** Runner Up



(e) Runner Up **(f)** Runner Up

Fig. 16: Top six evolutionary generated images, first, second, and third place marked, and the three runners up.