Chapter 8
Between Material and Ideas: A Process-Based Spatial Model of Artistic Creativity

Palle Dahlstedt

Abstract In this chapter, I propose a model of an artistic creative process, based on study of my own creative processes over twenty years of activities as composer and improviser. The model describes the creative process as a structured exploration of the space of the possible, emphasising the interplay between a dynamic concept and the changing material form of the work. Combining ideas, tools, material and memory, creativity is described as a coherent, dynamic, and iterative process that navigates the space of the chosen medium, guided by the tools at hand, and by the continuously revised ideas, significantly extending previous spatial models of creativity. This involves repeated misinterpretation and coincidences, which are crucial in human creative processes, adding meaning and depth to the artwork. A few examples from real life are given as illustrations of the model, together with a discussion of phenomena such as appreciation, skill and collaborative creativity. Finally, I discuss how the proposed model could form a foundation for computer implementations of artistic creative process, to increase our understanding of human creativity, and to possibly enable believable artistic behaviour in machines.

8.1 Introduction

Humans have always wanted to build intelligent machines, with various degrees of success. One particularly elusive property of intelligent behaviour is creativity. How do we form new ideas? How do we create something nobody has previously seen? Creative insights may seem like momentary events, but under the surface of the consciousness, they are gradual processes, combining and elaborating previous knowledge into new thoughts, until the conditions are just right for them to surface.

In art, creativity is essential. The formation of ideas is important, but in my experience, the depth and meaning of an artwork emerge from the process of implementation of the original ideas, during which these ideas may very well change, drift and be elaborated upon, sometimes beyond recognition.

P. Dahlstedt (✉)
Dept. of Applied Information Technology, University of Gothenburg, 41296 Göteborg, Sweden
e-mail: palle@chalmers.se

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In this chapter I propose a spatial model of the artistic creative processes, which combines the conceptual aspects of a work with the implications of the artistic tools we are using and the material in which the work is created. I take a process-based perspective, founded primarily on introspective study of my own artistic creative processes, but also on experience from artistic collaborations and extensive artistic teaching and supervision.

The model combines key concepts such as ideas, tools, material and cultural background, and views creativity as a dynamic, iterative process that navigates the space of the theoretically possible (in the chosen medium) following paths defined by what is practically possible (by the tools at hand). The process is guided by a continuously revised conceptual representation—the changing ideas behind the work. The model also involves phenomena such as self-interpretation, coincidences and reformulation of the concepts behind a work, which are crucial in human creative processes. Both real-time creativity (e.g. improvisation) and non-linear processes (composition) are included in the discussion, as well as collaborative creative processes, such as group improvisation and larger collaborations.

I believe the presented model can help us understand the mechanisms of artistic creative processes better, and it provides a framework for the discussion and analysis of artistic creativity. And it can form the basis for experiments in computational creativity.

8.1.1 Background

Spatial models of creativity have been presented before. Perhaps the most well known is Margaret Boden's concept of exploration and transformation of spaces (Boden 2004), and the ideas presented here may be considered an extension of her ideas, primarily through the introduction of a material space in addition to her conceptual spaces, and the implications of the interplay between these two forms of representation.

The model is based on observation of my own creative work during more than two decades of artistic activities as a composer, improviser, programmer and sound artist, from collaborations with other artists from many genres, and from extensive artistic teaching and supervision in music and technology-related art. I have consciously observed my own creativity and creative processes since my early teens, up to the present. In the last ten years, I've pursued research into computer-aided creativity, primarily based on evolutionary algorithms, in parallel with and overlapping my work as a composer. From these two related fields, a number of originally unconnected observations have fallen into place, forming a coherent view of creative processes, as I see them unfold in my own daily artistic practice. Hopefully, it is also more generally applicable. The model was presented in a more preliminary form at the Computational Creativity Dagstuhl Seminar (Dahlstedt 2009a).

Being both researcher and professional artist/composer, I have a peculiar advantage, because I have access to a level of information about my creative process that

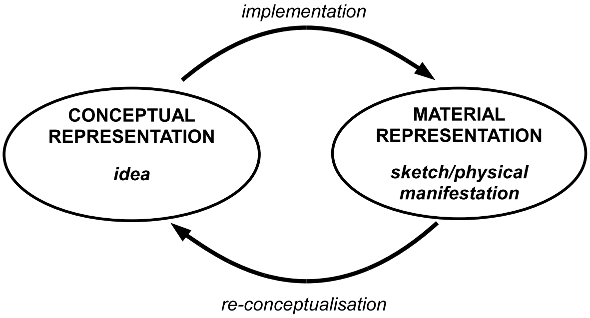

Fig. 8.1 The artistic work is developed in an iterated process between a conceptual representation, as ideas in the head of the artist, and the current temporary material form, as a sketch or unfinished work. Each translation step between these two forms helps adding detail and depth to the work

is unavailable to an outside observer. Aware of existing theories of creativity, and with knowledge about key concepts and mechanisms, I can systematically observe my own processes and draw conclusions which would be impossible if constrained to artistic results and rhapsodical accounts by others. So, as a researching artist, I am able to form theories and models based on observation. Then, these theories and models can be confirmed by others, if they fit their observations of their own or others' creative behaviour. And potentially, they can be confirmed by simulation in software, and by evaluation of the artistic outcome of those simulations.

