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Novel images?
Artistic image creation with science and technology protocols: GANs and CRISPR-Cas9

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This article investigates two technology- and science-based methods and their potentiality and use in contemporary art, specifically in image-making traditions. Firstly, the article will briefly present digital image creation processes involving Artificial Intelligence (AI) and GANs, and secondly it will introduce a possibility for science-based image modification using a lab-based CRISPR-Cas9 system. Both methods have become available for artistic use with an increase in DIY and open science developments.
These scientific methods impact the produced result aesthetically, according to the context and through associations. The question this paper focuses on is what kind of images are created with these methods? How is the meaning conveyed with these types of images? And what is the artistic point of making images with such technology-based processes?

Art. Science. Technology. GANs. CRISPR. Image making.

1. INTRODUCTION

This article must start with the basic definition of the verb *editing*. According to the Online Etymology Dictionary, the etymology of the term originates from the 1790s with a meaning derived from Latin *editus* “give out, push out, publish,” and the definition “to make revisions to a manuscript” is from 1885. The affiliation to digital tools, such as Photoshop or other similar software, meant that in the early 1990s the use of the term was adopted for computer-based work and referred to as image editing with a computer (Etymonline). Today, we also encounter the same term also within the field of genetic engineering as gene editing or genome editing. The discoveries of the 1950’s and 1960’s of DNA and its structure paved the way to today’s advances in gene editing (Synthego).

Even if it sounds like a cliché, art is always reflecting and reacting to its time and surrounding world. Concerning the connection of art to science and technology developments, the history of art presents us with various examples of works that have been impacted by the specific era’s technological advancements and inventions. One well-known example is the invention of oil colour in tubes. In 1841 the American painter John G. Rand patented a method of packaging oil paint in flexible zinc tubes with a screw cap that could be opened and closed easily without the paint drying out. Famously, this is claimed to have enabled the Impressionists to develop a new style that took inspiration directly from the surrounding world and the natural light affecting it. The invention of the paint tube also enabled a wide range of colours to appear on artists’ palettes, including completely new ones invented by industrial chemists (Hurt 2013; Art World News 2015). Another obvious example from art history is the invention of technological reproduction methods such as photographic film and its mass production, which, for example, released painting from its reproductive function. The list of technological and scientific influences in the history of art is long and continuous. Today, computer-based image editing, digital photography, programming and 3D modelling or prototyping have become common practices for

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artists. The next section briefly discusses DNA and computer code, with an aim to bring these parallel to each other.

2. CODE

The discovery of the double helical structure of DNA by James Watson and Francis Crick in 1953 led to a deciphering of the genetic code, considered one of the most important discoveries of the 20th century and the basis of molecular biology (Tamura, 2016). Francis Crick wrote about the discovery in a letter to his son in 1953:

> It is like a code. If you are given one set of letters you can write down the others. …Now we believe that the D.N.A. is a code. That is, the order of the bases (the letters) makes one gene different from another gene (just as one page of print is different from another). You can now see how Nature makes copies of the genes. Because if the two chains unwind into two separate chains, and if each chain then makes another chain come together on it, then because A always goes with T, and G with C, we shall get two copies where…

According to Lily Kay the genetic code was established in conjunction with the development of post-war era technosciences, such as cybernetics, information theory and computer science. While these areas were developing in parallel, the information discourse seemed a fitting place for thinking about the genetic code as a scientific object and scriptural technology.

> No longer was biological specificity captured solely within the viscous materiality of biological pattern; now the transmitted messages were constituted through alphabetical writing, as a form of "verbal heredity." The new discourse emerged as pure representation. (Kay, 2000, 294)

At the moment of constituting DNA as a code it also meant that the elementary unit of life became informational. The concept of life as a code based on DNA took a step towards computer science, communication theory and their concepts.

