UAL : Creative Computing Institute
MSc Data Science and AI for the Creative Industries

Creative Application: Exploring the Use of Interactive Genetic Algorithm to Augment the Creative Process

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Abstract

This thesis project aims to answer two research questions: How could Interactive Evolutionary Computation (IEC) be utilised to augment the creative process and how best to present the evolutionary options to people? The aim is to further the field of evolutionary computing within the creative industry and explore what future work is needed in regards to augment human creativity. To achieve this, a CPPN-NEAT evolutionary model incorporating traditional drawing methods was developed allowing the study of both the automation aspect and the human-in-the-loop (HITL) aspect of the model. The aim was to firstly develop a creative application which combined the evolutionary computational aspect with the traditional drawing one and secondly, add to the knowledge of how the use of IEC can augment the human creative process. The experiment conducted, as well as the preceding literature review, showed that although automating practical functions of the model is useful to creative practitioners, the HITL aspect is significant in augmenting the user's creative workflow. Both research questions are answered in this paper and in regard to the first one, it is necessary to include the HITL aspect within the evolutionary tool to ensure collaborative working between human and computer in order to augment human creativity. The answer to the second question would be to emphasise the collaborative approach within the model rather than the automation of the computers evolutionary abilities. This would allow users to retain some control and adapt the model to their individual workflows.

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1 Introduction

Darwin (1859) in discussing his biological theory of evolution wrote about the beauty and grandeur of evolution occurring, and continuing to occur, from the initial one or few simple forms to create a complicated and exotic organism whilst the earth itself simply keeps turning (Darwin, 1859). The biologically inspired evolutionary computational tools have been around since the mid 1900's and the 'natural selection' methods they incorporate are efficient in providing the optimal solutions to complex problems. The inclusion of human-in-the-loop (HITL) within the evolutionary computing process, making it interactive, is key for the optimization of a solution (Mitchell, 1998).

There are plenty of reasons and research that show that collaborations between computers and people are beneficial and according to Yang & Zhang (2016) reducing the gap between the two will both strengthen this collaboration and further augment human creativity. It has been shown that users prefer HITL within the process but reject high-level automation although they are open to the use of automating practical functions such as 'undo'. (Li, Hashim & Jacobs, 2021). The balance of a user with suitable control alongside an intelligent computer can augment the user's creative process (Wang, 2019) and implementing evolutionary computational tools is an established way of augmenting creativity. However, how best to implement it in the creative process is still not clear nor is how the user's contributions get brought into it (Bentley & Corne, 2001).

Addressing the knowledge gap regarding how to utilise Interactive Evolutionary Computation (IEC) to augment creative process, this research explores how to present IEC in creative applications and how editing its nodes and connections can work as a design tool. For this purpose, creative practitioners are asked to trial a creative application that makes use of CPPN-NEAT evolutionary model, allowing them to explore the model's parameters and its output in tandem with traditional drawing methods, iterating between the two. The questions this thesis project asks is how could IEC be utilised to augment the creative process and how best to present the evolutionary options to people. The optimal end result of this research is; 1) to develop a creative application that combines CPPN-NEAT evolutionary images and traditional drawing methods and; 2) to add to the knowledge of how IEC can be utilised to augment the creative process.

The background chapter of this thesis focuses on the literature review and gives an overview of the theories and concepts of the topic within it. The development chapter discusses the Design Science Research (DSR) process which was applied throughout the project itself. The results chapter explains the main findings from the experiments with participants and this will be discussed in some detail as well as the ethical concerns and future works being addressed. The conclusion is that including the HITL aspect within the model is important in reducing the gap between human and computer creativity and thus emphasising the collaborative working of the two. To present an IEC model to users in a meaningful way it is necessary for the automation to be limited to practical functions and it must not take away control from the user but instead work alongside the user to augment their creativity.

2 Background

The literature review was conducted to gather knowledge about the thesis topic and discuss theories and concepts behind it. The materials used in the literature review were mainly collected from IEEE Xplore, ACM Digital Library, ResearchGate and Google Scholar. The key search terms included ‘interactive evolutionary computing,’ ‘creative workflow/process,' 'creative computing,' and mostly focused on evolving computational creativity as well as the development of evolutionary algorithms (EA). Importance was placed on publications regarding how CPPN-NEAT was previously used to evolve images.

2.1 Creativity & Computation

Developing creative computing has proved challenging as the unpredictability of human creativity is difficult to emulate. According to Yang & Zhang (2016), the advancement of civilization worldwide and improved quality of life is largely due to human creativity as well as it playing a part in almost every aspect of life. They go on to express that computing is already seen as an effective support mechanism and mention that it has assisted researchers to scientifically explore creativity. The field of creative computing investigates the process of teaching a computer to be creative by imitating the creativity of humans and this field is continuously developing in support of users. The idea is that the user and the machine collaborate creatively although there are still limitations in the computer's creative ability due to the unpredictable nature of creativity itself. Yang & Zhang (2016) do point out that computers have immense processing power and tremendous amounts of data which can enhance human creativity by utilising the instinctive aspects of creativity in aid of the users. Although most current applications aim to imitate existing creative tools in a virtual format to aid users' creative work, introducing a completely new and unusual environment may also improve the human's creative process. There is currently a gap between the computer's objective process and the human's subjective process when it comes to creativity. By bringing the computing aspect closer to the unpredictable nature of creativity and with the collaboration of machine and user the combined knowledge of the two will enhance the support of human creativity. The aim is to inspire and ignite the user to think creatively and use creative computing, which simulates the essence of creativity, to augment human creativity (Yang & Zhang, 2016).

By applying qualitative research, further knowledge was gained about the possible collaboration of machine and user to support human creativity. In their (2021) study, Li, Hashim & Jacobs explored artists' use of software as well as the effects of creative artists developing, or being involved in, the development of the creative software tools. They found that the artists were generally open to this as a form of creative growth but that they steered clear of high-level software automation. Their study identified some obstacles in regards to the artist not being able to physically manipulate their media when working with computer models and them preferring the use of applications which supported their already established workflow. Each artist worked on a broad range of visual art domains but despite this, they described workflows integrating physical processes and digital ones and using digital and physical production non-linearly with a diverse set of approaches and tools. One of the artists' most important aspects was to be able to input manually into the digital tools as automation would add unwanted aesthetics that needed to be manually changed afterwards. Practitioners still depend on being able to manually input information into computers and prefer automatic features, such as 'undo' which mean they continue to be the HITL. Certain tools forgo this control and the final outcome is in essence decided by the developer, not the user. Enabling the user to have more control may support them in completing a creative task although the study highlighted some difficulties encountered by the users to adapt their usual workflow to the use of the creative computational tool. By re-thinking the software as a sublayer of information which merges application functionality and data, more support is given to software adaptability and a wider range of collaboration forms. Much of the research on creativity support is aimed at broadening participation but some researchers have raised the idea that creative systems should instead reduce entry barriers and support a wide range of outcomes (Li, Hashim & Jacobs, 2021).

Automation within a creative process is about finding the correct balance between the tasks that require a HITL and the tasks that may be beneficial to automate. Wang (2019) believes that the solution will be found in between the extreme of automating nothing and automating everything and is a balance between the two, the independent technology and the tools we are used to using. Automation can be thought of as the part-inclusion of human involvement instead of the complete removal of it and this may result in a process which utilises intelligent automation whilst keeping the HITL aspect. Instead of exploring how to build a smarter system we would be considering building relevant human interaction into the system. Each part of the system process which includes human involvement needs to be designed so that humans understand to take the next step and that humans have some decision powers over which steps are critical. Ultimately, it is a collaboration between the two which means the process is more transparent. It should include human judgement in some chosen ways because after all, AI systems are meant to support humans. To augment the users' ability to create, the question of how to develop a flexible system useful to varied users is necessary to consider (Wang, 2019).

There are many possible solutions to augmenting the creative process. According to Bentley and Corne (2001) creative evolutionary systems allow their users to discover new ideas while exploring the space of possible images or other objects. As new avenues are revealed through the process the users often experience surprise regarding the new possibilities (Bentley & Corne, 2001). The evolutionary stystem can propose new methods and principles to use in creative work and bypass design fixation and conventional wisdom that can confine creative workflow. There are many creative evolutionary applications which aim to assist with innovation. However, there is still a knowledge gap of how to implement evolutionary computation (EC) in the creative process. EC is about search and computational problems are explained with regards to a search space. There is an enormous number of possible solutions to each problem in this space as each point entails a unique solution. Bentley and Corne (2001) suggest the reason why creative evolution has been popular in fields such as design and architecture is due to the complexity of their problems and the hardest ones involve people and their preferences. With evolution comes novelty, that is one of the guarantees of new generations. Making evolution and human judgement into a collaborative combo will also generate diversity in creativity. EC tools are defined by their representations and have been found to expand creativity and imagination. However, there is missing knowledge regarding how the computer can give feedback on the contents and structure of the space it is exploring and how the user's contributions get brought into the interactive evolutionary process (Bentley & Corne, 2001).