The chapter is not primarily about the novelty aspect of creativity, or the social and cultural aspects (these issues are addressed in other chapters in this volume). It concentrates on what goes on in the mind of an artist during the birth and development of an artwork from concept to material form. It is primarily based on experience from music and sound art, but I believe the ideas are applicable to many other domains. I aim to provide a framework for how artists actually go about realising an artistic idea—maybe not all artists, but I believe many can feel at home in my description. For simplicity, I will often use examples from simple drawing in my explanations, to avoid musical terms that may be unfamiliar to the general reader.

The model also provides a terminology and apparatus for analysis of actual creative processes, and a new framework for the emulation of human artistic creativity. A lot of computational creativity research focuses on the birth of ideas, but as a practising artist and composer, I see in my daily practice that more important than the birth of ideas is this dialogue with the material; with given material (as for a sculptor and his archetypical marble block) or crafted material—temporary results and sketches. In my experience, ideas emerge from this dialogue, from misunderstandings, ambiguities and mistakes. A very small part is the original concept. It is but a seed, and in some creative processes it may not even exist, e.g. in certain kinds of improvisation. Much more important is the process, the bouncing between concept and material. Tools provide the paths to go from concept to material—I call this *implementation*, while *re-conceptualisation* takes us the back from material to idea, as illustrated in Fig. 8.1. This is the hard part, where we interpret our own temporary results, and extend, constrain or revise our concept. This process is repeated, until idea and material have converged into a finished artwork.

8.1.2 Outline

In the following section, I discuss the idea of tools, the implications of their use, and the notion of spaces and topologies related to these tools. Section 8.3 presents the model, explaining the main ideas on a general level, such as material and conceptual representation, and the interplay between them, including brief discussions on topics such as craft, skill, novelty and appreciation, and collaborative creativity, in the light of the proposed model. It is also discussed in the context of existing theories. How the model could possibly be implemented in computers is discussed in Sect. 8.4, followed by some concluding remarks.

8.2 Tools

The word *tool*, in a wide sense, is used a lot throughout this chapter, denoting everything from a traditional drawing tool (e.g. a paintbrush) or a musical instrument to an abstract organising principle (spectral harmony), a given musical form (the fugue), computer programs (Photoshop filters), generative procedures (grammar systems, evolutionary algorithms, Markov chains) or representational systems (Western music notation).

Artistic expression is clearly affected by the choice of tools. New genres and subgenres constantly emerge in music, triggered by the availability of new kinds of tools for music-making, such as loop samplers, live sequencers, time- and pitch-altering algorithms, and many more, allowing new ways to work with sound and structure. A tool embodies a complex behaviour (Gregory 1981) and enables lines of thoughts that would not be otherwise possible.

With more advanced tools, the contribution from the toolmaker cannot be ignored. It may be good or bad, but the artist has to be aware of it. Sometimes you do not want to spend time on developing your own tools, but prefer to be confronted with an existing tool, and take advantage of the extensive design effort put in by the tool maker. He helps transport me a fair way towards sophistication, through using his tool. A well-known risk is that the tool steers users towards similar results. But given that the tool is complex enough, i.e. it 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.

Each tool defines a virtual space of possible results. It also defines a *topology* within this space. A topology is a set of neighbourhood relations within the space, determining which points are near each other, and consequently how we can traverse the space. A neighbour point, in this case, is another point that you can reach with a single application of the tool. These topologies defined by tools are very important, since they correspond, in different ways, to how we think about the work. First, we naturally think about ideas in terms of how to realise them, using tools. Second, I believe the realm of our imagination is to a large extent constructed from our knowledge about existing tools, from practice and studies, and what we have learnt from the results of their use in art, our own and others. The design of the tool also steers our thoughts and our imagination towards what is possible or easy, and towards what is achievable, practical, or challenging. This amounts to Norman's (1988) use of Gibson's (1977) term *affordance*.

When learning a new tool, I gradually form a cognitive model of how it works. Spaces of potential results open up in my mind, expanding as the cognitive model gets more elaborate and accurate. If it is reasonably adequate, it gives me a predictive capacity in relation to that specific tool. That is, I have some expectation of what will happen when I use the tool in a certain way. But the predictions are not always correct, because of my limited cognition, or because of mistakes or tool failures, which introduce unexpected results and irregularities to the material.

The topology inferred by the tool also brings a kind of metric—a system of distances. Different points in the result space are at different distances from each other, i.e. certain points are easier or more difficult to reach from where you are. This is dependent on a formal metric—the number of times you have to apply the tool to get there, but also on a perceived metric, affected by the tool precision, the difficulty of use, and the affordance of the tool—certain paths are more easily accessible than others, and narrow paths may be more rewarding. A skilled listener or viewer can perceive this metric, and it is part of the experience of the artwork; the perceived effort, respect for craftsmanship and skill, in a kind of empathetic appreciation.