> The molecular vision of life was supplemented by the information gaze and empowered by the technologies of the DNA word. (Kay, 2000, 297)

This kind of developing understanding of DNA as a code and life as information was obviously debated across scholars from philosophy, linguistics, biology, life sciences, computer science, anthropology, communication theory and many others during the 1960s; an overview of the debate is given in Lily Kay's book, Who Wrote the Book of Life (Kay, 2000, 307). These developments and their affiliation with linguistics, communication theory and computer science were also bringing to light and enforcing possibilities for genetic modification; similarly to how languages evolve and are sometimes intentionally modified, any written code can also be copied, modified and edited.

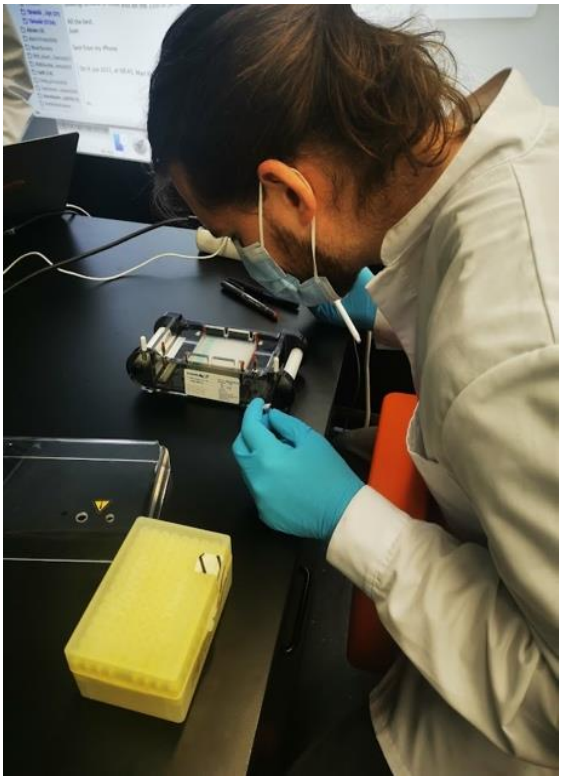

Figure 1: *Workshop in progress within the Hybrid Lab Network project*

For all of us today, it is obvious that computers and other digital devices are based on programming and code. A short look into the history of computers shows us that what is today considered as the first computer programming language was made for a mechanical computer by Ada Lovelace in the 1840s (Fuegi & Francis, 2003). Then, around 100 years later, electrically powered computers and the first high-level programming language were created in the 1940s and 1950s (Giloi, 1997). These machines can be seen as the ancestors of today's computers. But what is especially interesting about the 1950s is that this was around the same time as DNA was thought out as a code.

Our entire lives today are interlaced with code and data, and it is no wonder that art practices and practitioners are also involved in using and manipulating digital and biological code.

The larger question is how to perceive and retrieve meaning from these types of art works that are strongly affiliated with code-based practices and scientific methods.

The next two sections describe the two processes that are the focus of this article; Generative Adversarial Nets (GAN) and the CRISPR-Cas9 system, which is introduced in more detail as it is a new development by the author and others within the Hybrid Lab Network project.[1]

2.1. GANs

During recent years, many artists have taken up work with Artificial Intelligence (AI), Machine Learning (ML) and Generative Adversarial Nets (GAN). In addition, several humanities and cultural studies scholars have investigated the impact of computer-based image making (Lee, 2020; Parisi, 2013; Zylinska, 2017; among others). The recently developed GAN method specifically deals with image creation and has been used in the field of the arts in numerous experiments.

In brief, GAN is based on the idea of teaching machines to figure things out themselves. GAN consists of two deep networks; one is the generator and the other is the discriminator. The GANetwork is trained, for example, with some images that are 'real' and some that are generated. The discriminator aims to distinguish between them and learns gradually what features make images 'real' (if that is the set target), and it also provides constant feedback to the generator network, which tries to generate images that look increasingly 'real'. These two deep networks are in continuous competition with each other to improve themselves. The generator aims at producing images that fool the discriminator while trying not to be fooled (Hui, 2018). GANs were invented by Ian Goodfellow and colleagues in 2010-2014 during his PhD research (Goodfellow et al., 2014). Many new variants of GANs have been developed in recent years, such as the recent VQGAN + CLIP which offers some new features (Crowson, 2021). In general, one can say that GANs have both disadvantages and potentiality in many areas.