Reducing the gap between human and computational creativity will strengthen the collaboration between the two and augment human creativity (Yang & Zhang, 2016). Users prefer that HITL is incorporated in the process and that automation is restricted to practical functions (Li, Hashim & Jacobs, 2021). User control alongside an intelligent computer system will support users in the creative process (Wang, 2019) and implementing evolutionary computation tools is an established way of augmenting creativity. However, it is still not clear how to implement evolutionary computation in the creative process and how the user's contributions get brought into it (Bentley & Corne, 2001).

2.2 Interactive Evolutionary Computation

Evolutionary computational tools have been around for a number of decades. Throughout the 50s and 60s a number of computer scientists separately explored evolutionary systems with the aim of using evolution as a tool to optimise engineering issues. The plan with these systems was for a group of participant's solutions to a certain problem to evolve with the use of programs based on natural selection and natural genetic variation. In the 1960s, John Holland invented genetic algorithms (GAs) and then further developed them with the aid of his colleagues and students at the University of Michigan through the 60s and 70s (Mitchell, 1998). Holland (1992) presented the mathematical basis for evolutionary algorithms in his book, 'Adaptation in Natural and Artificial Systems' as well as giving a theoretical framework for further GA adaptation (Holland, 1992). Unlike evolutionary programming and strategies, Holland's initial aim was to study adaptation as a phenomenon as it happens in nature, rather than designing algorithms purely to solve identified problems. He could then advance methods for the mechanisms of natural adaptation to be brought into computer systems (Mitchell, 1998).

To further understand the mechanisms of a simple genetic algorithm, one can look at Goldberg (1989) who describes it as a simple copying of strings of 0 and 1 and swapping of partial strings, the equivalent of chromosomes in nature. He further notes that GA is generally made up of three operators Firstly, fitness function (e.g. reproduction), a process where a string's objective function values dictate how and if they are copied. By using these values, strings with higher fitness values are more likely to have offspring in the following generation which is a simulated model of nature. Secondly, crossover, which is when new strings are randomly mated and then the string pair undergoes a crossover blending their attributes into their offspring. Innovative ideas are basically a juxtaposition of different ideas that have previously been successful. The third operator Goldberg (1989) mentions is mutation, which plays a smaller role in GA where the frequency of mutation has been observed to deliver good results. They are more frequent in GA than in nature and its purpose in both GA and nature is to ensure genetic material is not lost in the processes of function fitness and crossover. Another two important concepts in evolutionary computing are genotype, which in biology means the set of genes representing the chromosome, equivalent to the GA input in evolutionary computing and phenotype, the physical representation of the chromosome, i.e. the GA output (Goldberg, 1989)

But why look at solving computational issues using evolution as a basis? For evolutionary-computation researchers, the process of evolution is ideal to address some of the most important computational issues in a variety of disciplines. Numerous computational issues call for complicated solutions which are hard to hand-program as well as these issues requiring researchers to sift through a vast amount of possible solutions. A good example are the complexities of designing artificial intelligence. Evolutionary computation uses 'natural selection,' with the exception of mutation and crossover variations, because the outcome of this is the foundation of the best solution to complicated problems as well as the method being able to adapt the solutions to changes in the environment (Mitchell, 1998).

Evolutionary/Genetic algorithms (GA) are used to train and optimize the parameters of a neural network, similar to back propagation or hill climbing. Literature on GA shows that a numerous number of applications have been successful, but GA has also performed poorly on many occasions according to Mitchell (1998). When faced with a possible application, can we tell if GA will be a successful technique? A definite answer does not exist although the general thought of researchers is that if a large space is being searched and it is known that it is not unimodal, or that our understanding of it is limited, or if it has a noisy fitness function, and global optimum being found is not a requirement of the job, GA is likely to be as good, or even better than, other techniques. When looking at case studies of problem-solving, scientific modelling, and theory projects, we can conclude that: GAs hold promise as techniques to solve demanding technological problems, as well as machine learning (Mitchell, 1998).

When the human is included as part of the evolutionary computation process it is referred to as IEC (IEC). Professor Richard Dawkins, who inspired IEC research, devised a program called Biomorph Land which allowed users to lead 2D graphical forms through an evolution of generations. He chronicled his investigations in the book, The Blind Watchmaker (1987) and links it with Darwin's theory of evolution. In the book the human eye is the selecting agent which explores a group of offspring and selects one for procreation. The selected offspring consequently is the next generation's parent and its mutant children are shown on the screen all together (Dawkins, 1987). Following Dawkins writings, Takagi (2001) explored IEC research noting that IEC is a form of EC which supports system optimisation centred on subjective evaluation by a human. It is nearly impossible for human evaluation to contain crystal clear functions because even the finest system outputs are observed and the evaluation of them is based on the user's preferences, impressions, understanding and emotions. There are numerous systems whose structures or parameters need to be optimized from the standpoint of the user's evaluation and these systems exist in the education and engineering fields as well as the aesthetic and artistic fields. Human characteristics, which Takagi (2001) calls psychological space, inevitably affects evaluation however consistent the evaluation methods are. IEC as an optimisation method uses human subjective evaluation and adopts evolutionary computation (EC) based on this evolution. In simple terms it is an EC method where the human user replaces the fitness function. IEC evaluations are either individual ratings or simulated breeding with the interactive interface (user selection) (Takagi, 2001).

Using evolutionary computation's 'natural selection' methods to solve computational issues is ideal because it provides the best solution to complex problems. GA is at least as good, and possibly better than, other available techniques and including the human as a subjective evaluator in an IEC system is vital for the optimization of the solution (Mitchell, 1998). However, it is important to be aware of the effect of the psychological space on the outcome of the evaluation (Takagi, 2001).

2.3 CPPN-NEAT

Deep learning has been the focus of a great deal of current machine learning. However, a different method has derived from neuroevolution, a field which utilises evolutionary algorithms in order to optimize neural networks based on the evolutionary process of the physical brain. Important abilities which are usually not available to gradient-based methods, like learning neural network building blocks, architectures, hyperparameters and learning algorithms are made possible with neuroevolution. Another difference between deep learning and neuroevolution is that the latter maintains a cluster of solutions whilst searching, thus allowing massive parallelisation and extreme exploration. Neuroevolution has helped to progress effective and novel methods, which may be useful in different machine learning fields, as it has to a large extent developed separately to gradient-based neural network research. Another method, inspired from the biology behind the development of the human brain, is to use evolutionary algorithms to train neural networks (Stanley et al., 2019).

Stanley and Miikkulainen (2002) introduced an inventive NE technique, NeuroEvolution of Augmenting Topologies (NEAT). Its purpose is to reduce the spatial extent of a search space of connection weights using structure by evolving it so that topologies are grown and minimised progressively, thus gaining significant learning speed. NEAT's contribution to GAs is equally important as it demonstrates how evolution can both complexify and optimize solutions at the same time. It presents a possibility of progressively complex solutions over generations being evolved as well as the analogy being strengthened with biological evolution. NE is a synthesised evolving of neural networks with the use of genetic algorithms. NEAT searches for a solution throughout all generations in the lowest-dimensional weight space by beginning minimally and therefore not only the final artifact is minimized but also each of the intermediate networks throughout the process. This is the fundamental reason an advantage is gained from the evolution of topology. A mutation within NEAT can alter the network structures and the connection weights, which mutate as they would in any NE system. Allowing genomes to evolve without restrictions will inevitably result in a highly complex form of the competing convention problem incorporating numerous different weight combinations and topologies. So what is a practical way for NE to cross over various sizes of genomes? NEAT is given an important new capability with the historical markings as the system can accurately tell which genomes are a match with other genomes. NEAT uses historical markings for crossover by utilising linear genomes but does not need topological analysis which can be expensive. Evolving the population means organisms are able to compete in their niches and in this manner the topological innovations remain secure in a niche and are able to optimise their structure by competing within this niche. NE may run aground in a local optimum if it is directly trying to solve a more difficult task but if it first solves a simpler variety of the task the group will likely be located in a part of fitness space nearer to the harder tasks solution, thus avoiding local optimisation. One of the main strengths of NEAT is its awareness of the fact that the ultimate structure of the solution is not what is important, but rather the intermediate solutions structures which are part of the process of finding a solution. The analogy between natural evolution and GAs is strengthened by NEAT by both complexifying and optimizing solutions at the same time (Stanley & Miikkulainen, 2002).

