Ideas and Tools in Material Space – an extended spatial model of creativity

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1 Introduction

In this paper I propose a spatial framework for thinking about creative processes, both actual and computer modeled, which combines the conceptual dimensions of a work with the implications of the artistic tools we are using and the material in which the work is created.

Spatial models of creativity have been presented before. Maybe most well known is Boden's concept of exploration and transformation of spaces [1], and the ideas presented in this paper may be considered an extension of her ideas. The framework combines the relationship between the theoretically possible and the practically possible, the influence of tools on the creative exploration, what happens when we work with several tools at once and switch between them. It emphasizes the interplay between ideas, tools and material, between the desired outcome and the possible results, and the ambiguities in translating between them.

It is based on observation of my own creative work during more than two decades of artistic activities as a composer, sound artist, programmer and improviser. I have consciously observed my own creativity since my early teens (triggered by a copy of a 'creative-enhancing' book I got from my mother), and during the last ten years I have actively tried to model artistic creative processes in software, mostly based on evolutionary algorithms, in parallel with and overlapping my work as a composer. Lately, a number of originally unconnected observations have fallen into place, forming a coherent view of (my) creative process. Hopefully, it is also more generally applicable.

The paper is not about the novelty aspect of creativity, and not (so much) about the social and cultural aspects. It concentrates on what goes on in the mind of an artist during the birth and development of an artwork from concept

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to material form. It is primarily based on experience from sound, music and visual art, but I believe the ideas are applicable to many other domains.

2 Tools

The word 'tool' is used a lot throughout this text. I use it in a wide sense, denoting everything from a traditional drawing tool (e.g., paintbrush) or a musical instrument to an abstract organizing principle (spectral harmony), a given form (the fugue), advanced computer programs (Photoshop filter), generative procedures (grammar systems, evolutionary algorithms) or a representational system (Western music notation).

2.1 The Toolmaker

Artistic expression is clearly affected by the choice of tools. With more advanced tools, the contribution from the toolmaker cannot be ignored. The tool embodies a complex behavior [4] and enables lines of thoughts that would not be otherwise possible.

Sometimes this is good, sometimes it is bad, but the artist has to be aware of it. Sometimes you do not want to spend time of developing your own tools, but prefer to be confronted with an existing tool, and take advantage of the extensive design effort by the tool maker. He helps transporting me a fair bit towards sophistication, by me using his tool. I will be traveling in a space defined by the tool, but my departure point will be further away from trivial expressions. A well-known risk is that the tool steers users towards similar results. But given that the tool is complex enough (i.e., provides possibilities of considerable user-controlled variation), and that I spend a decent amount of effort on my work, the tool might not limit my artistic contribution. But we must not forget that for some tools the contribution of the toolmaker to the artistic result is considerable.

2.2 Tool Spaces

Every tool defines a space of possible results, and a topology, i.e. a definition of neighborhood relations within the space, which points are near each other, and consequently how we can travel in the space. By neighbors, we mean two points separated by a single application of the tool.

The topologies defined by the tools and concepts are very important, since they closely correspond, in two different ways, to how we think about the work. First, we naturally think about ideas in terms of how to realize them, using tools (again, in a wide sense of the word). Second, the realm of our imagination is to a large extent constructed from our knowledge about existing tools and the consumption of the results of them (i.e., existing art).

The idea of a space of possibilities for a specific tool or representation is old, but it is not enough in itself to give a complete picture of the creative

process. Also, very seldom we use just one tool to create art. We need to be able to discuss and compare the different spaces and topologies provided by different tools. We also need to consider the possibilities of the material, i.e., the medium in which we create our work (image, sound). Tools are the ways we navigate the infinite space of inherent possibilities of the material, but only along the pathways offered by the tool. Hence, we must introduce the notion of this larger space – the material space, of which all other spaces of possible results are topological subspaces.

