Embedding of Pixel-Based Evolutionary Algorithms in my Global Art Process

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Summary. My art comprises three levels: basic, methodical and superordinate. The basic level refers to the production of individual works of art. At the methodical level, I'm concerned with the development of artistic processes, in this case, inspired in evolutionary concepts. Finally, as a superordinate level, social sculpture, "Health Art", is considered.

Between 1995 and 2003 I developed and used several pixel-based evolutionary art processes. These artistic approaches resort to biological inspired concepts, such as population, variation and selection. The individuals were pixel images. In the reproduction phase two (or more) individuals were selected as parents and the images were recombined by the exchange of image parts (Regions-of-Interest). Variation (mutation) was performed by means of image processing operations such as the rotation of image parts with random but constrained parameters. Parents and offspring were evaluated by the aesthetic preferences of the artist and the best individuals built the next generation.

A unique and more complex evolution art process was developed in 2004, with no direct correspondence to known evolutionary algorithms like GA, ES or GP. It uses some additional evolutionary concepts, such as a global pool of images and multi-sexual recombination, together with ontogenetic concepts, such as spores or fruits, and other concepts such as image templates. In a narrow sense, there is no change of generations of image individuals. Selected individuals are directly inserted in the global image pool, being also involved in a second reproduction process where they are transformed by mathematical symmetry operations. The resulting images are also inserted in the global image pool, while all the images in this pool build the basis for recombination in the next generation.

Future plans, about file formats, other image reproduction operators, image databases and aesthetic preference modelling, are also discussed.

1 The three levels of my current art

In the next sections I explore the scientific and artistic issues that arise in the three levels – basic, methodical and superordinate – of my work as an artist.

1.1 Basic level: individual work of art

The first level raises purely artistic questions about shape, composition and colour.

I was strongly influenced by art styles such as Informel [6, 7, 8, 9], Abstract Expressionism [16] and Action Painting , as well as by artists such as Hans Hartung [15] and Jackson Pollock [25]. Pollock's dripping technique led me to the development of different methods of self-organizing painting [27], long before I came across the term "self-organizing painting" – I was about 13 years old. I was, and still am, fascinated by the ability of materials to build complex structures only by means of their physical and chemical properties. These structures are dynamic and the most interesting of them are far from balance. Therefore, capturing these interesting structures by photographing them was natural to me, which led me to abstract photography. A large archive of abstract photographs was accumulated over the years and they were digitized in the early 1990's. This marks a turning point because my work shifted from conventional visual art, such as painting, to computer aided art, using, however, conventional image processing methods.

These abstract (macro) photos have associations to satellite images of the earth and other planets. This is no coincidence because the dynamic effects that shape landscapes and atmospheric structures belong to the same class as the effects that shape the structures in self-organizing painting (dynamic structures in fluids; see Fig. 1).

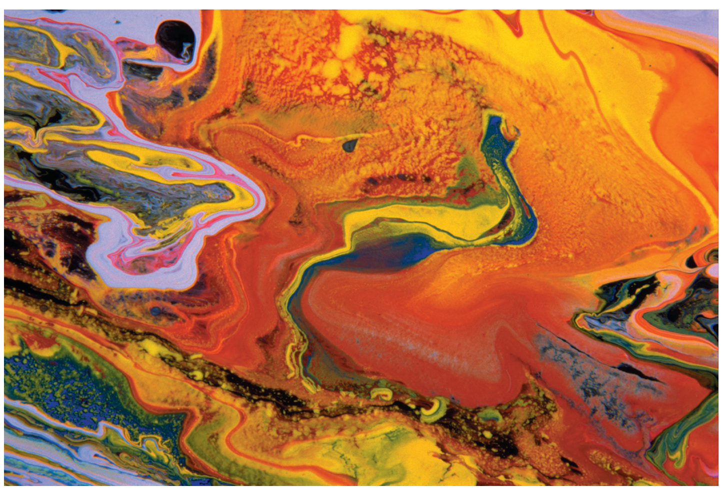

Fig. 1. Example of a digitized macro photo as part of a self-organized painting.

The idea of a "contrast aesthetics" developed over the years and I tried to recombine contrasting and partially contradicting concepts to create both aesthetic and interesting works. The biological concept of symbiosis constituted an increasingly important metaphor for this integration. To date, the following concepts have been integrated in my works:

- symbiosis of self-organizing painting (Informel, Abstract Expressionism) and geometric/constructive art (concrete art [22])
- symbiosis of biomorphic and hard-edge painting shapes
- symbiosis of symmetry and symmetry breaking
- symbiosis of local and global symmetry

Questions about symmetry and symmetry breaking have become specially under focus in the last two years. Bilateral symmetry is used in most cases because there are neural and evolutionary biological correlations to aesthetic feelings. This is shown by the scientific research on aesthetics which can be exemplified by studies about the attractiveness of faces.