Representation is central to artificial intelligence, especially if a problem includes search, in which case the difference between failure and success can rest simply on good representation of the solution space according to Stanley (2007). Development is one of the main processes in natural encoding because in it, DNA is mapped to a mature phenotype via the process of growth which constructs the phenotype over a period of time. The development allows for recycling of genes as the same gene can be activated anywhere and anytime throughout the process of development. Therefore a small geneset is able to encode a much bigger structural component set, a fact which has inspired a popular research field in artificial developmental encodings. This new encoding is named Compositional Pattern Producing Networks (CPPNs) and the basis of it is the ability to describe directly the structural relationship which is the result of a development process without stimulation. Description is encoded via a configuration of varied functions which are all based on gradient patterns observed in natural embryos. The structure of CPPNs is similar to artificial neural networks and therefore they are able to use existing techniques known to be effective for evolving neural networks and particularly the NEAT method. (Stanley, 2007)

Stanley (2007) modified NEAT and built CPPN-NEAT, which allows for increasingly complex CPPNs to be evolved and by doing this, progressively complex phenotype expression patterns were evolavable along with regularities and symmetries that are refined and elaborated throughout generations. Node genes in CPPN-NEAT incorporate a section to specify the activation function whereas the original NEAT networks included only hidden nodes with sigmoid functions. A new node is assigned a random activation function from a canonical set when it is created and the compatibility distance function used to decide if two networks belong to the same species is inclusive of a count of the amount of activation functions that differ between individuals This representational efficacy is possible due to genes being recycled during the assembly process of the phenotype. Without this reuse of genes, the genotype would have to match the phenotype in complexity which would involve the inclusion of millions and possibly trillions of individual genes, an uncontrollable search space. Simple solutions are easier to evolve than complex ones and developmental encodings try to minimise the search space's complexity with the encoding of a complex phenotype within a substantially lower-dimensional phenotype. But even this does not solve the dimensionality issue because despite developmental mapping, representing complex phenotypes still requires thousands of genes (Stanley, 2007).

The NEAT algorithm is generally used to evolve CPPNs as this allows for increasingly complex architectures to evolve from an extremely simple form. The use of CPPNs covers a broad spectrum of applications which make the most of their propensity to regular structure from producing images to the creation of three-dimensional artifacts (Stanley et al., 2019).

2.4 Related Work

One of the earlier users of evolutionary computation was the digital media artist and software developer Karl Sims. A paper written by Sims (1991) reports on the use of evolutionary techniques of selection and variation in computer animation and graphics to create complex simulated textures, motions and structures. Based on observed procedurally generated results, a user can lead simulated evolutions in certain directions using interactive selection. An example of this is when mutating symbolic lisp expressions are used to evolve images artificially by initially producing and presenting a group of random expressions in a grid allowing interactive selection. The appearance of the selected images are replicated with mutations in every younger generation in a way that increasingly complex presentations and ongoing images are able to evolve. Sims (n.d.) named this Genetic Images, which is a media installation where users can evolve abstract images interactively. 16 images are displayed on screens by a supercomputer and users then step onto sensors next to the image they select for survival and these then 'breed' to give birth to another generation (Sims, n.d.).

Drawing inspiration from Sims, Picbreeder offered an online application using collaborational evolving of images (Picbreeder, 2020). Like any other IEC, it allows users to evolve images by choosing ones that they like to create the next generation. Picbreeder also includes an online community where generated images can be shared and other users' images can be further evolved. Through the continuing branching effect and CPPN-NEAT ability to expand the complexity of the images, users can search for images collaboratively (Secretan et al., 2008). The image's complexity will continue to grow due to the CPPN-NEAT algorithm, reflecting the user's selections. Using this mechanism, complex digital content can be evolved by the users regardless of their experience which is not generally the case in groupware systems. Users have the option to either select images and explore what happens or they can choose to evolve one selected image. An interesting image within a generation might prompt the user to change directions unexpectedly. The user's creative exploration of a design space is supported and they are able to lead the computer to wherever their interest lies which, if working with a large search space, can take numerous generations. If the user is interested in evolving an image they can choose to branch it which means that Picbreeder will continue the evolution. Domains with subjective fitness or difficult formal expression IEC is an obvious choice as the design process at times will call for substantial domain knowledge and skill. One big challenge is the vast size of search spaces meaning that locating the most interesting can be hard so a more efficient design process via augmentation or automation of the designers capability is an important area for research (Beato et al., 2011).

EndlessForms is a website which evolves 3D objects by using the same technology as Picbreeder (EndlessForms, n. d.). However, one of its limitations is its subjectivity but the encoding needs to be able to create the objects so that they can be selected in the first place. Although a bias regarding types of patterns will arise from different encodings, this also means interactive evolution will teach us about the biases and the expressive power. Clune and Lispon (2011) showed that interesting and complex shapes could be evolved using CPPN generative encoding based on developmental biology principles. They created the website EndlessForms.com allowing users to collectively explore CPPN-encoded objects space using interactive evolution where users choose objects they find interesting and these become the parents of the next generation. Clune, Chen & Lipson (2013) included the option to convert non-digital objects to be evolved but no prior technique was available to begin evolution with generative encoding in this manner. The seed object (non-digital object) was defined as the one to be reproduced and the seeded-CPPN-object (genotype object) was the result of this reproduction. To create a seeded-CPPN-object, a distanceFromSurface CPPN input was added. The technique they displayed in their paper (Seeded-CPPN) furthered the field toward the creation and production of design (Clune, Chen & Lipson, 2013).

Similarly to EndlessForms' seeded-CPPN, DrawCompileEvolve compiles vector graphics into CPPN-encoded images and then interactively evolve these via CPPN-NEAT using Picbreeder. DrawCompileEvolve is an online tool allowing users to utilise a common drawing interface to create shapes which they are then able to evolve as rasterized images which are CPPN encoded. The vector drawing is then assembled into a genetic representation, indirectly encoded, which can be interactively evolved whilst letting the user alter the patterns and colours of the image and completely transform it. An artist would have complete control during the drawing of the seed initially to be used in the evolutionary run and then would have indirect control whilst evolving it interactively meaning that DrawCompileEvolve is a mixed-initiative art tool. Early findings from the paper display the opportunities that DrawComplieEvolve raises to ignite evolutionary art with meaningful images alongside the ability of the genetic representation at its foundation to alter the users initial images into another artistic offering with just as much meaning. A fundamental motive of DrawCompileEvolve is to allow users, technical and non-technical, to create images encoded by CPPN and to achieve this, a web application allowing users to create images in the browser is utilised. For future studies it will be vital to compare evolved products more closely via a seeded approach with products which have been evolved from scratch. Using the initial groups seeded with relevant images will allow the creation of evolutionary bias affecting particular sections of the search space (Zhang et al., 2015).

One of the earlier evolutionary computation users was Karl Sims, who reported in (1991) on the techniques used in creating complex structures amongst other things. Inspired by Sims, Picbreeder offered online collaborational evolving of images with IEC (Picbreeder, 2020). EndlessForms used the same technology to evolve 3D objects and create seeded-CPPN (EndlessForms, n. d.) but noted that subjectivity is a limitation within the process (Clune, Chen & Lipson, 2013). Similar to this, DrawCompileEvolve compiles vector graphics into CPPN-encoded inmates and then evolves them via CPPN-NEAT.

Future studies will need to compare the evolved products via a seeded approach with products evolved from scratch (Zhang et al., 2015).

2.5 Literature Review Summary

The literature review provided an overview of the techniques used including NEAT-CPPN which supports ever more complex structures to evolve from a simple form. The use of the technique covers a wide range of applications which are able to complete tasks from producing images to creating more complex three-dimensional products (Stanley et al., 2019). IEC is discussed and noted that a HITL inclusion in the system is likely to optimize any solution (Mitchell, 1998).

Users preferences including their thoughts on automation plays a significant role in the literature search and users generally prefer that HITL is part of the process and are less keen on automation except as part of a practical function such as undo (Li, Hashim & Jacobs, 2021). Allowing for some user control in collaboration with an intelligent computer system will support the human creative process and using evolutionary computational tools is already a proven way of augmenting human creativity (Wang, 2019). Furthermore, the gap between human and computational creativity should be reduced to enhance the collaborational aspect between human and machine in order to achieve this (Yang & Zhang, 2016). That said, it is still unclear how implementing evolutionary computation into the creative process is best done and how to bring the user's contribution into it (Bentley & Corne, 2001).