As an example of how tools steer our thoughts, we can compare two common kinds of musical tools: *predesigned* and *modular synthesisers*.[1] The first category, the predesigned synthesiser, provides a certain number of functions in a fixed configuration, typically routing sound signals from tone generators through a filter and variable amplifier, modulated by a limited set of gestural modulators to shape the sound over time. All these functions are controlled by a fixed number of parameters. Behind such an instrument are careful considerations by the instrument designer regarding playability, choice of features, interface design, relevance of parameters, etc. A modular synthesiser, on the other hand, provides a large number of abstracted functions in modules that can be connected in any order and configuration, with free routing of audio and control signals. Typical modules include: oscillators, filters, modulation sources, amplifiers, mixers, etc. Digital modular systems, additionally, provide free configuration of processing resources, and their openness and flexibility essentially equals that of computer programming. The predesigned synthesiser is a subset of the modular synthesiser, and the latter can easily be configured to mimic most predesigned synthesisers. Despite this shared functionality, we seldom use them in the same way. Users of modular synths are predominantly occupied by changing the configuration and routing, adding and removing modules from the signal chain. It is only rarely used to build an optimal configuration which is then subject to extensive exploration of its parameter space. The main difference between the two is in the variables they provide. Their spaces are different in size and scope,

[1]These comments on how synthesisers are used, are based on background studies made in conjunction with the design and development of an interactive evolutionary sound design tool for the Nord Modular G2 synthesiser (Dahlstedt 2007).

and as users we tend to explore the space that the tool provides, and we tend to travel the easy and accessible paths first. If you *can* add new modules and connections, you will. To impose further constraints on this freedom requires discipline and knowledge, and an understanding of why you would want to lock certain variables. And sometimes the toolmaker provides that understanding for you.

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 do we use just *one* tool to create a work of art. We use a whole toolbox of them, and we switch between them, depending on what is needed at the moment. To understand the creative implications brought about by the tools, we need to be able to discuss and compare the different spaces and topologies provided by them. And equally important, we need to consider the constraints and possibilities of the material: the medium in which we create our work, such as image or sound. Tools are the ways we navigate the infinite space of inherent possibilities of the material, but only along the pathways offered by the tools. Hence, we must introduce the notion of a *material space*, a larger space containing all possible images or sounds, and which can be traversed along the topologies provided by the tools at hand.

And if we are going to emulate human creative behaviour, 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 ideas and cultural context. In the following section, I will describe a model based on these ideas.

8.3 The Model

I will first give an overview of the model, including the main concepts, each of which will be further detailed in separate sections. This is followed by a couple of real-world examples from composition and improvisation, and a discussion of how the model relates to existing theories. This is followed by a brief discussion of related concepts, such as skill, collaborative processes and tools, examined in the light of the proposed model.

The basic idea is that a creative process is an exploration of a largely unknown space of possibilities. The exploration follows paths that are not arbitrary. As an artist, I do not believe in 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 or preferred outcomes—subspaces, and neighbourhood relations—topologies, which form possible paths for our search. These topological subspaces, one for each tool, form networks (or graphs, sometimes trees) in the larger material space, which intersects each other. For simplicity, in the following I will use the word *network* to denote such a topological subspace, for lack of a more suitable word.

While exploring, the work that is being created 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, e.g. as a sound sketch or an unfinished image. It corresponds to a single point in the material space, the space of all theoretically possible images. The conceptual representation is the current form of the work in terms of ideas and generative principles. It corresponds to a point in a conceptual space; the space of all possible conceptual representations. A particular conceptual representation defines a subspace in the material space—the set of all images or sounds, i.e. points, that could be interpreted as corresponding to this concept. In parallel to the topological tool networks, there is also a topology of subspaces in the material space, defined by the variability of the conceptual representation. If the conceptual representation is changed or revised, this subspace is transformed, and will cover new regions and allow new pathways in the material space. This system of related subspaces corresponds to topological networks in the conceptual space, but I will call them conceptual networks, for simplicity. An illustration of these related spaces is given in Fig. 8.2.

The focus of the creative process continuously changes between these two forms, and requires mechanisms to translate from one into the other, in both ways. Let us call them *implementation*, when we go from concept to material, and *re-conceptualisation*, when the concept is revised or recreated based on the current material form. The discrepancies between the two representations, 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 the creative process onto the work itself.

The implementation of a concept into a material manifestation 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—visible as a limitation in his predictive capacity.

In the other direction, the continuous re-conceptualisation of material form into a new conceptual representation, which may or may not resemble the previous one, is by its very nature imprecise and prone to misunderstandings. It is precisely this vagueness that is the heart of the field of interpretative arts, such as musical performance and theatre. But I think it is also crucial within the creative process of a single author, since he continuously interprets and re-interprets his own work as it is given form.

8.3.1 Material Space and Representation

The material representation is simply the current, temporary form of the work, e.g. as a drawing, a musical sketch, or a sound file. The material space is a theoretical