Given that social beings humans depend on recognizing and interpreting faces and facial expressions, a large part of the visual system is focused on face recognition.

Faces have an overall bilateral symmetry, although they present plenty of small local symmetry breaking (the same can be said about the bodies of most animals). Therefore, the visual system specializes in recognizing bilateral symmetry and its deviations.

There is a long standing hypothesis according to which symmetric faces are more often selected, given the task to select faces with higher attractiveness [23]. Some empirical studies validate this hypothesis [23] specially if female subjects are selecting male faces, although other studies came to inconclusive results ([5] or [17]). The attractiveness of symmetric faces could be explained by evolutionary biology. The deviation from a symmetric ideal could point towards development alterations which might be caused by genetic defects or by parasitic influences. Both cases would possibly affect reproduction success, therefore, reproduction partners with symmetric properties are preferred. Such an explanation would indicate that aesthetics has an established foundation in evolutionary biology [26].

The starting point for me to develop a meta-strategy to find a balance between symmetry and symmetry breaking, was based on the positive correlation between symmetry and aesthetic feeling (on the one hand) and between symmetry and boredom after some time of perception (on the other), so as to find aesthetic and interesting works of art.

1.2 Methodical level: Evolutionary Art

The second level is the methodical level, where I transfer evolutionary concepts and methods to develop evolutionary art processes that enable me to create non-representative works of art that fit my aesthetic preferences. I view an art process as a sequence of actions by an artist or group of artists whose outcome is a work of art (image, sculpture, ...) or the process itself is a work of art (performance, dance, ...).

In this context, an evolutionary art process can be defined as an artistic process where the three evolutionary concepts population, variation and selection are used. This does not necessarily mean that the whole process is computerized, or even that a specific evolutionary algorithm is incorporated, because evolutionary art can be done with paper, pencil and a dice. For instance, William Latham was doing evolutionary art on paper, long before his ideas were converted into a computational approach [24]. Such a definition includes cases where an implemented evolutionary algorithm is only a part of the whole process, specially if the outcome of the algorithm can be optimized by the artist. If the desired output of an art process is a complex image, it is natural to use the aid of computers to generate image individuals, otherwise the change of generation would take too long. The resulting evolutionary art process might be style and material independent.

The background for this development dates back to around 1995, when my scientific interests shifted from Neural Networks [21] and specially self-organizing maps [18, 2] to Evolutionary Algorithms and particularly Evolution Strategies [20, 1, 3]. I first became aware of Evolutionary Art when reading the exhibition catalog of Ars Electronica , 1993 about Artificial Life and Genetic Algorithms [10]. I realized immediately that this could be a crossroads, a junction, bringing together my research and artistic interests.

In the first stage I developed an integration of my conventional art process, (self-organizing painting), and an evolutionary art process that uses the basic concepts: population, variation and selection. I used the digital images in my archives for the initialization of the whole of my early evolutionary art runs and I evolved these images over some years (see fig. 2 for example).

Fig. 2. Image individual from the end of my first evolutionary art phase.

I also used the results for post-processing operations – such as the creation of abstract panoramas (see fig. 3) which were developed until 2003. They can be viewed on the web with a specific panorama viewer (see `http://www.vi-anec.de/Trance-Art/Gesamt-Panoramen.html`). A physical transformation of this kind of art is difficult because panoramas often have a height:width proportion of 1:10.

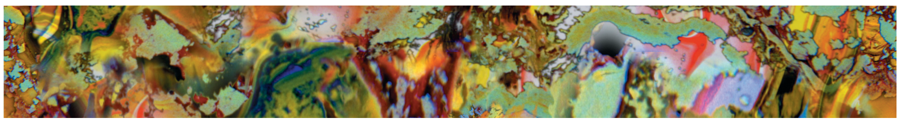

Fig. 3. Example of an abstract panorama.

Around 2002, I realized that this kind of evolutionary art process was ending. So, in the context of my contrast aesthetics , I began to play with the idea of how to combine contradicting approaches (such as geometric, constructive and concrete art) with the images derived from the non-representational art of self-organizing painting. The combination of geometric shape and non-representational content opened a new dimension to my work and the combinatorial properties of evolutionary art were suitable for exploring this new dimension.

Geometric forms naturally lead to questions about symmetry, so I combined this development with the wish to work with biomorphic shapes by applying the supershape formula [11] in many of my new works. Fig. 4 shows some examples from the repository of masks generated from supershapes.