3 The model

3.1 Overview

The main idea is that creativity is exploring a space of possibilities in a largely unknown space. The exploration follows paths that are not arbitrary. There is no such thing as free creation, since we are influenced by many things: the tools at hand, our knowledge of the tools, our ideas and concepts, what we have seen before, liked and unliked, and by our view of the world. Each of these form patterns in the space of possible results, in the form of possible outcomes (subspaces) and neighborhood relations (topologies). These topological subspaces form networks in the larger material space, which intersects each other.

While exploring, the work exists in two forms simultaneously: in a material representation and a conceptual representation. The material representation is the current form of the work in the chosen medium, as a sound sketch or an unfinished image. It is a point in the material space, the space of the theoretically possible. The conceptual representation is the current form of the work in terms of ideas and generative principles, forming a topological subspace (in the following I will use the word *network* to denote such topological subspaces, in the lack of a more suitable word) in the material space, defined by the variability of the representation. If the structural form of the representation is changed, this subspace changes, covers new regions and allows new pathways in the material space.

The focus of the creative process continuously change between these two forms, and requires mechanisms to translate from one into the other, in both ways. The discrepancies between the two, and the imprecision of the translation in both directions fuels the creative exploration, embeds qualities of human expression in the work, and imprints a trace of its own creative process.

The implementation of a concept into a material incarnation happens through the application of tools, and this process is imprecise due to the natural vagueness of ideas, the characteristic incompetence of the artist, the imperfection of the tools themselves, and his possible lacking mastery thereof.

In the other direction, the continuous re-conceptualization of material form is by its very nature imprecise and prone to misunderstandings, which, I'm quite convinced, is essential to the creative process. And this vagueness is the heart of the whole field of interpretative arts, such as musical performance and theater.

3.2 Material space and representation

The *material representation*, and the *material space* that contains all its possible instances, is a theoretical construction. If we work with images, the material space is the space of all possible images. To simplify the discussion, we can think of the material representation as a bitmap (of a certain size) in a resolution on par with our eyesight, which theoretically can represent any conceivable image. If we work with sound or music, the material space is all theoretically possible sounds (of a certain maximum length). A suitable representation is a digital sound file at a resolution as good as our hearing. These spaces are truly huge, with as many dimensions as there are sound samples, for example. Musicians or artists seldom conceive of sounds in these representations, since they are very distant from the conceptual level of a work, but as theoretical constructs they are very convenient, as we shall see.

At any specific time, the temporary form of a work is represented by a specific point in the material space[1]. Most of it is noise, or appears completely disordered to our perception. It is worth noting, that the material space in itself may be regarded as having its own topology, based on the most obvious neighbor relation – a single-pixel or a single-sample change. However, this topology is so far removed from our conceptual level, so it is not of particular interest, and we cannot even imagine how it would be to navigate a such a space freely, since such a small part of it contains anything we would call meaningful.

A specific tool connects points in this space, forming a network of paths. It defines a topological subspace (see Fig. 1). The points of this subspace are not necessarily neighbors in the material space, but the tool itself defines connections between far-away points.

Other tools define different topologies in the same material space. Together they form intersecting networks (see Fig. 2), forming the possible paths of artistic exploration. Combinations of tools allow us to travel more freely in the material space, since the combined networks cover a larger subspace of the theoretically possible, and provide a larger selection of travel paths. At any intersection, I can switch to another tool, and hence to another network.

This can be compared with physical travel – some places can only be reached by car, because they are distant. When the road ends, we put on skis or snowshoes, or simply walk. Some locations can only be reached by airplane or helicopter, or require extra oxygen. Each means of transport provides certain navigable paths, and only where the path networks intersect, i.e. where both means are possible, can we swap vehicle.

Some tool topologies may encompass all points in the material representation, e.g., if they can be applied to any possible bitmap. But they only offer certain paths of travel. They define a star-shaped network out from each point, to a set of other points. I can paint with a paintbrush on any conceivable picture, but I cannot, with a single brush stroke, get to any other picture.

[1] Artistic works can of course be constructed from parts created individually, and in this case the above is true for each part.