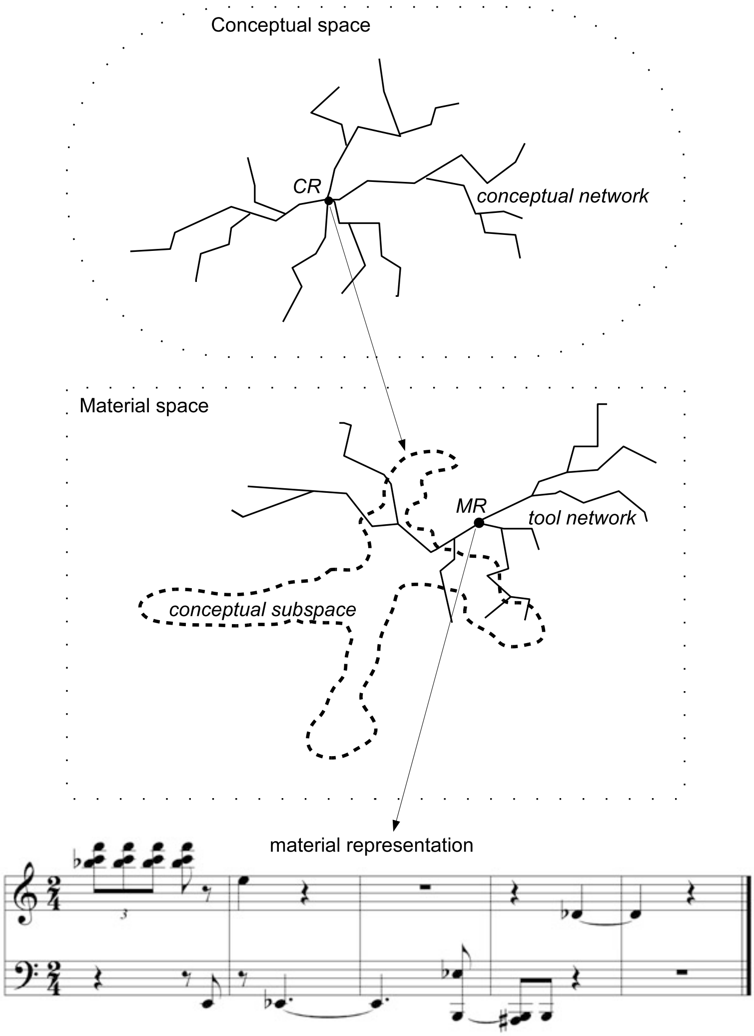

Fig. 8.2 At a certain moment, the artwork exists as a conceptual representation, which corresponds to a point (marked *CR*) in a conceptual space of all possible conceptual representations. Possible variations to the idea constitute a topological network in this space. The current conceptual representation defines a subspace in the material space of all possible material manifestations of this particular concept. The current material representation of the work is a point (marked *MR*) in the material space of all possible material results. This point can be either inside or outside of the current conceptual subspace. If it is outside, the artist can either alter the concept to include the current material representation, or change the material form, by the application of tools. Possible alterations by a specific tool are indicated, forming a topological network in the material space

construction that contains all its possible instances. If we work with images, the material space consists of all possible images, for example, a bitmap of a certain size and resolution, which theoretically can represent any conceivable image. If we work

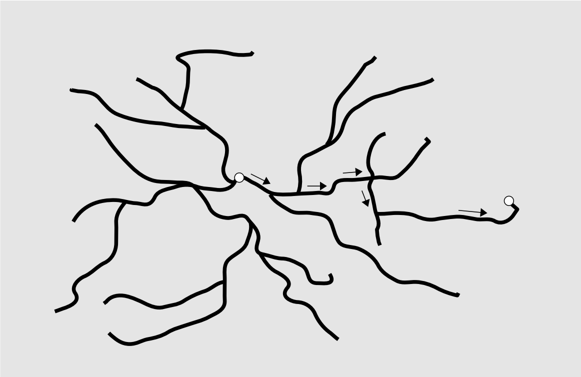

Fig. 8.3 The topological subspace defined by a specific tool forms a network in the material space. Each application of the tool (e.g. a brush) moves a small step along the accessible pathways. Repeated use of the tool can take us far

with sound or music, the material space consists of all theoretically possible sounds of a certain maximum length and bandwidth. These spaces are truly huge, with as many dimensions as there are sound samples or pixel colour values. 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 convenient and important, as we shall see.

In other contexts, the material representation could be a three-dimensional form, a musical score, or a text, the latter two are slightly closer to a structural-conceptual description of a work, but the mechanisms are similar.

At any specific time, the temporary form of a work is represented by one point in the material space; one image out of the almost infinitely many possible images. Through the application of a specific tool, we can reach a number of neighbour points. In this way, a network of paths is formed, defining a topological subspace: a network (see Fig. 8.3). In some contexts that don't allow repeated configurations to occur (e.g. wood-carving), these networks are structured like trees, while in other cases periodic trajectories can occur.

Let us look at a simple example. A specific tool, e.g. a paintbrush or a filter in Photoshop, with some parameters, operates on a particular bitmap and returns another. That is, it goes from one point in the material space to another. From a specific image you can travel to a certain number of other images that are within reach by a single application of this particular tool. With this tool, I can only navigate the material space along these paths. I can go from an image of a red square to an image of a red square with a blue line by using the brush to make the line. But I need two steps to go to an image of a red square with two blue lines. Hence, the vertices of the topological network of this particular tool are the points in material space (representing in this case bitmap images), while the edges are connections between points that can be reached by one application of the particular tool.

The material space may also have an inherent topology, based on the most obvious neighbour relation—the change of a value of a single pixel colour or a single-sample. However, this topology is too far removed from the conceptual level of the human mind to be of particular use, and we cannot even imagine how it would be to navigate the material space in this way, since such a small part of it contains

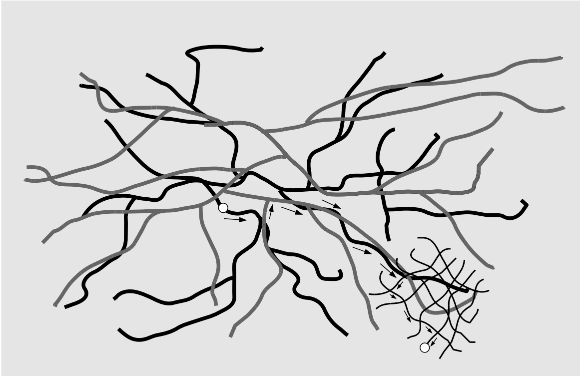

Fig. 8.4 The tool networks of a set of tools in material space. Each tool defines a different network, covering different areas, with different resolution. At each intersection, we can switch to another tool and continue navigation along different paths. Here, two coarse tools are used first (*black* and *grey thick lines*), followed by more fine-tuned editing by a tool of higher resolution