The 2018 art auction at Christie's created a great deal of attention as on sale was *the Portrait of Edmond Belamy*, which was the first AI-generated work sold at Christie's (Vincent, 2018). Behind the generated artwork was a small group of students called Obvious. But the group was using a code that was written by a young programmer – this issue caused a stir as the image was sold for over $400,000.

> Using a dataset of European paintings as training examples, the resulting image, produced by a generative adversarial network (GAN), appears similar to a smudged oil painting, complete with what appear to be simulated brush strokes. These are an interesting touch, as they transfer the technical qualities of painting into a medium in which they are not necessary. (Lee, 2020)

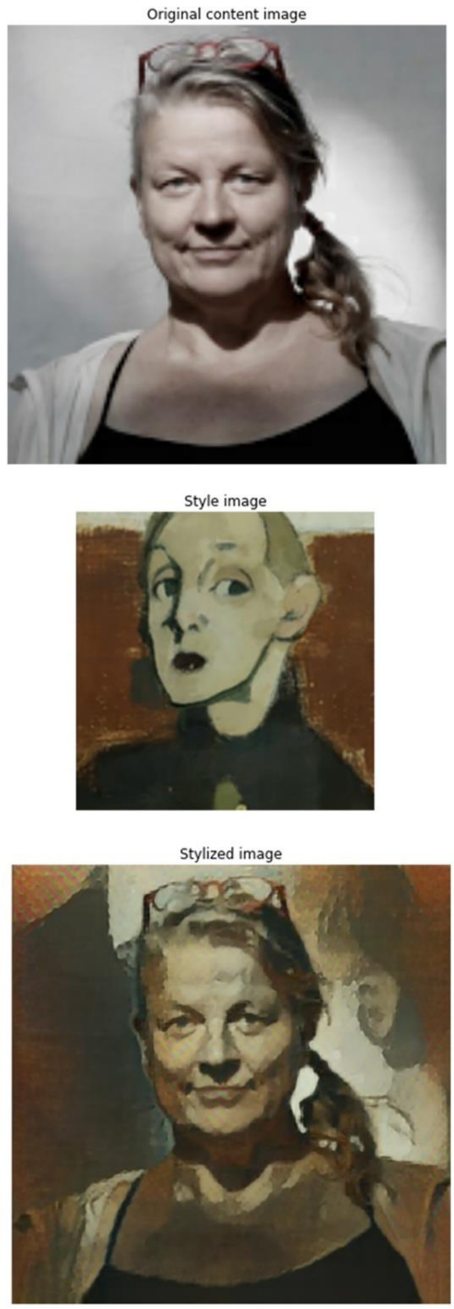

Figure 2: *Style transfer experiment by the author*

Experiments with images and GANs have also been focused on so-called style transfer (styleGAN), which is a transfer of 'style' from one image to another. Popular styles have included, for example, the recognisable painting styles of well-known artists, such as van Gogh or Picasso, which can be transferred to any existing image (Pasini 2019). Below is a quick style transfer example, in which the author's self-portrait is generated using the style of the well-known Finnish artist Helene Schjerfbeck's self-portrait.[2]

It seems that many of these early experiments with AI and GANs have been focused on these types of approaches, such as an imitation of existing styles. One can say that the *Portrait of Edmond Belamy* followed a track of historical portraiture paintings and their style, although made with a trained network and not using the style transfer system.