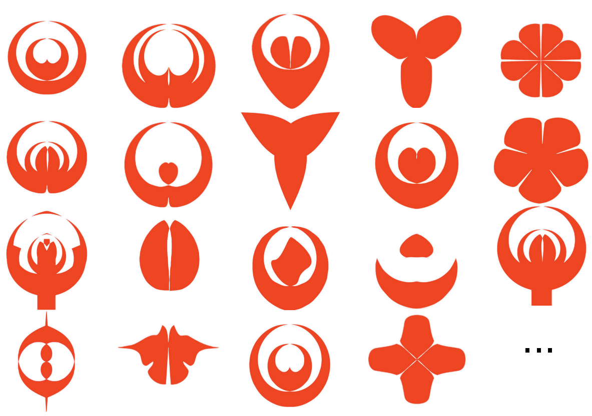

Fig. 4. Examples of supershape masks.

The new questions about symmetry, symmetry breaking and biomorphic shapes required a new adapted kind of evolutionary art process. Such a unique and more complex evolutionary art process is being developed since 2004, dealing with these new requests and using additional concepts, namely, multi-sexual recombination and global image pools, as well as ontogenetic concepts, i.e., spores.

1.3 Social sculpture: Health Art

Since 2004, I have embedded the first two levels into a larger artistic process, a social sculpture ([14], `http://www.social-sculpture.org`) called "Health Art" invented by me. Health Art is a completely new way to combine art and health within the environment, and a new answer to the old questions about the effects and benefits of art. Health Art works, in general, possess an intended and objectively quantifiable influence on environmental factors which positively affects health. This general concept is specialized in AROSHU® Health Art by integrating in my art works absorber materials which neutralize and/or bind a large number of gaseous air pollutants. The effectiveness of the absorber materials was scientifically confirmed by several research institutions such as the DW-Institute (`http://www.dwi.rwth-aachen.de`) at the technical University of Aachen and the Eco Umweltinstitut (`http://eco-umweltinstitut.de`) in Cologne. A unique AROSHU® picture frame was developed in which the absorber material is suspended in such a way that it allows a multiple area of absorber material surface (up to 4x., indicated, AROSHU®-4). An AROSHU® picture of 1 sq. meter has approx. 4 sq. meters of integrated absorber surface, capable of cleaning a room with approx. 80 cubic meters of air.

The social sculpture of Health Art has connections to the work of Joseph Beuys (`http://www.beuys.de`) specially to his examination of the connections between medicine and art ("healing forces of art", [19]) and with socio-ecological projects like the "7000 Eichen" , (7000 Oaks; `http://www.7000eichen.de`). Beuys's project 7000 Oaks started in 1982 at Documenta 7 , the large international art exhibition in Kassel, Germany. The plan was to plant seven thousand trees, each paired with a columnar basalt stone through greater Kassel. The project was carried out under the auspices of the Free International University and it took five years to complete. The last tree was planted at the opening of Documenta 8 in 1987. Beuys intended the project to be the first stage in an ongoing scheme of tree planting that would extend throughout the world as part of a global mission to effect social and environmental change. Locally, the action was a gesture for urban renewal. The projects, "7000 Oaks" and "Health Art", are both intended as open-end growing social sculptures that integrate artistic, ecological and social aspects.

Health Art integrates the additional aspect of human health because indoor air pollution is a large, but underestimated problem and many millions of people in industrialized countries are affected by environmental diseases like allergies, sick building syndrome (SBS) or multiple chemical sensitiveness (MCS).

2 The first Evolutionary Art processes (1995–2003)

As previously stated, in this context evolutionary art is seen as art created by a method that resorts to evolutionary concepts.

Since I use the help of computers in my evolutionary art method, it can be explained by the description of a generic evolutionary algorithm with four main components: population, evaluation, selection and reproduction. The goal was to transfer these components to an artistic context (here: visual art) and determine what could be the meaning of these central concepts in the scope of visual art. There is no obvious or single answer to this question, since a huge variety of possible evolutionary art processes are possible.

2.1 Population and individuals

Although most conventional evolutionary art approaches resort to an expression-based image representation, all the individuals in my evolutionary art processes are bitmap images . The population is simply a set of such individuals i.e. it has no other internal structure such as a graph. In contrast to expression-based representations, I have named this approach "data-based" evolutionary art.

It is possible to use the whole range of concepts that have been implemented in graphic file format, such as alpha channels and layers. File formats using meta-information (commentary, IPTC-Header, XML tags, ...) can be used directly as image individuals, since the fitness value can be saved as a kind of meta-information in the file.

The seeding operation, i.e. the creation of the first population, is an important part of my approach. Typically, in expression-based approaches, the individuals of the first population are created through the random generation of the corresponding expression trees. A random initialization in the case of data-based evolutionary art is not reasonable because such an image would not have any structures. It is more efficient and effective to start with images from outside an evolutionary process which have already satisfied to some extent the aesthetic preferences of the artist.