The 'natural selection' method used in evolutionary computation is ideal to solve computational problems as it has been shown to provide the best solution to complex problems. However, the psychological space will affect the outcome of the human evaluation and this is something which is important to be aware of (Takagi, 2001). Karl

Sims was one of the earliest users of evolutionary explorers and wrote about the technique in a (1991) report which later inspired Picbreeder, an online application offering the use of IEC to collaboratively evolve images (Picbreeder, 2020). The same technology was used by EndlessForms, a website which allowed the evolution of 3D objects to create seeded-CPPN (EndlessForms, n. d.) and this was followed by DrawCompileEvolve, which compiled vector graphics into CPPN-encoded inmates and evolved them via CPPN-NEAT. The literature review noted that a requirement of future studies is to compare products evolved via a seeded approach with those evolved from scratch (Zhang et al., 2015).

3 Development

This thesis project was done as a final MSc thesis project in Data Science and AI for the Creative Industries. Part of the criteria and indicative content for it was to identify a relevant data science and AI research question using evidence from existing academic research in the context of the creative industries. This included a literature review and practical development of software and/or creative outputs. Findings were critically evaluated and analysed using experimental and/or historical evidence and presented in a thesis and presentation. To meet these objectives as well as to answer the research questions, the methodological approach chosen was Design Science Research (DSR) since its process suits the overall aim of the research project.

Design Science Research (DSR) originates from the sciences of the artificial as well as engineering and is essentially a model to create novel items which expand human knowledge and generate design knowledge (DK). The aim is to create an understanding of how best to design things to meet specific goals using original solutions to real-life problems (vom Brocke, Hevner & Maedche, 2020). DSR sits within Information Systems (IS) and according to Hevner, Park & March (2004) there are two models that pervade research into IS, design science and behavioural science. The design science model aims to expand the confines of human and societal abilities with novel products whereas the behavioural science model aims to advance and confirm theories which foresee or explain human or societal behaviour. Both models are fundamental to IS, which is positioned where individuals, society and technology converge (Hevner, Park & March, 2004).

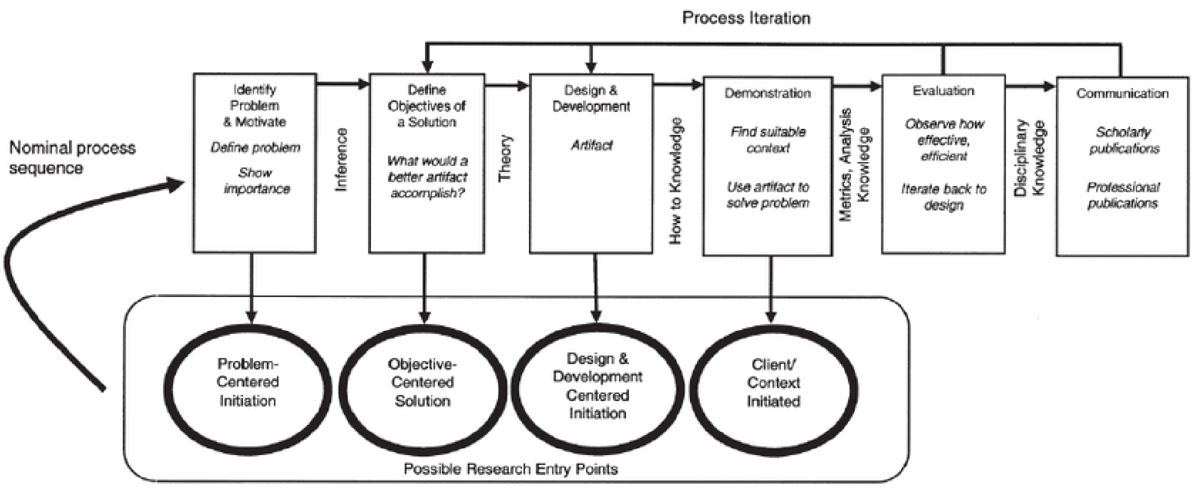

Figure 1: DSR Methodology Process Model (from Hevner, Park & March (2004))

Peffers and colleagues (2006) proposed a model (figure 1) which is now the most widely referenced model in Design Research Methodology (DSRM). The process involves six steps or activities including: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation and finally communication. (vom Brocke, Hevner & Maedche, 2020). Each activity is discussed in relation to this research project in the chapters here after.

3.1 Problem Identification & Motivation: The Knowledge Gap

The aim of the first activity is to identify and clearly define a certain research problem and justify the solution's merit. The definition of the problem will be the basis for developing a manufactured solution so fragmenting the problem from a theoretical basis to fully present the complexity of the problem may be beneficial (Peffers et al., 2006).

The literature review revealed that evolutionary computation has been extensively researched and explored. Despite this, and the technology having been used in various applications, it is still unclear how implementing evolutionary computation into the creative process is best done and how to bring the user's contribution into it (Bentley & Corne, 2001). Addressing this gap this thesis explores how to present IEC in creative application and how best to present the evolutionary options to people. The research questions are: How could IEC be utilised to augment the creative process? How best to present the evolutionary options to people?

3.2 Objectives of a Solution: Augmenting the Creative Process

This activity is about defining the objectives of the solution and these objectives can be either quantitative or qualitative. Quantitative objectives would aim for a solution which is an improvement to previous ones whereas qualitative objectives would aim to find solutions to previously unexplored problems. The objectives should be a logical conclusion to the parameters of the problem (Peffers et al., 2006).

A significant part of the literature discusses users preferences including their thoughts on automation and users generally prefer that HITL is part of the process and are less keen on automation except as part of a practical function such as undo (Li, Hashim & Jacobs, 2021). Allowing for some user control in collaboration with an intelligent computer system will support the human creative process and using evolutionary computational tools is already a proven way of augmenting human creativity (Wang, 2019).

For this purpose, making use of the CPPN-NEAT evolutionary model in tandem with traditional drawing methods allows study of using both automation and HITL in the creative process. The optimal end result of the research is; 1) to develop a creative application that combines CPPN-NEAT evolutionary images and traditional drawing methods and; 2) to add to the knowledge of how IEC can be utilised to augment the creative process.

3.3 Design & Development: The Creative Application

The third activity is creating the artifactual solution that can, amongst other things, be a model (Hevner, Park & March., 2004). Doing this activity involves deciding on the construction and functioning of the artifact prior to the actual creation of it and in this process a basic knowledge of the theory as well as being able to move from design and development to objectives and back is necessary (Peffers et al., 2006).

For the research a creative JavaScript web application combining CPPN-NEAT evolutionary images and traditional drawing methods with an interface with options to modify the machine learning model's parameters was developed. The application's drawing board was adapted from Harmony's source code (Cabello, 2010) and its brushes Sketchy, Shaded, Chrome, Fur, LongFur and Web were first used in The Scribbler (Frank, n.d.). The CPPN-NEAT model that generates evolutionary images by evolving neural networks (NN) was inspired by Picbreeder and adapted from the source code of David Ha`s (2015) Neurogram.

Ha's (2015) version of the CPPN-NEAT was written in JavaScript with some variation of the original one used in Picbreeder. The input is pixels (x, y) as well as the distance (x, y) from the origin (d), and also a bias of 1.0 (figure 2). By feeding it the distance as well it generates circular shapes and makes the images more natural and interesting. Ha´s implementation of CPPN-NEAT outputs three values for every pixel as a representation of the colours red, green, and blue (rgb). By formatting the network with a single linear additive hidden neuron and having all the inputs connected to that initial neuron will keep a more consistent image as the three colour channels will likely be more similar. Also for more richness of the network, Ha extended the Recurrent.js library so that the CPPN-NEAT could randomly choose different activation functions while evolving the network, functions like sine, cosine, gaussian functions, in addition to sigmoid, tanh, relu, square, multiplication, abs functions. Previous CPPN-NEAT used primarily the gaussian function as the activation function of each neuron, in addition to the sigmoid, and occasionally used sine and cosine. (Ha, 2015)