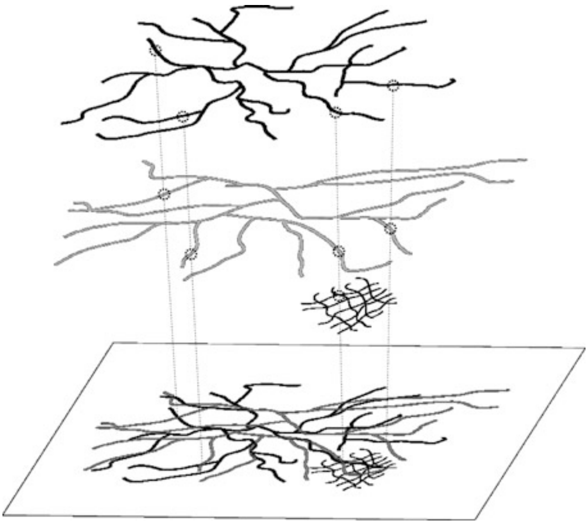

Fig. 8.5 The different tool networks are not separate structures, but different organisational principles in the same material space—represented by the *bottom rectangle*. A single point in this space, representing, e.g. a particular image, can be part of a number of different networks, that provide or control movement out of that point—how it can be varied

anything we would consider meaningful. Most of it is noise, or would appear completely disordered to our perception. We need tools to navigate this space; to get from one interesting point to the next, which do not get their proximity according to the inherent topology of the material, but by the tool-based networks.

Each tool defines a different topology in the same material space. Together they form intersecting networks, defining 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 of accessible pathways, as illustrated in Figs. 8.4 and 8.5.

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. Some points are easier to reach aided by GPS navigation, others require ropes and harness. Each means of transport provides certain navigable or facilitated paths, and where the path networks intersect, i.e. where both means are possible or needed, we can change our way of travelling. All of them bring different potential and constraints, just like different tools.

So, one idea behind the introduction of a material space is that we can start thinking about application of different tools in succession, since they all operate in the same space—the material space. They all define different topological networks in the material space, which intersect, and we can switch between tools at any time. Another reason is that the material representation introduces true open-endedness, since anything can happen in the material form. I can spill coffee on my score, or there can be a tool failure. A teacher or collaborator can alter my sketches. All this of course adds further complications to the process, but these cases still fit the model.

8.3.2 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. If my idea is a picture of ten monkeys forming a pyramid, this conceptual representation corresponds to the set of all images that can be interpreted as a pyramid of ten monkeys. Since nothing is said about the colour and species of the monkeys, where they are located, or from which angle we see them, there are a lot of images that fit this description.

In the course of the creative process, the conceptual representation is changed, e.g. by being made more specific, which shrinks the subspace, or altered, which transforms the subspace. The internal structure of the conceptual representation determines which transformations are possible, along the lines of the variable parameters of the representation. If my idea, again, is ten monkeys forming a pyramid, the variables in this representation are the kind of animals, the number of individuals, their formation, etc. If I decide that it should be specifically ten cotton-top tamarines, or ten monkeys in a pyramid under a rainbow, the subspace shrinks. If I elaborate my idea to be ten mammals forming an upside-down pyramid, or a number of monkeys in any formation, the subspace is restructured or expanded. This relates directly to the invention of new knobs to turn (Hofstadter 1985) or Boden's transformation of spaces, and is one of the challenges of computational creativity.

The conceptual representation can be vague in at least three different ways. First, there may be many points in the material space that comply with the ideas expressed—it defines a subspace of many possible results. Second, the conceptual representation may not yet include the necessary small design decisions that we often postpone to the implementation stage. Third, because of our limited predictive capacity, generative works can be exactly defined by concepts, but we don't know what the outcome will be. Our expectations—what we envision—form a subspace of the material space, but when we carry out the generative procedure, a single point will be the result. That point may or may not be a part of what we expected, possibly requiring a revision of the conceptual representation.

8.3.3 Interplay Between Representations

The philosopher Daniel Dennett has said (Denton 2004):

> The purpose of the brain is to predict the future, to make plans and hopes, and in following these predictions, we partially make the future.

The brain is good at prediction, because that is what it is evolved to do. The musician and writer Stephen Nachmanovitch (1990) said that life *is* improvisation. But creative processes also mimic what life is about—predicting, pursuing, acting, adjusting, etc. in a continuous circular process. So, in describing how we form our world, Dennett also gave us a good description of how we create art.

As a composer, I use generative processes to project my ideas beyond my predictive horizon (Dahlstedt 2001). I may understand the conceptual network in the immediate neighbourhood, and apply the algorithm or process to get further away, hoping that the interestingness will carry over to distant parts of the space. Or I may understand the broad paths in the conceptual network of the process, and apply it, leaving the details to the process. I may use generative processes that are too complex for my predictive capacity, in a trial-and-error fashion: adjusting parameters as I go, based on temporary results, and possibly, at the same time, adjust the actual algorithm itself. This amounts to the reiterated interplay between material and conceptual representation, through development and parsing.