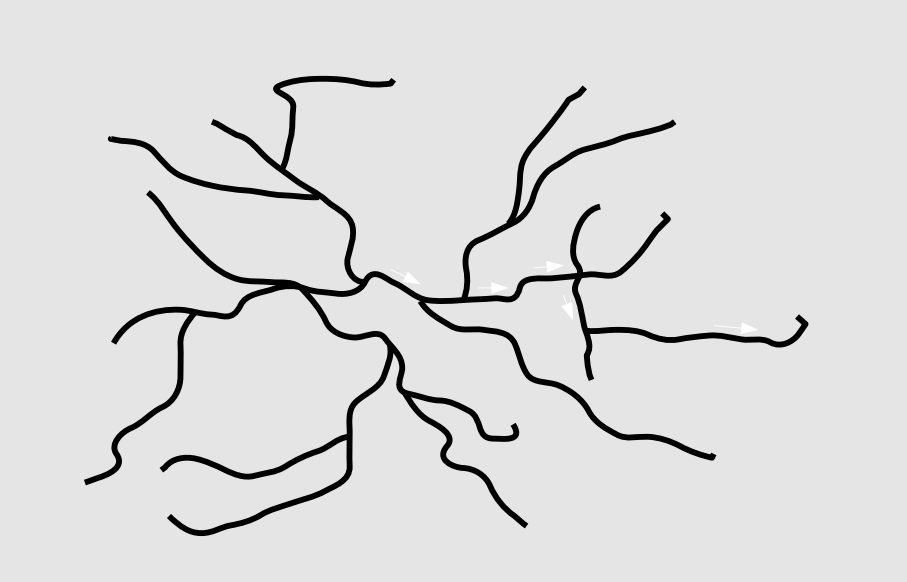

Figure 1: The topological subspace defined by a specific tool forms a network in the material space.

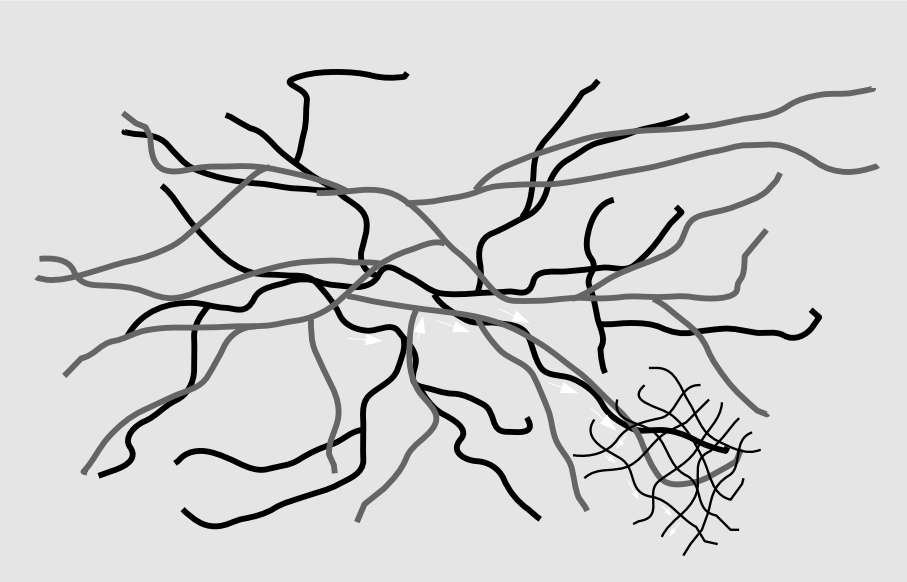

Figure 2: The tool networks of a set of tools in material space. Each tool defines a different network. At each intersection, we can switch to another tool and continue navigation along different paths.

3.3 The conceptual representation

The conceptual representation of the work is how it is represented in the mind of the artist, in terms of abstract or concrete ideas and generative principles. This representation is vague with respect to the material representation, since probably many properties are not included in the representation. If my idea is a picture of ten pigs forming a pyramid, nothing is said about the color and age of the pigs, or where they are standing. The representation corresponds to a set of all points in material space representing images that can be interpreted as a pyramid of ten pigs.