2.2 Evaluation and Selection

After the initialization and after the generation of offspring, the individuals are evaluated . In most evolutionary algorithms this is done with a fitness function. However, in the case of interactive evolutionary art, the quality of an individual reflects the aesthetic preference of the artist who is evaluating the image individuals. In my evolutionary art processes there is no explicit fitness function, therefore this is an interactive evolution approach, requiring input from an external source, the artist.

A binary evaluation is applied as strategy to select the individuals and parents for the next generation. My evolutionary art process depends solely on my aesthetic judgments, images that do not satisfy my aesthetic needs are not selected and are deleted at a later stage.

2.3 Reproduction

Reproduction is the operation by which new individuals (offspring) are produced from the genetic code of one or more mature individuals (parents). It is necessary to define recombination and mutation operators suitable for data-based evolutionary art.

If we use bitmap images as individuals, the interpretation of reproduction with the two components (recombination and mutation) is not that obvious, but it is clear that the interpretation is different from expression-based evolutionary art. My solution, in 1995, was to apply some image processing functions as reproduction operators and to use random but constrained parameters of such functions so as to introduce variations in the next generation.

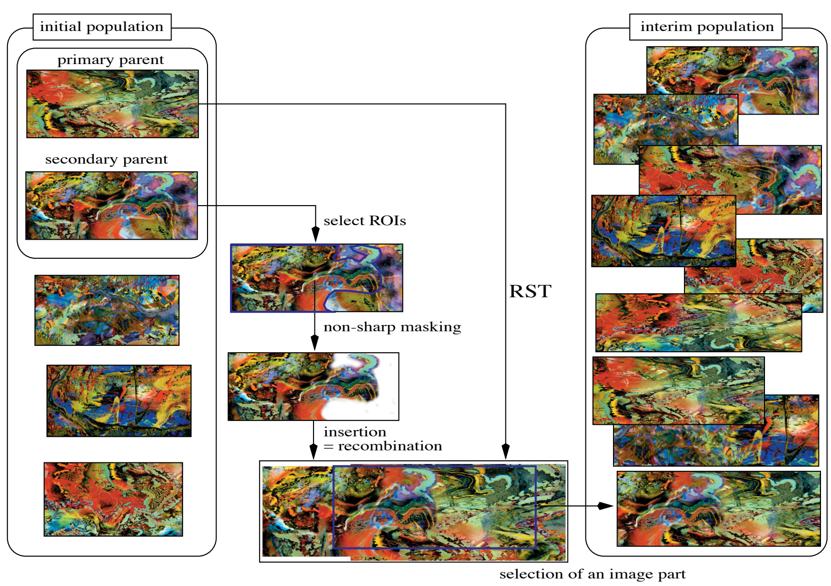

Fig. 5. Recombination and mutation in the first evolutionary art processes.

Recombination

One possible definition of recombination , used in my art process, is an analogy to the crossover operations in genetic algorithms, or to the discrete recombination operator in evolutionary strategies.

Segments of one parent image are selected which, in turn, build an offspring image with the complementary parts of the second image. The concept through which this is achieved is called Regions-of-interest (ROIs), i.e., possible overlapping segments of an image defined by the artist.

A simple reproduction strategy that was used first selects at random two parents from the image population (see fig. 5). One of them is selected randomly as the primary parent who is copied to one layer of the offspring individual. Then ROIs of the secondary parent are selected randomly and they are masked with non-sharp edges and later copied to a higher layer of the offspring.

This reproduction strategy can be generalized to multi-sexual reproduction if the offspring obtain their genetic material (image components) from more than two parents, i.e. a second, third, ... parent inserts their selected ROIs in the copied primary image.

Mutation

Copying images and image parts in an offspring individual is the recombination part of the reproduction process. Additional variation (mutation) is introduced by transforming the transmitted regions by means of image processing operations with randomized parameters within certain constraints. The primary image is not just copied but also undergoes transformations. In most cases, a RST-transformation (Rotation-Scaling-Translation) was used i.e., the image of the primary parent and the ROIs are rotated by an angle between 0 and 360 degrees, they are scaled by a scaling factor, e.g. between 0.8 and 2.4, and the result is moved in the x and y direction.

After recombination with mutation, the parents and offspring build an interim population and the elements from this population are evaluated, i.e., the artist decides if the images are compatible with his aesthetic preferences. The images that survive this evaluation are selected for the next generation.

3 The current evolutionary art process (2004-ongoing)

My current evolutionary art process was developed in 2004 using some additional concepts, such as a global image pool , image templates (as an analogy to the genome), multi-sexual recombination and specific types of meme reproduction, as a translation of the ontogenetic concept of spores or fruits.

3.1 Overview

The process begins with the definition of a template image that consists of several masks, each on one layer (see point 2 in fig. 6). A multi-sexual reproduction process (see point 3 in fig. 6) exchanges those masks randomly by images from a global image pool (see point 1 in fig. 6) that consists of several classes of images. Recombination strategies define which mask is exchanged by an image from which class. This reproduction is multi-sexual because more than two layers and image parents are always selected.