GANs have entered the art scene quite quickly and as professional artists have begun using GANs, it has raised more demand for stronger concepts and meaningful experimentation. Artist Anna Ridler has trained a GAN network with images of existing tulips and generated new tulips as images in her work *Mosaic Virus 2019*.[3] In her work *Bloemenveiling*[4] one can see short GAN-generated videoclips of possible digital tulips. Comparably, there are also examples of GAN-generated birds that look delusively 'real' but are actually new digital species that do not exist in the biological realm.

What is specifically interesting in the realm of GANs for artists is the idea of training a type of machine to generate novel images. Instead of perceiving the artist as the maker whose signature is imprinted through the hand gestures on a painting or a drawing, an artist's function here is to decide on the training material rather than finalising the end result.

A slightly different approach is found in a work by the author, *Fly Printer Extended* (Beloff, 2016). This work does not generate actual images but aims at telling us what we are looking at by its use of AI and neural networks. In the work, small fruit flies are fed with printer ink and while they produce small random dots on the paper, the neural network analyses this evolving image with dots based on a large database of images. As a result, it will predict for us what the image might depict.

2.2 CRISPR

In 1987 clustered regularly interspaced short palindromic repeats (CRISPR) were identified by Japanese researcher Yoshizumi Ishino and his team (Ishino et al., 2018; Ng, 2020). After a few other discoveries over the next decades, such as the role of Cas proteins and understanding DNA sequencing, a group of researchers – Church, Doudna, Charpentier and Zhang – found that the so-called CRISPR-Cas9 system can be used as a cut and paste tool to modify an organism's genomes (Cohen, 2017). The method has been said to be more precise and also simpler than the methods that were used previously in genetic modification practices.

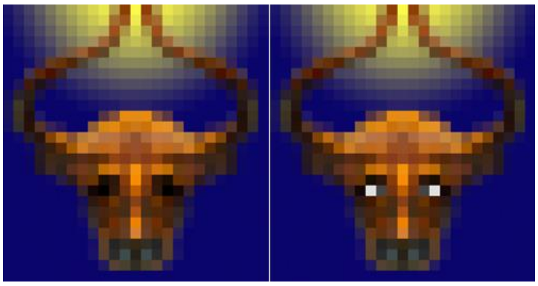

Figure 3: *Return to Dilmun (2017) by Seyfried, van Dierendonck, Petschko and Muffatto*

The idea to use a wet lab-based process using the CRISPR-Cas9 genome editing method for image creation originates from an art project by Günter Seyfried and Roland van Dierendonck. In the project titled *Return to Dilmun* (2017)[5] Seyfried and Dierendonck developed and tested a proof of concept for image editing with the CRISPR method. In other words, the idea is to use scientific genome editing method for image modification.

In general, as the gene modification of organisms has been heavily regulated, there have not been massive amounts of art experiments done in the area. Some art works in history were made prior to the CRISPR-Cas9 system discovery and used synthetic DNA in experiments. Such an example is the transgenic artwork *Genesis* (1999) by Eduardo Kac,[6] which converted a biblical sentence firstly into Morse code and second into DNA that was inserted into a genome of bacteria. In this work, DNA is treated as a code that is synthesised based on a literary sentence and then inserted into bacteria.

> The installation – as a systematic interactive process – can also be accessed online, allowing users (with a click of the computer's mouse) to focus ultraviolet light on the display, causing mutations in both the bacteria's genome and in the coded message. Art no longer imitates life, instead, as Kac states, "art is creating life". (Stafford, 2007)

One should briefly clarify that creation of synthetic DNA is not a strictly regulated scientific method, but it is typically synthesised in outsourced specialist labs and easily available. However, tampering with the genetics of a living organism is very strictly regulated and often artists and art-based labs do not have the licences to make this possible.

During 2020-21 a series of workshops were arranged within the EU-funded Erasmus+ project Hybrid Lab Network.[7] Several of the workshops focused on the CRISPR-Cas9 gene-editing technology with experts from the life sciences, humanities and arts.