The internal structure of the conceptual representation defines a topological subspace in the material representation, along the lines of the variable parameters of the representation. If my idea, again, is ten pigs forming a pyramid, the variables in this representation are the number of animal, their formation, etc. It is not always obvious which parameters can be varied in such a vague representation in the human mind – maybe the actual species of the animal could be changed while keeping the idea, maybe not. If I decide that it should be specifically ten spotted piglets, the network shrinks. If I elaborate my idea to be ten pigs forming a pyramid, plus a rainbow, or a number of pigs in any formation, the network is restructured or expanded, and can be traveled along new paths. This amounts to the invention of new knobs to turn [5] or Boden's transformation of spaces, and is one of the challenging part of computational creativity.

3.4 Further networks in material space

The conceptual network is closely related to the *cognitive network*, the subspace of results that are cognitively graspable, what we can understand and comprehend, which might be defined as the union of all possible conceptual representations. This network might be different for each person, and will naturally grow as we learn about new concepts, and possibly also when we are confronted with our own artistic results, even though this is probably a very slow process.

This is in turn related to the *perceptive network*, the subspace of what we can perceive. Our perception, visual, aural or whatever, has limits to its speed, precision, bandwidth, resolution, to its pattern recognition and feature extraction capabilities, etc. This might also be possible to extend by training, but to a much more limited extent.

Furthermore, there is a network of connections to reality – the *semantic network*, the semantically possible, which also has its topology. These connections determine which subregions in material space are interesting and available for us, personally. Our cognitive image of reality structures our thinking, and hence affects the topology.

And, there is the *network of cultural knowledge, expectations and appreciation*. We are trained to recognize and appreciate certain subregions of the space, and there might be a pressure (even if we don't want to admit it) from the outside. This is evident in the fact that some properties may be uncon-

sciously included in a conceptual representation, only to be realized when we are confronted with something that is "wrong" with respect to this property. It is so deeply embedded in our cultural heritage that we do not realize it is there as a constraint.

Contextual knowledge also defines what we can relate to. This is a learning process, and it is possible to re-learn. What is learned defines the network of what points in the material space we can relate to, and what we appreciate.

Appreciation often coincides with the moving edge of an expanding network[2]. New art has to connect in some way to this. It can possibly go beyond the edge of a conceptual network a little bit. If it is completely within existing networks, it is uninteresting. If it is completely outside, it is difficult to relate to – there is no path to go there. It is conceptually disconnected. If it strikes the right balance with respect to the receiving individual, the new work extends his networks, and forms the foundation for further curious explorations in our continuous strife for novelty.

3.5 Interplay between representations

A key point in this model is that we have two representations, the conceptual and the material. An idea expressed in a conceptual representation is realized by searching for a suitable material representation, either by gradually shrinking the set of points covered by the conceptual representation in an iterated process between idea and tools, or by searching for a pleasing result by trying a sketch, evaluating it and modifying it until it is found good enough. Once again, this is an iterated process between idea and tool, and can be illustrated in terms of networks.

The different networks (tool networks, conceptual networks, etc) are not directly connected. Instead, they communicate by way of the material representation (see Fig. 3). Each one has, by itself, a projection in the material space. Because of this, it is necessary to have mechanisms to go both ways, to and from the networks.

We seek the intersections between these networks. When I paint with a brush I seek intersections between the network of the tool (the brush), the network of what my perception can take in, and the conceptual network formed by the ideas I want to convey. This is a feedback process. I observe what I do, see if it fits, or if it can fit with slight modification. These intersections has a kind of gravity. We are attracted to them, and this is where the final version of the work will be found – in an intersection between the idea networks and the tool networks – something that is realizable but still contains something of our ideas.

There has to be a path from the material back to the conceptual representation, to carry interesting coincidental results back into the conceptual representation, and to provide for feedback from temporary results to affect the conceptual representation. How do we recognize pregnant ideas and interesting

[2] Sometimes to the degree that I think there might be a well-being hormone being produced when new neural connections are formed. Is this what curiosity is about?