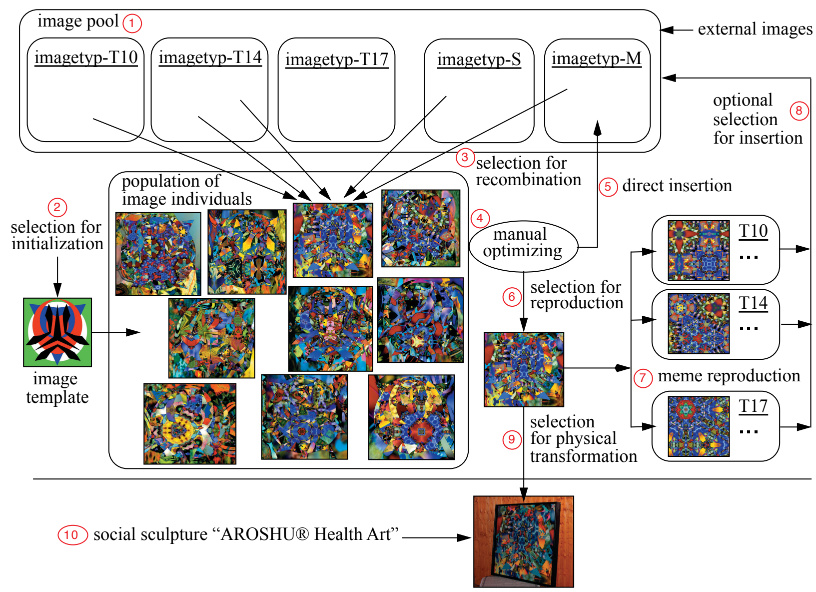

Fig. 6. Overview of the current Evolutionary Art Process.

After generating a population of about 100 individuals, the evaluation is done by the artist putting each image in one of three classes: "non-reproduction" class for images that do not match the aesthetic preferences and which will be deleted; "optimization" class for images that have a good overall impression but with local faults or defects which will be optimized by hand; "direct reproduction" class for images that match the preferences. After the time-consuming manual optimization, (see point 4 in fig. 6) the images from the second and third classes are directly copied into the global image pool in their own class (see point 5 in fig. 6).

Additionally, they undergo a second reproduction phase where mathematical symmetry operators with random but constrained parameters are applied to them (see point 7 in fig. 6). Forty to eighty meme images were generated for each symmetry operator. These images were directly inserted into the global image pool, where every symmetry operator used has its own image class. Images from the first and second reproduction processes are then available for selection in the next iteration or generation, where the same or a different image template is used.

3.2 Global image pool

A huge global image pool consisting of pixel images is provided. The images come from non-evolutionary art processes such as self-organizing painting and from previous evolutionary runs. The image pool is structured into different classes, (see imagetyp-T10, T14, T17, M, and S in fig. 6) depending on the origin and method of generation. Many of the image individuals from the first evolutionary art processes are included in a specific image type S, called “Spaces”. These individuals are often used as background (first layer).

The idea of a predominant image or meme pool is derived from the idea of genetic load [4]: Preserved genes from the evolutionary history of a population or a species to be used now or later. These genes were originally included in the gene structure of the individuals, but in my evolutionary art process all memes were externalized in the image pool where they are used for recombination purposes. Such a predominant image pool has no close biological analogy because it represents not only all the genes of a present ecosystem, but also the whole history of such an ecosystem.

3.3 Initialization by determination of an image template

An important building block is the use of an image template in analogy to a genome. A genome is defined by a certain number and position of genes. A certain number of masks and their position to each other exemplify the analogy in this evolutionary art process. Each mask is located on a specific layer of the image template. The masks and their composition in the template are generated by the artist and they reflect my interest in the dependencies between symmetry and symmetry breaking. In most cases, bilateral symmetry is used for the masks.

3.4 Recombination of image individuals

A population is defined by a number of image individuals. Those image individuals are generated by using a multi-sexual recombination process that randomly takes images of the image pool and exchanges the content of masks by the corresponding content of the selected images (see fig. 7). This recombination process has a similarity to the multi-sexual recombination of viruses where more than two individuals recombine to build offspring. The gene pool is the set of all individuals that ever existed which corresponds to the image pool.