This interplay is crucial to the proposed model. An idea expressed in a conceptual representation is realised 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 unknown pleasing result by trying a sketch, evaluating it and modifying it until something interesting is found. Once again, this is an iterated process between ideas, tools and material, and can be illustrated in terms of these networks (tool networks, conceptual subspaces, etc.) that coexist as different organisational principles in the material space.

There has to be a path from the material representation 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 recognise pregnant ideas and interesting coincidence? What we need is a kind of reverse development process: the parsing of a material representation into a conceptual description. This is a central part of the creative process; our brains do it all the time, but computationally it is a non-trivial problem. The translation from concept to material is essentially irreversible, and to form a cognitive model of a material is imprecise and gives a model different to the original. This difference gives birth to new material and creative variations. It is analogous to the concept of interpretation, as in classical music and theatre. We cannot recreate the conceptual model of the original composer or playwright, and each performance is different. During the creative process, the artist has to interpret his own work repeatedly, to be able to evaluate the temporary form of the work, and to take advantage of unpredicted results. The artist himself has the advantage of having access to the previous conceptual representation, and he can form a new model based on the current temporary material form of the work, and check if it corresponds to his original idea. 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 and prejudice.

The self-interpretation and subsequent evaluation can be done rarely, to let a generative process finish. Or it can be done often, or even continuously, but this can obstruct the creative flow. Postponed judgement is liberating, as described so well by Nachmanovitch (1990) and many others.

In the process, we seek the intersections between the tool networks and the current conceptual subspace. When I paint with a brush I seek intersections between the network of the tool—the images that I am able to paint, and the conceptual subspace formed by the ideas I want to convey. These intersections have 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 realisable and contains a representation of our ideas. This is a feedback process. I observe what I do, see if it fits the concept, or if it can fit a slightly modified concept, then redo or continue to work on the image. The conceptual subspace changes because of the modifications, and the material representation change because of my actions. When the conceptual and material representations have converged, the work may be considered finished.

8.3.4 Example Scenarios

The creative process as a back-and-forth translation between material and conceptual representation is illustrated by the very simple example in Fig. 8.6, and by the following examples from my own works:

(1) When composing, I might have the idea to try to overlap certain rhythmic and melodic patterns of different lengths, a medieval technique called isorythm. I cannot predict the output in any other way than by implementing it, generating a sketch score—the first material form. It turns out OK, but at many places the two voices collide in an interesting manner, hinting at unusual chords, and sometimes the two voices combine into a single pregnant motive, where the two voices intertwine. I revise and extend my original concept to involve elaboration of these coincidences.

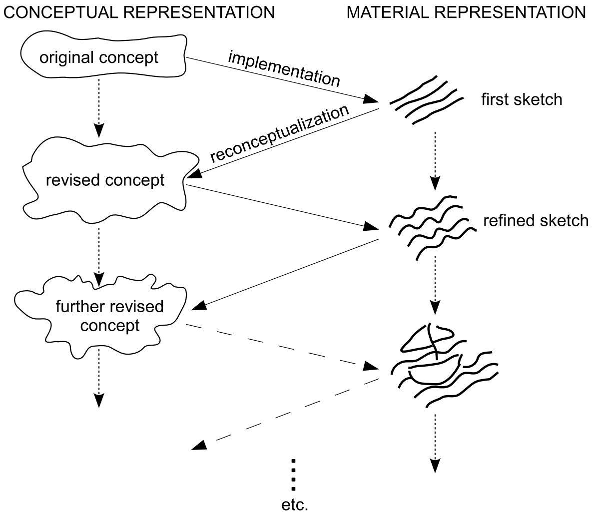

Fig. 8.6 The creative process as an iteration between idea and material. In each step, the conceptual representation is revised based on the previous material result. This particular process could be described like this: Draw something, maybe a few diagonal lines. One became a little wavy by accident. Hmmm...let's make them all wavy. Ah, that looks like the sea! Let's draw a boat, too. Interestingly, this trivial example came about exactly like that

I implement this, extrapolating from them in each place, modifying the formally derived skeleton, arriving at a new material form. This extrapolation at some places triggers new coincidences, which make their way into the conceptual representation, and so on, until I am satisfied with the result, i.e. there is no room for more elaboration, or all coincidences have been elaborated upon. The above is a true account of how I composed my own *Wedding March* for church organ, in 1999.

(2) When doing a free improvisation at the piano, I might just start and let the first notes be formed by pre-learnt ways of the hand, as described by Sudnow (2001), or by unconscious ideas. Hence, my initial conceptual representation is empty. But tool-based, cultural and physiological constraints guide my actions. These form topological networks and subspaces in the material space. The material representation is the sounds I hear, and I immediately try to make sense of it, to form a conceptual representation of what actually happened—because I am not always consciously aware of what I am playing. I might detect a certain rising figure in the left hand, or a particular unintended interval combination, and I choose to elaborate upon it. This is the re-conceptualisation step, and the next version of the conceptual representation is a variation on this idea. I perform it, but it does not end as I expected, because of my limited prediction capacity, and I re-conceptualise what happened, perform it, and so on. This is a real-time accumulative process, and in this case, the creative process unfolds right in front of the listener. The conceptual basis for the music emerges from the complex interplay between what I happen to play and what I extract from it, gradually becoming a composed whole, since for each new step in the process, there is more existing material to relate to in the re-conceptualisation.