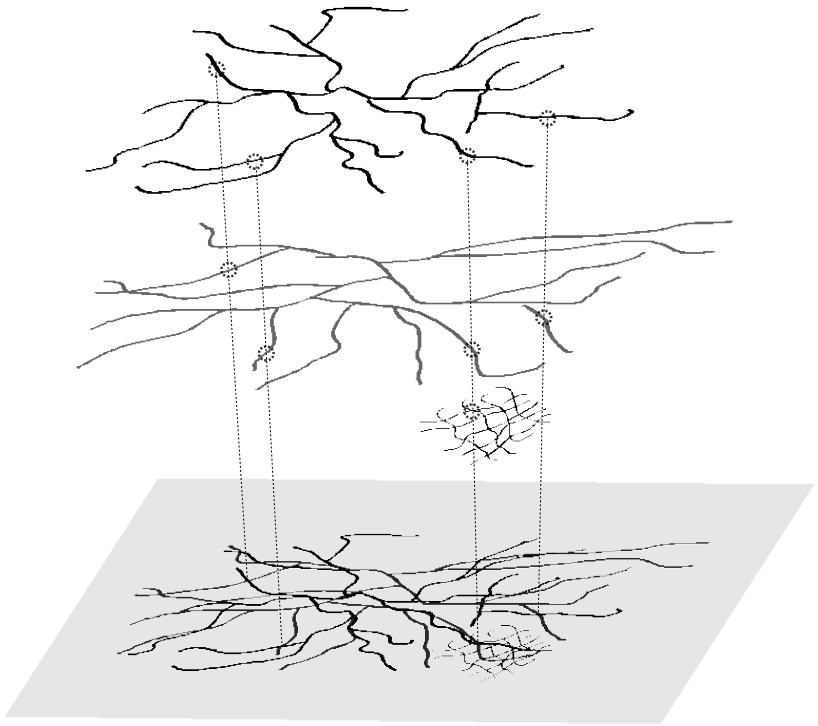

Figure 3: The different networks (tools, conceptual, cognition, etc) are not directly connected. Their only way of communication is through the material representation. The illustration shows three different networks in the material space (the gray area), with four intersections highlighted.

coincidents? What we need is a kind of reversed *development process*, the parsing of a material representation into a conceptual description. Our brains do this all the time, but computationally, it is a non-trivial problem. But is a key to creativity. The process from concept to material is essentially irreversible, and to form a cognitive model of a material is imprecise and gives a different model than the original. This difference gives birth to new material and creative variations. This is analogous to the concept of interpretation, as in classical music and theater. We cannot recreate the conceptual model of the original composer or playwright. During the creative process, the artist has to interpret his own work continuously, to be able to evaluate the temporary form of the work, and to take advantage of unpredicted results. The artist himself has the advantage that he has access to the (previous) conceptual representation, and forms a new model based on the current temporary material form of the work, and check if it corresponds to his original model. On the other hand, this is not so easy, since the artist is so deeply engaged in the work that he cannot judge it like someone from the outside. For this reason, artists use various tricks, e.g., to let a work rest for a while, and start anew with fresh ears, or observing a painting upside down to fool perception.

This self-interpretation and subsequent evaluation can be done often, after each step, or rarely, to let a generative process finish, to allow oneself to be confronted with unpredicted results. It can be done continuously, but this can obstruct the creative flow. Postponed judgment can be liberating. Each time, the cognitive model of the work, and hence the corresponding conceptual network, is modified.

Conceptual networks has the same effect as tools – but as *guiding* tools, in contrast to executive tools. The thoughts wander along the idea networks, but the sketch is realized along the tool networks, guided by the current conceptual representation. The discrepancy between where we want to go and where we can go add qualities to the work. The tools fail in a characteristic way, and hence my choice of tools becomes a part of my style.