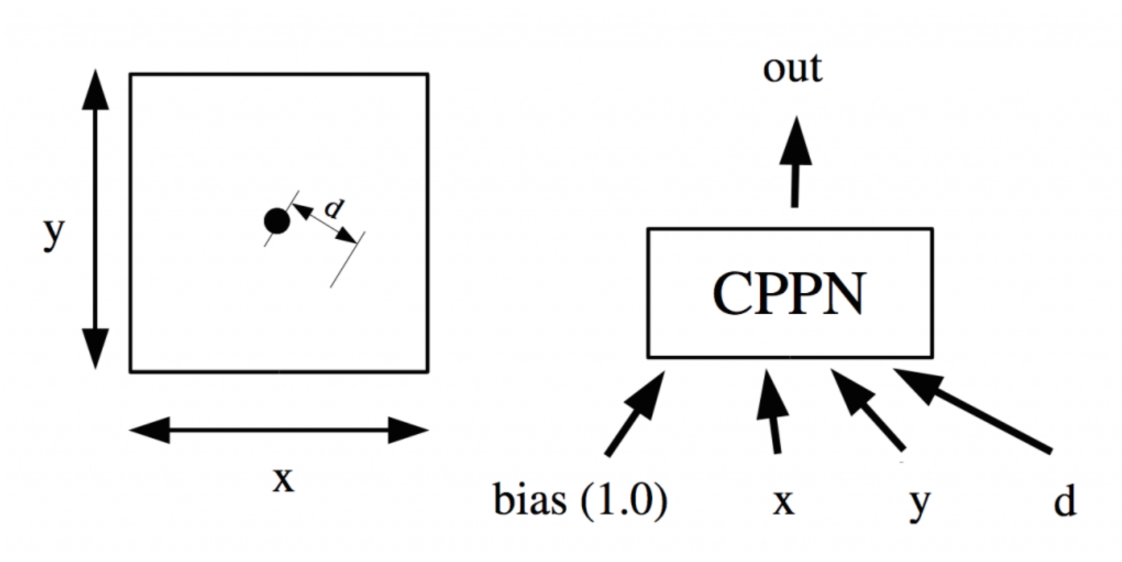

Figure 2: CPPN flow diagram (Ha, 2015)

In the beginning of the image evolution process the model displays 25 images (population) in its interactive interface. The initial 25 images are made from random networks of simple topologies i.e. randomly arranged pixels. To evolve an image the user selects 1-5 images (parents) from the 25 image collage. After choosing the images the user pushes the “evolve” button and generates a new generation of population. The evolve process can continue as long as the user wants. The networks become more and more complex and sophisticated with each generation made and more neurons with random activation functions are added. When the user sees an image they like to work with they select it by double-clicking it and send it to the drawing board. There the user can use the brushes to add to the image as they see fit. Images of the creative application’s interface are in Appendix A as well as further information about its functions.

3.4 Demonstration: The Experiment

This activity studies the artifact’s efficiency in solving the research problem. It is possible to use various methods, including experimentation or other appropriate activity and the researcher would have to have sufficient understanding of the product’s functionality (Peffers, et al., 2006).

A semi-structured qualitative study as well as some unstructured discussions and experimentation was conducted Zoom Cloud Meetings. Allowing researchers to research subjective points of view and collect extensive data from participants' experiences is one of the key values of semi-structured interviews (Evans, 2017). The definition of semi-structured qualitative study (SSQS) in this text refers to a blend of interviews and observations which are structured to some extent but also allow for some unstructured discussions and experimentation. The point of an SSQS is to address questions but not to explore hypotheses with the aim of gathering data in regard to an observed task and its context. As the researcher becomes more aware of the context of the study it is natural that the way it is administered may change to further aid the data gathering and often the semi-structured interviews become more conversation-like with time (Blanford, 2013).

To understand the end-users behaviours and needs as well as to evaluate the technologies used, qualitative research methods are important although due to the varied number of different qualitative methods it can be challenging to design or choose the appropriate method according to Blanford (2013). All participants came from the creative industries and were all actively working either as employed or self-employed creative practitioners. They were selected based on their professional experience which ranged from 7 – 21 years. I also observed them using the application through Screen Sharing in real time and discussed their choices and methods whilst they were using it. The interviews themselves were conducted both prior to the observation and afterwards. The interview questions can be seen in Appendix B. The participants were asked to use the application as they saw fit while being observed. The shared screen session and interviews were recorded in both audio and video.

3.5 Evaluation: Methods of Analysis

The aim of this activity is to observe and assess to what extent the solution to the problem is achieved by the product by comparing the results of using the product with the initial objectives of the solution.. Once the evaluation is complete the researchers will establish if they need to relook at the design and development for further product improvement. Alternatively, they may decide to continue onto the next step and take note of improvement requirements for later dates (Peffers et al., 2006).

The interviews were transcribed and translated from Icelandic to English. The screen-sharing sessions were analysed by registering the participants actions and attitude towards the application. Then the data was divided into themes. The process of thematic analysis involves picking out certain themes and patterns from the data, starting with the collection of data and continuing through the transcribing, analysing and interpretation of the data. During the process the research questions need to be kept in mind as they will guide the extraction of data and which segments may be developed into a theme, which will be something that reappears on multiple occasions throughout the dataset. However, the amount of times a theme emerges is not a valid measurement of the importance of it but instead linking the themes to the initial research questions will indicate their individual value (Evans, 2017).

3.6 Communication: The Academic Paper & the Presentation

The last activity revolves around the key points of communicating the research problem and its value as well as the product itself, how it is used, its originality and its design and functional efficacy in regards to the target audience. This is similar to the academic method of structuring a research paper and to be able to effectively complete this stage the researcher needs to have knowledge of the working environment the product is meant for (Peffers et al., 2006). This has been fulfilled in the writing of an academic thesis and also in a presentation of its process and results. Submitting this academic thesis as well as developing the computational model was a requirement of the MSc final thesis project.

3.7 Methodology Summary

DSR requires the researcher to develop a novel and useful product for a certain problem and the product needs to be useful specifically for the identified problem (Hevner, Park & March, 2004). This was achieved by developing a NEAT-CPPN creative computational model aimed at augmenting human creativity. For this reason, a rigorous evaluation of the product is key (Hevner, Park & March, 2004). This was achieved with a semi-structured interview and observational experiments with three designers currently working in the creative industries.

The product is meticulously defined, represented formally, and must be consistent. The process involved in creating the product, as well as the product itself in most cases, involves an exploration of a problem and a planning and building of a product specifically designed to find a solution to the problem (Hevner, Park & March, 2004). This was done by an initial thorough literature review to identify a problem and then the planning and developing of a product aimed at exploring the identified gap in the human-machine creative process.

In the end, the DSR results need to be communicated efficiently to a varied audience including technical individuals such as researchers and creative practitioners as well as an organisational individuals including researchers within the field of work and practitioners who may possibly incorporate the product in their workflow or organisation (Hevner, Park & March, 2004). This was archived by completing this thesis and a presentation of the results and techniques used.

4 Result

The results from the semi-structured interviews showed that although all participants had similar workflow habits, they also had their own individual preferences which was sometimes guided by the work that they did. All participants had some basic knowledge of AI and connected it more with their work application tools but they were also unaware of the extent to which it was a part of their day-to-day life outside of work or to the extent it affected their information gathering from sites such as Pinterest. After experimenting with the model all participants could see a benefit from the technology's incorporation in their work although only one of the participants showed any real interest in what the technology actually was. All the participants were able to contribute ideas in regards to improving the creative application but none of them felt that more control over the evolutionary system was necessary and all the participants felt that the application inspired them and pushed them to be creative outside of their comfort zone.

4.1 Semi-Structured Interviews

The semi-structured interviews were arranged to initially explore each creative practitioner's usual creative workflow including exploration on where they seek inspiration, how they sketch ideas, what tools they currently use and how they work their way out of fixation. Two of the participants discussed starting by gathering information regarding their project either from customers although they use varied methods for this, with one favouring more collaborative working with their customers, including shared Pinterest boards, above gathering information first and then working from there. Participant #2 however, who works independently as a designer, would start by sketching ideas on a computer and seeking inspiration from there. All participants used Pinterest's recommender system as a form of inspiration as well as all of them favouring the use of Illustrator and Photoshop for drawing, although participant #1 would initially use pen and paper for their first sketches and other tools varied between participants. In regards to fixation two participants noted that his was usually due to work pressure and both of them discussed taking time out from the project at hand whereas the third participant preferred to persevere and continue working through the fixation until the creative workflow became easier again.

The next part of the semi-structured interviews involved gathering knowledge on the participants' experience with, knowledge of and attitude toward Artificial Intelligence (AI), both in work and in day-to-day life. All participants were familiar with, and used, Netflix and Spotify, but did not immediately make the connection with AI. Two of the participants expressed positivity about applications recommending personal suggestions whereas participant #3 expressed concerns about AI technology risking individuals becoming lazier in their search for information and instead simply accepting what was being pushed at them by the AI system. In the post model trialling questions all participants were positive toward AI becoming a larger part of their work process but also noted that this would need to have a practical purpose.