One of the workshops took as a starting point Seyfried and Dierendonck's idea of image editing with CRISPR-Cas9 method. The basic idea is quite simple and based on the fact that DNA is conceived as a code, as pointed out at the beginning of this article.

In brief, the principles of the developed process and protocol are as follows: the starting point is a digital image, which consists of pixels in different colours. The colour information of each pixel is transcribed to DNA code with genomic alphabets ATGC. This is done by using a (custom-built) encoder software that encodes colours into the genomic code. The code is sent further to an external company to be synthesised as DNA, which is received back in a test tube as liquid matter. This liquid is now the image. Meanwhile, the modification plan for the image editing is made on a computer – first as a visual design and afterwards also in the created DNA sequence. A specific area of the image is targeted and the corresponding section of the alphabetical code is located and edited according to the plan. The next step is to edit the actual (synthetic) DNA with the CRISPR method, which is performed in-vitro, and which involves a wet lab protocol and tools. After this is finalised, it is recommended to run a PCR test to see if the editing has been successful. If so, the edited synthetic DNA is sent to be sequenced (by an external company). The obtained sequenced DNA code is again run through the encoder software, which now translates the genomic code back into colour-pixel information. At the end, an edited version of the original image will be visible on the computer.

The CRISPR in-vitro method has benefits and also downsides; firstly, as everything is done in-vitro and in-silico, it requires no specific GMO licensing by the labs or artists. This makes it an interesting and suitable process for experimental artists interested in biotechnology and also for educational purposes. However, it is important to realise that in-vitro performed CRISPR has many steps and is quite laborious in comparison to in-vivo performed CRISPR, which is simpler but requires the correct licences. The greatest challenge with the in-vitro method currently lies in the pricing of the synthesising and sequencing of the DNA, which is often performed by external companies. The high price of the DNA sequencing affects the artistic experiments and possibilities to create larger images with more pixel data. Nevertheless, the possibilities and new thoughts that this method opens up in relation to art, image creation and also science are worthy of consideration.

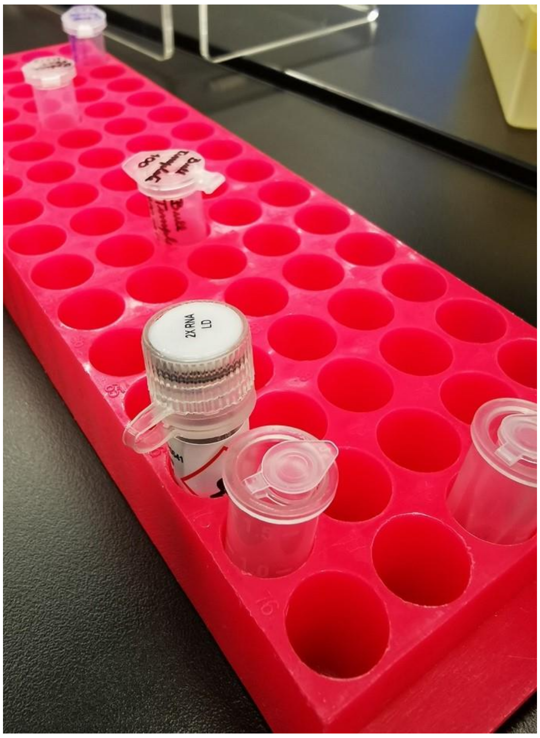

Figure 4: *Wet lab-based image editing materials*

3. EMBEDDED MEANING

The previous sections describe two methods of image creation that are very recent and novel. In the AI-based method with GANs the actual craft of image creation is automated to an intelligent machine capable of learning (to some extent). In the new development of creating images with the CRISPR-Cas9 system the laborious craft-based work of an artist returns, but this time it is primarily in lab-based skills and strict scientific protocols instead of the creation of, for example, unique hand gestures across a canvas.

There is one major question that concerns both of these image-making methods: how should we (the audience) view and understand these highly technology-infused images? And also, what is the point of using GANs or CRISPR-Cas9 system for image making?