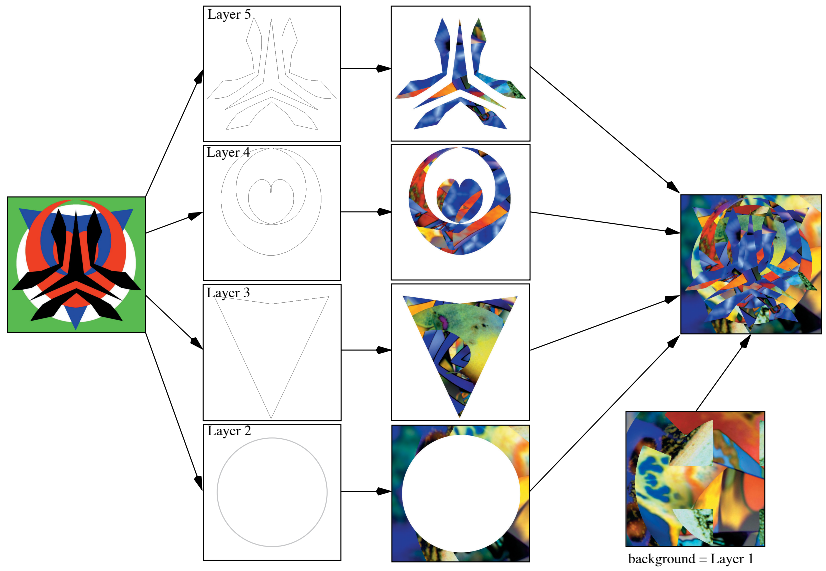

Fig. 7. Recombination with a template and masks.

There are lots of possible recombination strategies which determine what type of image should be used for one of the masks. It is part of the artist's task to specify such strategies. An actually used recombination strategy specifies that for the background layer (layer 1) a random image is chosen from the class "Spaces from the year 2004", for layer 2 a random image is chosen from imagetyp-T14 (plane group p3m1), for layer 3 a random image of imagetyp-T14 or imagetyp-T10 (plane group p4m) is chosen, for layer 4 a random image is chosen from imagetyp-T17 (plane group p6m), and for layer 5 a random image is chosen from imagetyp-M (image individuals that were directly transferred to the image pool, see point 5 in fig. 6):

- layer 1: "Spaces from the year 2004"
- layer 2: image type T14
- layer 3: image type T10 or T14
- layer 4: image type T17
- layer 5: image type M

A huge flexibility can be generated if the masks are previously transformed into paths. In this case, the images from the image pool are inserted and then they undergo a RST-transformation before they are transformed together with the path into a new mask or stencil.

3.5 Evaluation

After having generated a population of roughly 100 image individuals, the images are evaluated by the artist by putting them into one of the following classes:

- class "non-reproduction": images that do not match the aesthetic preferences which will be deleted.
- class "optimization": images that have a good overall impression but with local faults or defects; they will be optimized by hand.
- class "direct reproduction": images that match the aesthetic preferences.

3.6 Manual optimizing

The option of manually optimizing image individuals is specially important when paths are used, given that the probability of images with local faults can be high in this instance depending of the RST-parameters. A fault mask or stencil is built when the RST-transformed image does not fully overlap its corresponding path. Image individuals with one or more of such faults are called "non valid". If the overall impression of such an image is good, then it is selected for the "optimization" class and the fault is reversed by hand by moving the RST-transformed image on the layer in such a way, that it fully overlaps the path, followed by the merging of the image and path.

The detection of non valid image individuals is done manually by the artist during the evaluation, however a script was developed which can automatically detect such individuals if a specific background color is used that is not intentionally used in any of the images. One of the drawbacks of this procedure is the production of "false positive" detections, i.e. images are marked as non valid because there are pixels of the specific color, though they all have valid masks. A threshold of pixels was introduced in order to minimize the false positive detections: the image classified as non valid only when the number of pixels with such color is above the threshold

3.7 Selection for Meme Reproduction

After the optimization of image individuals, the classes "direct reproduction" and "optimization" are merged and then directly copied into the image pool in the imagetyp-M class. One of the unique features of my new evolutionary art process is that these images or a selected subset of them undergo a second stage of reproduction, the meme reproduction . In the present implementation, all images from the merged classes are selected for this second reproduction.

3.8 Image meme reproduction

This second stage of reproduction shares similarities with species that produce fruits or spores. Those fruits or spores have none or few morphological similarities with the parents but they are able to yield offspring by themselves.

Usually, parts of image individuals are selected and a whole new image can be generated from this part using a system of simple image operations. Given that symmetry is one of my main interests, special mathematical operations (two dimensional symmetry groups or plane groups [13]) are used to perform this task. There are 17 plane groups and four of them generate seamless images (pmm, p4m, p3m1, p6m). After experimenting in 2004 with all plane groups, three (p4m, p3m1, p6m) of the four seamless plane groups are now used in my evolutionary art process. Every symmetry group defines its own class in the global image pool. The plane group p3m1 fits my aesthetic preferences very well and it is used the most in the meme reproduction process. From every selected image individual from the first reproduction process, 80 different meme images were generated with p3m1, where p4m and p6m generate 40 each.