The third part of the semi-structured interviews were all post model trialling and focused on how the participants felt about using the creative application. All participants were positive toward the experience, found the application simple to navigate and control and they all felt that it pushed them into territory that they were not familiar with in regards to inspiration and creative working. Notably, the two participants who were more ‘graphic designer’ oriented paid more attention to the drawing part of the application whereas the third participant, despite being an illustrator, was less interested in this but fascinated by the evolutionary model within the creative application. They all found the experience of collaborating with this kind of AI system enjoyable and where one participant felt there was some likeness with their usual way of working, another likened it to the process of splashing watercolours on canvas and then creating images from this to work with. All participants agreed that the application was inspiring to use and enhanced their creativity and two of the participants specifically noted that it suggested to them colours and forms that they would otherwise not necessarily think of using or working with but would undoubtedly be able to utilise.

Participants were next asked how they felt about the level of control they had over the model and if there were any features they would like to add. Two participants mentioned the 'undo' function as something they missed whereas the third participant did not miss this due to her usual workflow and training, but understood why others might prefer to have the option. All participants also agreed that an export function would be beneficial and one participant mentioned a 'print' option and it appeared that the functions that the participants were missing were all functions that they were used to using in their usual creative applications. None of the participants felt that they needed more control over the evolutionary model in the application, even the one that had initially mentioned needing to be in control of their work tools. One participant noted that being able to slightly adjust the images would be beneficial and another noted that it was not possible to foresee how one would use the application further down the line, once they had gained more experience in using it.

Finally, all participants were asked what they felt the purpose of the application was. One participant felt that the entertainment level of the application allowed the brain to believe that it wasn't working and this was a good way to get inspiration without any pressure. Other participants also noted its usefulness in inspiring them and felt that it pushed them to work outside of their box, expand their ideas and ignite creativity. One participant specifically noted that in graphic design work it would be perfect for working backgrounds and patterns and that working in collaboration with the AI system would force them out of their usual 'bubble.'

4.2 Screen Sharing Sessions

All participants were quick to understand how to use the model, how to choose parent pictures and evolve them although one participant pointed out that the evolve button was too close to the restart button. Two of the three participants had limited interest in the actual technology behind the evolutionary system whereas the other participant was very interested in asking a number of questions in regards to this.

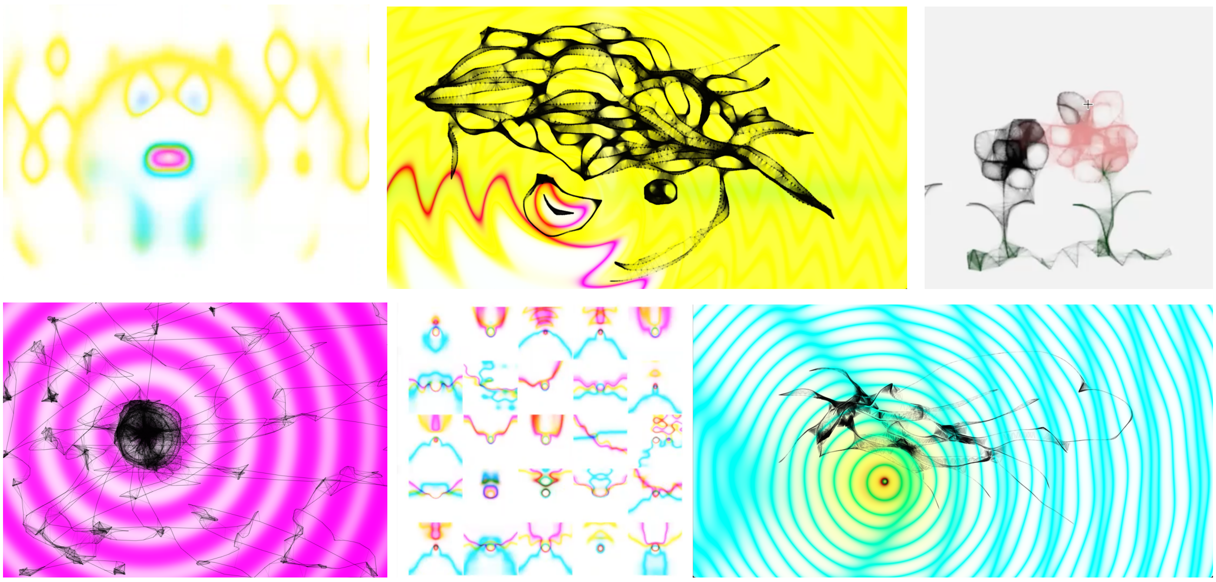

Figure 3: Collage of images from the observation session.

One participant in particular was inspired by the continued changes of the evolutionary process and eventually chose pictures from the 13th and 22nd generation pictures to work with, whereas the other two participants both chose pictures from the 5th generation. The latter two participants used more time to alter the image by using the drawing tool whereas the third participant, who had evolved their image the furthest, did not feel that altering it significantly with the drawing tool would be productive. That participant did however note that it would be useful to be able to 'tweak' the picture slightly, mainly to make the form more symmetrical.

5 Discussion

The thesis addresses the research gap regarding how best to implement evolutionary computation into the creative process and how to bring the user's contribution into it which remains elusive despite the technology having been used in various applications (Bentley & Corne, 2001). The main findings is that all participants valued the option to control their creative process but found it inspiring to be presented with output that they would not have chosen to make themselves which answers the first research question. In the final part of the semi-structured interview they all stated they could see the technology being incorporated in their workflow and felt that the application inspired them and pushed them to be creative outside of their comfort zone. Only one participant showed interest in the technology behind the process itself.

5.1 Interpretations

It was interesting to see that only one of the three practitioners favoured evolving images more than 20 generations whereas the other two only evolved up to five generations but focused more on the drawing aspect of the model. There was some difference in the participants' use of the tool and it was actually surprising that the one who illustrated for a living was the most interested in the evolutionary techniques. The other two came from a more graphic design background and they focused more on the drawing aspect and spent less time evolving the pictures although they spoke about the process being very inspiring. Users' contributions got brought into the interactive evolutionary process by allowing them to select the parents of the next generation evolved. All participants valued the option to control their creative process but found it inspiring to be presented with output that they would not have chosen to make themselves. It is well worth exploring more this way of integrating IEC into other creative applications.

Indeed, one participant in this thesis study discussed drawing in virtual reality and the difficulties of not 'feeling' the pen touch the paper. That said, all participants in this thesis study were used to working, at least to some extent, in a computational environment.

The participants' answers mirrored the ones from Jo et al (2021) research. One of the participants felt that they needed more control over the evolutionary model in the application, even the one that had initially mentioned needing to be in control of their work tools. They all found the experience of collaborating with this kind of AI system enjoyable.

To answer the second question, it is well worth exploring further this way of integrating IEC into other creative applications to present to users..

5.2 Ethical Considerations

IMonteiro (2017) article A Designer's Code of Ethics Design is a discipline of action discussing designers' code of ethics. You are responsible for what you put into the world. And while it is certainly impossible to predict how any of your work may be used, it shouldn't be a surprise when work that is meant to hurt someone fulfills its mission. We need to fear the consequences of our work more than we love the cleverness of our ideas. Criticism is a gift. It makes good work better (Monteiro, 2017). According to Takagi (2001) then user fatigue will always be a factor in regards to IEC because the computer does not need to rest but the individuals do. He goes on to note that a small population size and low numbers of generations are partly the result of the IEC user fatigue issue. The population size of EC may be constrained by the amount of images presented on the computer screen at the same time as well as by the ability of the human participant to take in, remember and compare the images presented. Equally so, the selected amount of IEC generations is also constrained by human tiredness and ability to focus and the maximum number of generations is usually between 10 and 20 (Takagi, 2001). With this knowledge IEC human–computer interfaces should be carefully designed in order to reduce user fatigue.

Data privacy is a big concern in today's world of AI. From an ethical standpoint avoiding harm is the main focus and this involves participants giving informed consent and the privacy of participants personal information being respected (Blanford, 2013). The CCI informs that making personal information available to a third party is not justifiable unless it is a collaboration agreement approved by the University and is fully explained and justified in the research proposal. Data gathered and used during research must be anonymised and any personal information should not be accessible to outside researchers unless further consent is gained. Participation in research is voluntary and participants may withdraw their consent at any point without giving a reason.

5.3 Future Work

All participants gave feedback that could be used in future works to improve the application including modifying the brushes to better fit the application's output, export the images to other applications and include a print and undo function to name but a few. Modifying the application as participants suggested and test it again with a larger and more diverse group of participants. Fitting the brushes and images better and making them available to evolve designers ideas.