Concerning art in affiliation with AI and GANs, one of the major artists pointing criticism towards the use of AI and Machine Learning (ML) methods is Hito Steyerl. Rosemary Lee writes in relation to Hito Steyerl:

> It is significant to consider the fact that although algorithmic approaches are able to produce new visual content, they do so by making conjectures from past content. This means that while they have a degree of novelty, it is restricted, effectively, to projecting the future from what has occurred in the past. (Lee, 2020,130)

This obviously references the machine learning function of neural networks, which requires training with existing 'past' images.

Barbara Maria Stafford has written about the use and significance of images at the intersection of art, science, philosophy and technology. She writes that the early modern publishing industry enabled the fusion of images that were not normally found together.

> In design terms, it added value to existing, deliberately devised structures and new forms which, in turn, it helped to standardize. Ultimately, it launched new and vexing patterns into the intellectual environment that had to be rethought by the viewer and thus contributed to the remaking of the self. (Stafford, 2007, 60-61)

Types of art-based images such as GANs require the audience to learn to understand the creation process. This may be true today, as the techniques are fairly new, but there is a good chance that GANs will be standardised in the future and become just one image creation possibility alongside traditional ones. Today's GAN aesthetics quite often follow the traditions of pictorial painting or photography and the generated results are somewhat recognisable as such. This is due to the fact that the training materials are existing images (which may be selected by the artist), and in this sense GANs will always make reference to existing (or past) aesthetics. However, it is much harder for us (humans) to recognise non-representational images as being machine generated, with the network trained with existing abstract images (Elgammal et al., 2017).

However, I believe that the largest challenges and highest controversy with GANs will be in the areas of representational images which reference concepts beyond the making of images, such as the creation of new (digital) species, as already mentioned in this article. This is one factor in today's world that blurs the traditional understanding of the concepts of the artificial and 'real' (Beloff, 2017). An example of the blurring between the artificial and biological is artist Maija Tammi's photo-series *One of Them Is a Human* (2017), which presents photographs of three human-looking robots and possibly one human.[8]

4. CONCLUSION

CRSIPR-Cas9 is a newly experimented method for the creation of images that is undoubtedly a fairly expensive and laborious lab-based method with somewhat uncertain results. One could claim that this method is addressing not only the human eye but perception as a whole in the age of a technologically expanded and modified world. It is obvious, as already mentioned previously, that some of the benefits of this method lie in the educational aspects of understanding CRISPR genome editing without being a scientist. But the technique also reinforces the idea of how we (humans) can modify, edit and design anything living and biological. At the same time as a new understanding of images and their creation processes happens at the intersection of material, cultural and biological cognition, these produced images also reference the new possibilities of biotechnology.

One could state that code and digital data appear to be the basis of today's world. Artists actively, and often critically, follow societal trends and changes and experiment with the possibilities of science and technology advancements. These above-described methods (GANs and CRISPR) that have been adopted into art from the fields of science and technology are examples of how art reflects the surrounding world and also challenges audiences with new perceptions.

Figure 5: *Biological Arts; Biofilia Lab, Aalto University*

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[3] http://annaridler.com/mosaic-virus (29 August 2021)

[4] https://bloemenveiling.bid/ (29 August 2021)

[5] http://www.polycinease.com/return-to-dilmun/ (29 August 2021).

[6] https://www.ekac.org/geninfo.html (29 August 2021).

[7] https://hybrid.i3s.up.pt The lead of the Hybrid Lab Network project with scientific expertise is the Portuguese biotechnology institute i3s. The artistic experimentation and academic participation are provided by Aalto University in Finland, citizen science approaches with a strong public connection is represented by the Waag Society from the Netherlands and the academic humanistic contribution is provided by the Slovenian Alma Mater Europaea University.

[8] http://www.maijatammi.com/artworks/one-of-them-is-a-human/ (29 August 2021)