4 Thoughts

4.1 The issue of craft

If you know your tool well, you are able to predict the result of your actions, based on training and experience from the application of the tool in many different contexts and situations. Then, the tool network is fine-meshed. You know what is possible and what is not possible before you do it. When you navigate along the conceptual network, you adjust according to tool networks. Sometimes you adjust the idea so that is becomes possible to realize, i.e., approach an intersection with a tool network. This is often possible without sacrificing any important part of the idea. Sometimes it actually adds something, since it forces you to deviate from your beaten tracks. If the tool network is sparse, due to lack of training or coarseness of the tool, if becomes more difficult to find

points that intersect the tool network. You might try to fill in the tool network when you have found a point you want to realize, by learning new tools, learn a tool better, or ask help from someone who knows something you don't.

Also, the better you know your tools, the more they become integrated in your conceptual thinking, and the tool networks may even overlap with the conceptual networks to a certain degree. This is especially evident in music, where abstract generative principles (which we regard as tools) may be the main conceptual ideas behind a work.

4.2 New tools

Especially in electronic music, there is a strong focus on the development of new tools. Why is that? And why do we need to learn new tools? A new tool might offer more precise maneuverability in certain regions of the material space, or let us reach completely new, hitherto unknown regions. It might take us faster to known regions, and hence push the limit of the possible, within a given time frame or within our cognitive capacity, by extending it — the tool embodies intelligent behavior and thus enables new lines of thoughts. A new tool also creates new structural relationships, which will unfailingly be exploited in new artworks. If you can reach from A to B in a new way, this will be used to create internal references within, for example, a musical piece, and will eventually affect the cultural network through the repertoire, and even the conceptual network.

For example, tonal harmony as an organizing principle, in gradually more complex forms, dominated Western music until early 20th century. All compositions were placed and composed along these networks in the space of possible music. When this constraint was removed (by Schoenberg), it was impossible to just start thinking freely. The minds of composers were literally (yes, I believe so, down to the level of neural connections) wired along this network (and others, regarding style, form and expression). A new tool was needed, to provide paths for composers' imagination and for the creative process. The dominating such tools were the twelve-tone theory (no chromatic note must be repeated until all others have been heard) and serialism (the use of tone-rows and their various permutations and transpositions). They provided a framework for exploration of the unknown space outside the traditional tonal network. After some time, composers became more accustomed to these new modes of expression, and the tools became incorporated in the cognitive and conceptual networks, with less explicit focus on the actual generative principles, and more on the sounding results. They became able to compose aurally in the style of twelve-tone music. If some other principles had been presented instead of twelve-tone music, the results would have been very different, both the music and the imagination of the composers.

4.3 Implications for computational creativity

The spatial theory presented in this paper does not solve any of the hard problems of computational creativity. In particular, the question of novelty is not

directly addressed. However, we believe that the complex interactions between tools and concepts in the process of realizing an idea caters for a larger part of the qualities of an artistic work than is normally acknowledged. Only a rather small fraction of the work consists of the original idea. The rest emerges from the realization of the work, adding depth, detail, and traces of its own creation. This theory might provide a framework for discussion about these key issues, and possibly form a basis for computational models such processes.

There are two hard problems involved. First, how to implement conceptual representations that are complex enough and open-ended, and that might extend themselves, based on feedback from their own preliminary output. Second, the related problem of how to implement parsing from material form into new conceptual models. It has been stressed that the "misunderstandings" in the parsing process actually contribute to the creative processes, since it is the imperfection in the interpretation that creates a personal expression, that causes creative misunderstanding, and that can give birth to new ideas from coincidences. If so, then a rather simple parsing model might suffice to start with. The choice of parsing model will contribute to the "personality" of the algorithm.

Based on the ideas presented, we can also discuss different categories of tools, by the properties of their networks. For example, we can distinguish between basic and more advanced tools. The networks of the basic tools are fine-meshed and has a topology that is not so far from that of the material representation, while the more advanced tools form networks that in density and topology resembles the networks of conceptual representations.

But if we are going to emulate human creative behavior, it is not enough to implement the tools. We also have to emulate the structured application of these tools by a human artist. Such a model thus operates on three levels: a material representation storing temporary results in simplest possible form, implementations of tools that provide a means of navigation in the space of possible results, and a model of how these tools are applied in a structured, iterated process in relation to a cultural context.