EndlessForms (n. d.) discussed human subjectivity as a current limitation within the process (Clune, Chen & Lipson, 2013) and this is something that could be addressed. Future studies will need to compare products which have been evolved with a seeded approach with products that have been evolved from scratch (Zhang et al., 2015) and finding ways to convert people's manual work or sketches into a genotype that can be evolved would be beneficial.

6 Conclusion

In answering the research question 'how could IEC be utilised to augment the creative process?' finding a balance between the automation of evolutionary computational tools and giving the user control over other selected aspects is necessary to reduce the creative gap between human and machine. Including the HITL aspect is vital to ensure that the evolutionary computational tool augments the user's creative process rather than restricting it. In regard to how best to present the evolutionary options to people, a IEC model incorporating an approach of collaborative working with the user rather than automating the creative aspect itself would be more beneficial to the creative user and thus, they would be more likely to incorporate it into their individual workflow. All participants in the experiment provided positive feedback regarding the use of the model and were able to envisage its incorporation into the creative workflow. Each participant had individual preferences in regards to which aspects of the model they used more and were able to utilise their existing skills whilst at the same time recognising that the model inspired them creatively and opened up possibilities in creativity which they would otherwise not have thought of.

Further research into comparing product results depending on the method of evolution is necessary as is continuing to progress toward a system which allows people's non-digital work to be converted to a genotype which can then be evolved using evolutionary computational methods. This thesis has contributed to the field of evolutionary computational research and explored further the use of CPPN-NEAT incorporated into a creative practitioners workflow by development of a computational model and observational experimentation with current creative industry practitioners.. The result is that continuing research would be beneficial and that further development of such systems would doubtlessly benefit the workflow for the creative practitioners and serve to augment the creative process.

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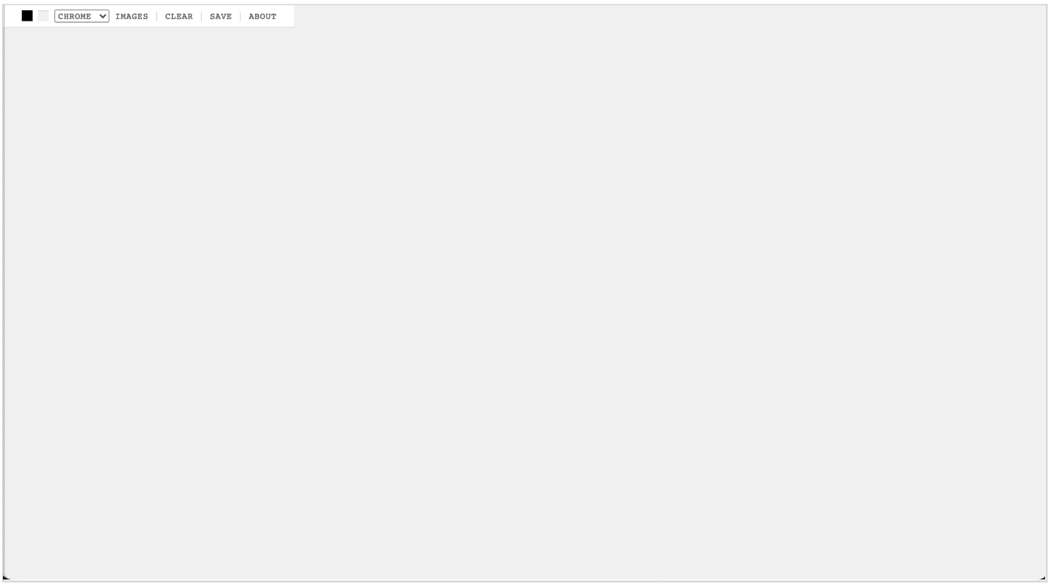
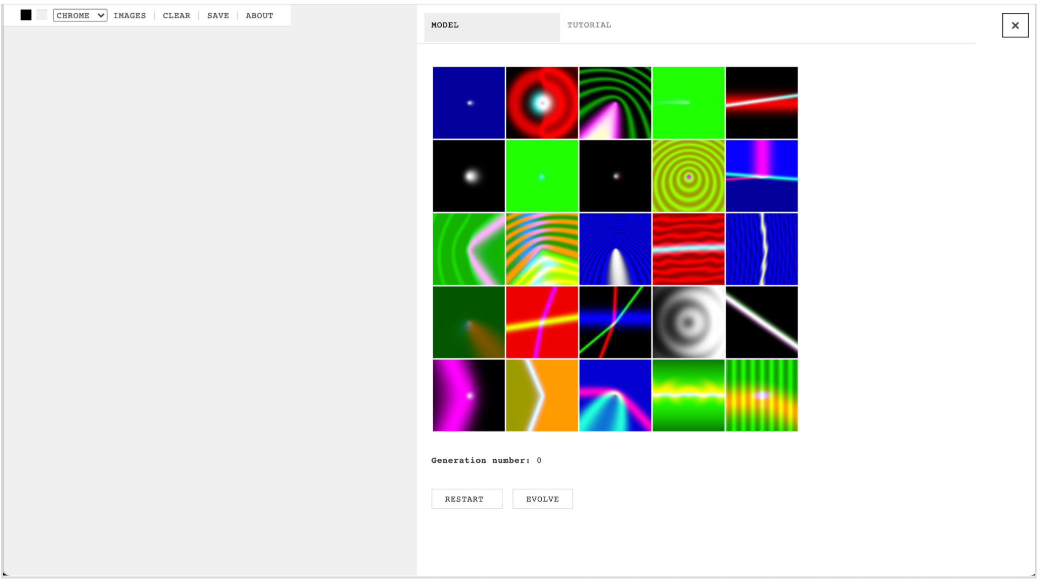
Appendix A: The Creative Application

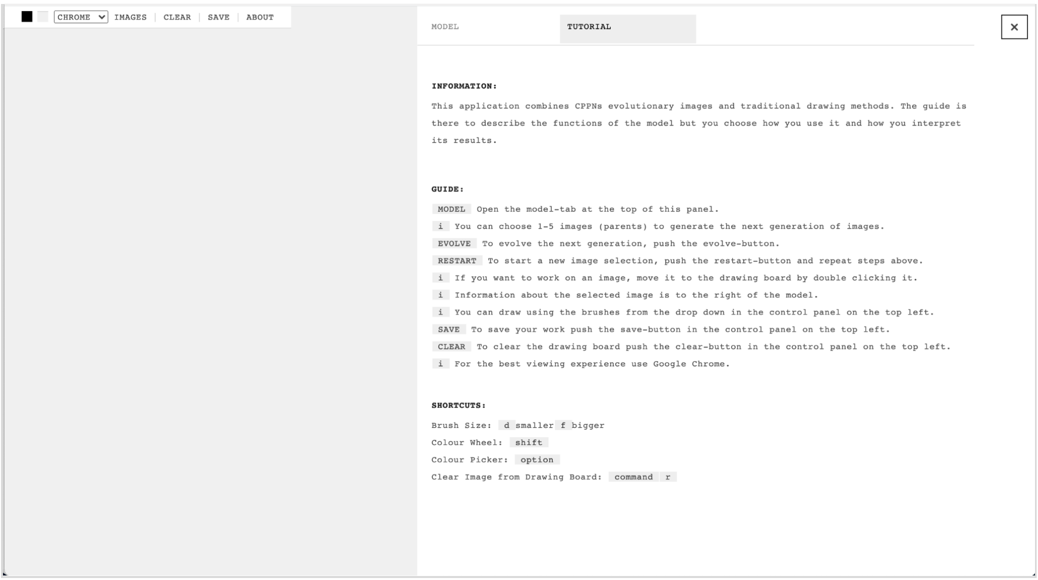


This is the drawing board of the creative application.