The conceptual representation is nil to start with, but implicitly it may express itself in terms of a feeling or a state of mind, that affects what is emphasised in the reconceptualisation. You see or hear what you can relate to (by affinity and knowledge), subconscious states and associations are projected onto what “just happened” and gradually take shape in the iteration between what you hear and what you chose to elaborate upon in your playing. For example, as an improvising pianist, I tend not to relate to advanced jazz harmony implied by other players, because it is not part of my personal musical heritage. Instead, I concentrate on structures, gestures and note-to-note relationships, and extract conceptual representations from them, to elaborate upon in my response.

If I was instead improvising a drawing on an empty paper, the scenario would be similar. Improvised theatre can also work in this way[2]—you have to accept what has been done, extrapolate from it and build something on top, this time together with others. You see hints of meaning, possibly unintended, in the emerging material, and you enhance and clarify with modifications, which in turn provide new departure points for your co-players.

8.3.5 Appreciation and Novelty

Many factors affect our traversal of the material space. In addition to the interplay between conceptual and material representations, there are also factors such as cultural knowledge, of expectations and appreciation. We have learnt to recognise and appreciate certain subregions of the space, and there might be a pressure from the outside about what kind of art to produce, what conceptual contents to depict, which techniques to use, etc. This is evident when such constraints are unconsciously included in a conceptual representation, only to be realised when we are confronted with something that is "wrong" with respect to this property. It is so deeply embedded in our cultural heritage or social expectations that we did not realise that it was there as a constraint.

An artwork is not interesting *per se*. It is interesting in relation to something, to what has previously been written and said within that field. The interest is in what it adds to that, what it contradicts, and how it may provide food for new thoughts within the field. The cultural baggage of the artist acts as a guiding force in the creative process—it determines acceptable regions in the space of the possible, because it defines what the artist considers art, as understandable and interesting, and hence constrains his conceptual representations. By continuing a bit further on these paths, or deviating from them (but in relation to them), he creates something new, based on what was before.

Appreciation is an interesting phenomenon. It often coincides with the moving edge of an expanding conceptual network, and the corresponding material subspaces. New art has to connect in some way to this, and 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

[2] In the 1990s, I worked as an improvising musician with a theatre group, participating extensively in this kind of emerging performances.

is no path to get there, and it is conceptually disconnected from my existing networks. If it strikes the right balance with respect to the receiving individual, the new work extends his networks too, and forms a foundation for further extensions, further curious explorations in our continuous strive for novelty.

Novelty in creativity is often divided into Boden's private P-creativity and historical H-creativity (Boden 2004). Is it new for me, or new for a whole cultural domain, or even all of humanity? Novelty in relation to myself includes the expansion of my networks to gradually encompass new areas. Tool networks and conceptual networks both contribute to this process. For some artists the tool networks lead into new areas. For others, the ideas take the lead, and the tool networks are expanded as needed. The former is more common in music, as an abstract art, where tools and techniques play an important role. The latter may be more common in contemporary fine arts, where real-world concepts often are of primary importance.

When a conceptual representation develops, it expands to new areas in interplay with continually accumulating cultural input, pushing the individual artist to expand further, past what has been covered by others. Nobody has access to a global database, but only to the fraction of human culture contained in the artist's memory, defining his cultural networks and subspaces. To put it simply, his exploration of spaces happens in interplay with what he remembers from what he has seen or heard before.

8.3.6 The Model in Context

There are empirical studies of creative processes within psychology research (e.g. Barron 1972, Konecni 1991) and abundant recollections on the subject from artists (e.g. Barron 1997, Klein and Ödman 2003). These accounts from artists are sometimes contradictory and personal, and concentrate on rhapsodical and very personal details of particular processes. Artists not aware of existing psychological theories of creativity, may not be able to give a systematic account of what is happening. They sometimes reconfirm well-known phenomena and myths, but hesitate, consciously or not, to reveal their creative techniques, or are not able to verbalise the mechanisms of their own creativity. Some seem to preserve the romantic mystery around creativity. And since not all researchers have first-hand access to these processes (since they are not professional artists themselves) computational implementations directly derived from artists' processes are rare, with a few notable exceptions. Harold Cohen's autonomous painting program *AARON*, is based on his own analysis of how he went about composing and painting a picture, from sketching the first lines down to colouring. It works very well, within a limited domain of certain motives (McCorduck 1990). In the field of music, David Cope is well-known for his advanced computer-generated pastiches of classical music. Recently, he has changed direction, and developed a composing program called *Emily Howell* (Cope 2005), which develops its own musical style in a dialogue with Cope himself. In this case external musical input and human feedback gradually helps form the stylistic character of the program. Cope, himself a composer, has based his model on careful analysis of musical creativity; he stresses concepts such as allusion and analogy, and his model is based on complex associative networks between musical components, similar to that which humans develop through extensive listening. Cohen and Cope both emphasise process—in Cope's case also in a longer perspective, between works—but neither explicitly describe their models in spatial terms.