There are quite obvious similarities between the presented model and evolutionary algorithms, which often have been put forward as a promising path for computational creativity. The conceptual representation corresponds to the genetic representation, and the material representation to the phenotype, which is realized through a complex development process in interaction with the environment. This corresponds to the process of finding the "optimal" material representation of the conceptual idea, which often may end up far away from the original vision. The repeated re-conceptualization and evaluation of the temporary material form of the work amounts to evaluation and selection, and subsequent variation, except that this variation might be less random in a human creative process. The genetic operators, which create the random variation, correspond to both the application of tools, and to the variation of the conceptual representation created by the re-conceptualization.

I have previously argued that evolutionary systems and similar creative algorithms require high-level genetic representations and a complex development process to allow for variation to happen on a conceptual level [2, 3]. One ar-

gument against material representations[3] is that variation operators need to be able to parse the structure of the material to be able to induce high-level variation to the evolved material. Since this kind of parsing is hard and computationally expensive, it is much easier and more efficient to use a generative representation. However, I now realize that both levels are necessary – the temporary material form of the work is an essential component, and the connection medium between all external constraints and processes active in the creative process. So, we need both a high-level conceptual representation and a low-level material form if we are to succeed in implementing believable creative behavior in computers. Perhaps the framework presented in this paper can form a basis for such a model.

4.4 Social and cultural aspects

The discussion in this paper has been focused on the individual creative process, even though the cultural aspects have been implicitly mentioned in terms of the networks formed by cultural heritage in the material space. But we can see the advantage of this model also in analysis of collective creative activities, both realtime exchanges such as musical improvisation, or in slower processes such as the general artistic discourse within a particular field.

In group improvisation, the musicians communicate through the material representation, i.e., the sonic result. This is possible thanks to the amazing human ability to interpret sound into musical conceptual structures. Once again, creative misunderstandings during this process will result, since the interpretation always is ambiguous.

In non-realtime activities based also on verbal discussion, such as collaborative painting or composition, or a continuous artistic discourse, we communicate through conceptual representations, exchanging and developing ideas, but also through material results, and misunderstandings and re-conceptualizations thereof form the basis for new ideas.

The advantage is, of course, that different individuals carry different networks, regarding concepts, tools, cognition and perception. The re-interpretation of a temporary result, an artwork or a musical output by someone else can tilt the concept sideways, i.e., adjust it so that it fits into his networks, and he can develop it further along different paths. When the originator is confronted with this re-interpretation, his own network can grow, to include also this kind of output. In this way, we learn from each other, in a continuous development of ideas.

5 Concluding remarks

The thoughts presented in this paper are to be considered a work in progress. This is the first time this theory is presented in written form, and it certainly needs to be further developed. However, in its preliminary form, as presented

[3] In earlier publications I have used the term "basic representations".

here, it already provides a framework for analysis, discussion and possibly emulation of a number of important concepts and phenomena related to creativity:

- of the relationship between the theoretically, the practically and the conceptually possible; between material, tools and ideas.
- of the relationship between the artist and his tools
- of ideas, concepts and generative processes as a guiding mechanism for realization of a work
- of choices, and how we navigate the space of the possible
- of the realization of a work as a non-linear process
- of our cognitive preconditions – our ability to structurally interpret material, to create variation, to see connections between different parts of the space of the possible, and to find or design tools that take us there
- of re-conceptualization as an essential part of the iterated process of realizing a work
- of personal style as characteristics of the personal topologies in material space
- of the parallel between creativity and evolution as a link to the creativity of nature

Based on thorough observation of my own creative processes, and experience from artistic teaching, from development of creative tools, autonomous creative systems and from my research into the creative applications of evolutionary algorithms, I am quite convinced that the model is applicable to a wide range of creative processes in various contexts, human or computational. I hope to develop this theory further, and I gladly welcome feedback and constructive criticism.

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