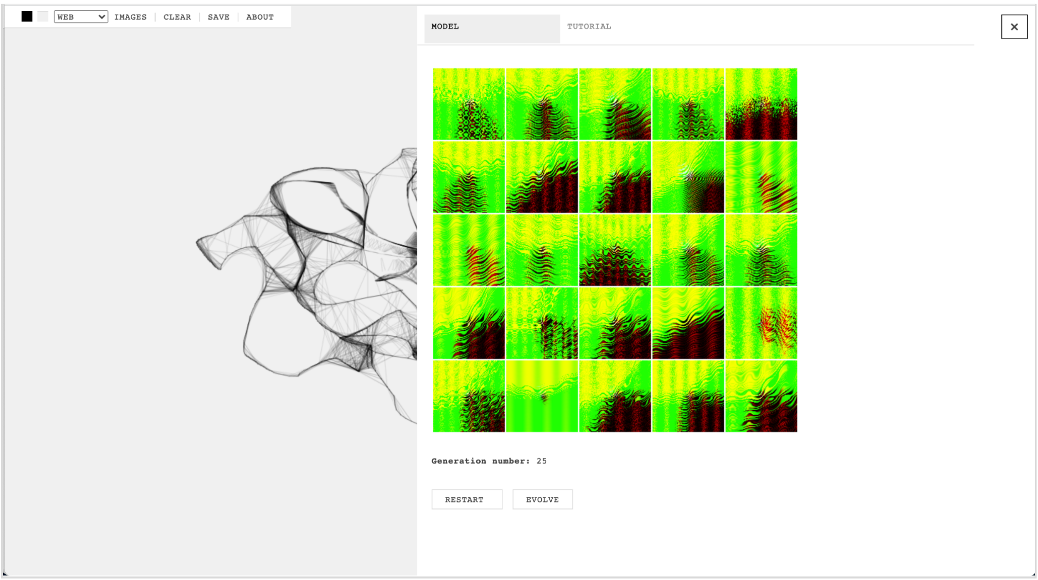
These are the different brush options to use for drawing.



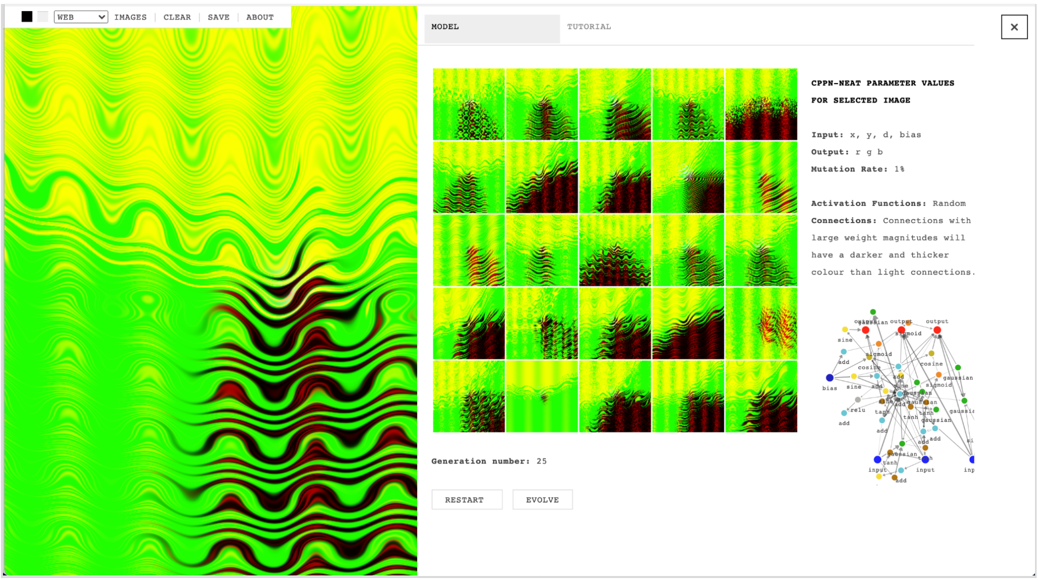
This is the interface for the interactive evolutionary model.



This is the tutorial panel for further guidance.



Here the evolutionary model has evolved 20 generations of images.



Here an image has been chosen and sent to the drawing board for further work.

About the Creative Application

Creative Application's Website: https://hallabjork.github.io/CreativeModel/

Source Code: https://github.com/HallaBjork/hallabjork.github.io/tree/main/CreativeModel

Information: This application combines CPPNs evolutionary images and traditional drawing methods. The guide is there to describe the functions of the model but you choose how you use it and how you interpret its results.

Guide:

- Open the model-tab at the top of this panel.
- You can choose 1-5 images (parents) to generate the next generation of images.
- To evolve the next generation, push the evolve-button.
- To start a new image selection, push the restart-button and repeat steps above.
- If you want to work on an image, move it to the drawing board by double clicking it.
- Information about the selected image is to the right of the model.
- You can draw using the brushes from the drop down in the control panel on the top left.
- To save your work push the save-button in the control panel on the top left.
- To clear the drawing board push the clear-button in the control panel on the top left.
- For the best viewing experience use Google Chrome.

Appendix B: The Experiment Material

UAL CREATIVE COMPUTING INSTITUTE

CONSENT FORM

PARTICIPANT INFORMATION

Research Project: Final Thesis in MSc Data Science and AI for the Creative Industries
Researcher: Halla Bjork Kristjansdottir, student ID 20038170
Location: Zoom Cloud Meeting
Time: 1 hour
Language: All material in English / Interviews in Icelandic
Application's Website: https://hallabjork.github.io/CreativeModel/

About the Research: Addressing the research gap regarding how to utilise machine learning (ML) to augment creative processes, this research explores ways to present interactive genetic algorithms (IGA) in creative applications and how editing its model's nodes and connections can work as a creative tool. For this purpose, creative practitioners are asked to trial a creative application that makes use of CPPN-NEAT evolutionary model, allowing them to explore the model's parameters and its creative output in tandem with traditional drawing methods, iterating between the two. The optimal end result of this research is; 1) to develop a creative application that combines CPPN-NEAT evolutionary images and traditional drawing methods and; 2) to add to the knowledge of how interactive genetic algorithms (IGA) can be utilised to augment the creative processes.

Experiment Description: The participants will be asked to use the application as they see fit while being observed through Zoom Cloud Meetings - Screen Sharing. They will also be asked to talk through their work and describe their actions and intentions. If needed they have access to the researcher and the application tutorial for guidance. The participants will take part in semi-structured interviews before and after the shared screen session. The shared screen session and interviews will be recorded (audio and video).

DATA AND ANONYMISATION

The CCI aims to never conduct research where personally identifiable information is made available to any third party outside the context of a University-approved collaboration agreement that fully incorporates the precise circumstances, reasoning and relevant exclusions required for specific research to be undertaken.

As such, data collected and utilised as part of all research will be archived in anonymised form, and no personally identifiable information will be accessible to any researchers outside the core research team without further consent.

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YOUR CONSENT

By participating in the CCI Research Project, You agree to the following statements:

- You confirm that You have read and understand the information provided prior to participating.
- You understand that Your participation is voluntary and that You are free to withdraw at any time without giving any reason.
- You understand that the researchers named above will have access to the Research Data collected during this project.
- You agree that the anonymised findings may be used in academic reports, publications and academic presentations.
- You agree to take part in the research project.

Signed:_________________________________ Date:____________

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1. **Demographics**:
    - Occupation (how they identify themselves)
    - Occupation duration
    - Age
    - Sex/gender/pronouns
    - Ethnicity / Nationality
    - Education
    - Geographical area
2. **The Participant's Creative Workflow / Process**
    - How would you describe your normal creative workflow?
        i. How do you find your inspiration?
        ii. If you experience fixation how do you work your way out of it?
        iii. How do you sketch your ideas?
        iv. How do you transfer the ideas / sketches into a prototype?
        v. What tools do you mainly use in your creative work?
        vi. If you use computers, then what applications do you mainly use?
3. **AI Experience:**
    - What do you think about AI in general?
    - What part do you think AI should play in our lives?
    - What are your experiences with AI applications in day-to-day life?
        i. If not, have you used Netflix or Alexa?
    - What are your experiences with AI applications in work?
        i. If not, have you used Photoshop neural filters?
    - Have you heard about machine learning and do you know how it works?
    - Would you be interested in including AI more in your work process?

Follow-Up Interview Questions:

1. **The Creative Application - Interface:**
    - How did you find using the creative application?
        i. What aspect of the tool did you like, if any?
            1. Model
            2. Drawing board
    - Did you find it difficult to navigate?
    - Did you find it difficult to operate?
    - Do you understand how to use the model's controls?
2. **The Creative Application - Affect on process:**
    - How did you like creating in collaboration with the model?
    - Did the collaboration affect your workflow / final creation?
    - Do you feel that you understood the model's workflow?
    - Did you feel more or easily inspired / creative using the ML model?
3. **The Creative Application - Usage:**
    - Did you like / dislike being able to control the model's parameters?
    - Would you like to be able to control more aspects of the model?
    - Are there any attributes in regard to the model that you would like to add?
    - What would you say the purpose of the application is?
    - Are you still / now interested in including AI more in your work process?
4. **Feedback / Other:**
    - Were there any technical difficulties while doing this experiment (Wi-Fi)?
    - Would you like to give feedback?