The generation of a meme image with p3m1 will be described next in some detail. The process begins with the selection of an image part from the source image, e. g. M04-05-08b-1-026 (rotated 90° counter clockwise) in fig. 8.

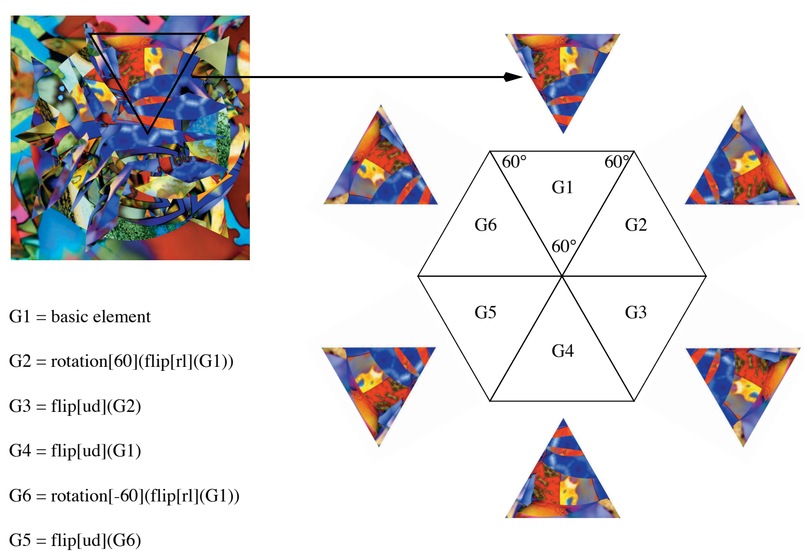

Fig. 8. Building blocks of a seamless plane covering with p3m1.

The selection with a polygon selection operation is an equilateral triangle. Its side length is a predefined constant or a function of the side lengths of the source image (e.g. 0.8 of the infimum of the two side lengths). The position of the triangle in the image M04-05-08b-1-026 is random and different in every of the meme reproduction processes. The selected image part, serves as a basic building block, G1, that can be copied and altered with some simple geometric procedures to generate five other building blocks, G2-G6, in the following way (see fig. 8):

- G2 is generated if G1 is flipped right-left and than rotated by 60^o clockwise (rotate[60](flip[rl](G1)))
- G3 is generated if G2 is flipped up-down (flip[ud](G2))
- G4 is generated if G1 is flipped up-down (flip[ud](G1))
- G6 is generated if G1 is flipped right-left and than rotated by 60^o counter clockwise (rotate[-60](flip[rl](G1)))
- G5 is generated if G6 is flipped up-down (flip[ud](G6))

A seamless covering of the plane is possible with those six building blocks. A meme image can be interpreted as a region of such a patterned plane and, as default, the side lengths of the meme image are the same as the side lengths of the source image (see fig. 9). The resulting meme image is named according to the symmetry used to generate it (here T14 for p3m1) and it is numbered, so the image in fig. 9 could be copied as T14M04-05-08b-1-026-001 in the T14-class of the global image pool.

3.9 Optional selection for insertion in the image pool

The images generated by the meme reproduction process can be copied directly in the global image pool or they can be evaluated. The direct copy option was implemented since evaluation by a human is not reasonable, due to the large amount of meme images and because of the unavailability of an aesthetic preference model that could evaluate these images with machine learning methods. This approach is also reasonable because experience has shown that meme images generated by the selected plane groups fit, in most cases, the aesthetic preferences, provided the source image was selected according to the same preferences.

3.10 Selection for physical transformation

The selection for physical transformation is not part of the evolutionary process in a strict sense, but it is part of my art process in general. It is not only selected here which image should be physically obtained but also all other aspects related to this decision: Size, materials, kind of printing, number of copies printed, etc.

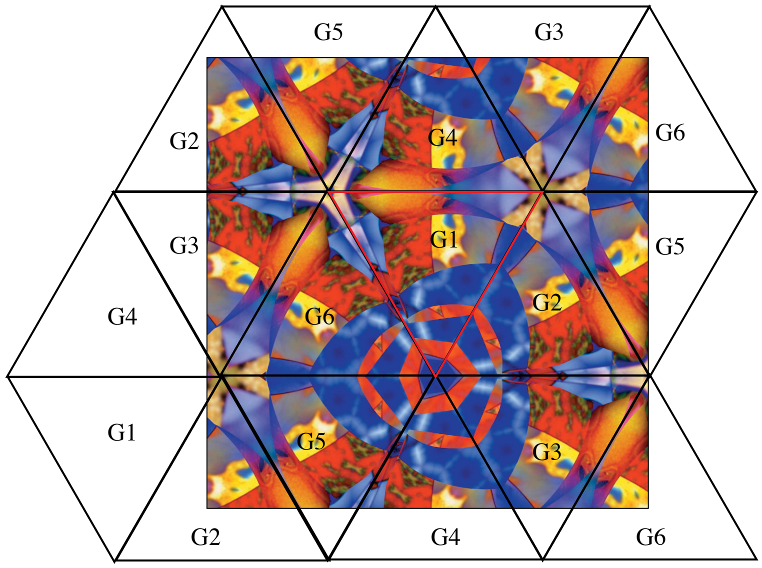

Fig. 9. Selection of a meme image from the seamless plane covering.

3.11 The social sculpture AROSHU® Health Art

Since 2003/04 the evolutionary art process is embedded in my social sculpture "Health Art" , therefore the selection for physical transformation is constrained by specific techniques and materials which are compatible with this ecological and health-conscious concept. First, the selected image individuals were printed with acrylic on canvas and then sealed with shell lack to avoid toxic emissions from the paint. Then the canvas is integrated in the AROSHU® picture frame with the absorber material that neutralizes and/or binds a large number of gaseous air pollutants.

3.12 Change of generations

In evolutionary art processes which are more closely related to the biological processes, there is a change of generation after the reproduction and selection of individuals. The selected offspring or a mixture of parents and offspring build the next generation, followed on by further reproduction and selection processes. In my evolutionary art process there is no change of generation in the this sense, because none of the individuals are transferred directly to the next generation. Selected individuals and the meme images are transferred instead into the global image pool. This has a biological correlate to species that produce fruits or spores, e.g., plants that live only one year.

3.13 Resulting Images

Fig. 10 shows two prototypical image individuals that were generated with this new evolutionary art process (on the book DVD the two image population of these examples are shown). They include most of the factors of my current contrast aesthetics indexcontrast aesthetic: Concrete art shapes and Informel content, biomorphic and hard-edge shapes, shapes with global bilateral symmetry, local and global symmetries and symmetry breaking in the content.

Fig. 10. Two examples of prototypical new image individuals: M04-05-08b-1-026 and M05-06-11-2-020.

4 Future plans

The continuous update of the predominant image pool with large pixel images demands much higher requirements to the underlying hardware than the use of expression-based evolutionary art methods, because the functions or programs that represent an image need much less hard disk memory. At the moment two terabyte (TB) hard disk spaces are in use, they must be upgraded at short intervals. The plans until 2010 are to use a small farm of computers and a large hard disk array to establish a balance between the recombination process of image individuals, consuming less resources, and the meme reproduction processes, consuming plenty of them.

Until then, a further development considering the used file formats has to be tackled. With the file formats used today, the image pool would grow at this point at a rate of more than 30 TB a year. The replacement of the used file format cannot be done easily, because the elements in the image pool have a specific file format which is used in the recombination operation of the image individuals. Only a reimplementation of the recombination operation would allow other file formats like JPEG 2000 (jp2, `http://www.jpeg.org/jpeg2000`). The conversion of the image pool with several hundred thousand images to jp2 is completed (September 2006) and the reimplementation of the image recombination process with ImageMagick (`http://www.imagemagick.org`) is in process.

A further development of the evolutionary art process will focus on the image meme reproduction by reimplementing the used plane groups with ImageMagick and generalizing them. Generally speaking, methods for covering the plane or finite plane parts should be examined, where one part (or more parts) of a source image is selected and a set of geometric operations are applied, such as copying, transition, rotation and flipping. The present meme reproduction process uses seamless, periodic and non-overlapping covering of the plane but there is a large design space of possible non-periodic and non-overlapping (Penrose patterns; for tilings and patterns see [12]) and overlapping methods that might be aesthetically interesting and could perhaps be explored by genetic programming. Apart from the geometric operations such as rotation or flipping, there are topological methods that could be applied to correct overlapping covering of the plane to generate seamless coverings. There is no way for a seamless covering with regular identical pentagons (five fold symmetry) but if the pentagons are stretched or squeezed (topological operations), then it becomes possible.

The supershape formula from Johan Gielis [11] is a generalized Superellipse Equation capable of modeling a wide range of biomorphic shapes in two or three dimensions and could be even generalized to higher dimensions. It might be worth to investigate with genetic programming methods if there are generalized and derived equations with symmetries that deliver interesting biomorphic shapes and others. I have chosen for my work an a posteriori generation of shapes with bilateral symmetry which is easily done because the specific plane group (a subpart of pmm) can be applied to all of these shapes.

A long term goal is the introduction of aesthetic preference models. Such a machine learning model should be able to predict aesthetic judgments of a specific person (me as the artist) in a specific domain like my non-representational images. This model could be used as an explicit fitness function which would constitute an important step to allow my evolutionary art processes to grow independent from me and, in the long run, to turn them from transhumanist into posthumanist art processes.

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