My proposed model is certainly not the first spatial theory of creativity, but it extends previous theories significantly (most notably Boden's, 2004) by introducing the idea of a material space, linked by the dynamic interplay between different descriptive levels—the conceptual and material representation of the work. The model of course relies on many previous results from peers, and various parts of it are related to previous theories. For example, Pearce and Wiggins (2002) provide a link between psychological research and the question of compositional creative processes, giving a rather detailed account of the cognitive aspects of musical composition. However, they do not dive deeper into the actual processes of composition itself.

Many previous attempts have focused on a formal approach, with the explicit generation of new ideas as the primary aim. In contrast, I believe that new ideas emerge from the process, and primarily from the iterated reconceptualisation and implementation, allowing for ambiguity, misunderstanding, associations and coincidences to contribute to the generation of new ideas and artistic results. This is a very rich process, involving all aspects of the artists mind, his cultural context, and of the material he is working in, with plenty of possibilities for unexpected results, leading to radically revised and new ideas.

The idea of iterated conceptual representations is related to Liane Gabora's work. She says:

> Creative thought is more a matter of honing in a vague idea through redescribing successive iterations of it from different real or imagined perspectives; in other words, actualising potential through exposure to different contexts. (Gabora 2005)

This also resonates well with Harrison's (1978) ideas about creativity being a goalless, non-rational process. Understanding of the re-conceptualisation mechanism could also be informed by a closer study of Karmiloff-Smith's (1994) thoughts on representational re-description in a developing mind, where knowledge gradually is transformed from simple procedural descriptions into conceptual contraptions of a higher level.

My model also transcends the distinction between exploratory, combinatorial and transformational creativity, for several reasons. The search space has been extended to the whole material space of the chosen medium, which includes all theoretical possibilities. A search in such a space equals a generative process, and is neither simply combinatorial nor transformational. Maybe it could be described as being based on *processual emergence*. This relates to Wiggins's (2006) idea that the search strategy can be more crucial than the definition of the conceptual space. He also presents a few theoretical devices for revising it depending on the results. In my model, the conceptual network is continuously being transformed as new conceptual dimensions—along which change can happen—appear from the re-conceptualisation.

The idea of including the material space in the model is related to McCormack's (2005) claim, that for true open-endedness, generative systems and their outcome must reside in the same domain, as is the case with evolutionary creativity in nature where genome, phenotype and developmental mechanisms share the physical environment. It is however unclear if this applies to human creativity in art, but it certainly would allow for more complexity and openness in the process, which is what the material representation adds in my model.

The importance of a material representation became clear to me when confronted with unexpectedly interesting musical results from my autonomous evolutionary composition system *Ossia* (Dahlstedt 2004; 2012), where configurations of notes resulting from separate branches of a generative processes are brought back into the same process in a finite recursion, allowing structural re-use of coincidental material. Essentially, temporary results from branch nodes of a generative tree structure are fed back to the leaves, forming a rudimentary iteration between concept and material. A generative representation provides access to high-level variation, but if used without a material representation, it may not permit behaviour as complex and unpredictable as human creativity.

The material representation is also, in most cases, the shared layer between creative agents in the human world. If we had direct access to each other's conceptual representations, we could have a perfect transfer of thoughts between people, removing a lot of the complexity from human culture. A hypothetical scenario, yes, but it illustrates the point. Continuous need for interpretation, and the unavoidable misunderstandings that follow, are quintessential properties of a society of creative agents. One of my points with this model, is to show that this is also happening in single-agent creative processes, in a type of dialogue between artist and the material.

This possible sharing of material is also interesting in another way. It allows for explanation of processes where the material is revised by someone else, e.g. a teaching situation, or when someone is tinkering with the artist's material. Hence, it is robust and flexible, fitting a number of scenarios that feature multiple creative agents.

8.3.7 Craft and Skill

If you know a 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, and because you have a well developed cognitive model of the tool. Then, the tool network is fine-meshed. You can make a qualified guess about 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. Out of necessity, you sometimes adjust the idea so that it becomes possible to realise, i.e. so that the conceptual subspace intersect 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, it becomes more difficult to find these intersections. You might try to fill in the tool network when you have found a point you want to realise, by learning new tools, learn a tool better, or ask help from someone else.

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, because your concept may be constructed from your tools. This is especially evident in music, where abstract generative principles may be the main conceptual ideas behind a work, and at the same time the tools to create it.

8.3.8 New Tools and Tool Design

Especially in electronic music, there is a strong focus on the development of new tools, such as new synthesis techniques, signal processing algorithms and new physical interfaces to control the music. Why is that? And why do we need to learn new tools? A new tool might offer more precise manoeuvrability 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 behaviour and thus enables new lines of thought. A new tool also creates new structural relationships, which will unfailingly be exploited in new artworks. If you can get from A to B in a new way during a compositional process, this can be used to create internal references within a musical piece, for example, and will eventually affect the cultural network through repertoire.

For example, tonal harmony as an organising principle dominated Western music until the early 20th century, in gradually more complex forms. All compositions were placed and composed along these networks in the space of possible music. When this constraint was removed (by Schoenberg and others), it was impossible to just start thinking freely. The minds of composers were literally wired along this network of tonal harmony, in addition to others of style, form and expression. New tools were needed, to provide pathways for composers' imagination and for the creative process. Most influential was the twelve-tone idea (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 into cognitive and conceptual networks, with less explicit focus on the actual generative principles, and more on the sounding results. Some composers were able to compose aurally in the style of twelve-tone music, as described by Valkare (1997). If some other principles had been presented instead of twelve-tone serialism, the results would have been very different, in terms of both the music and the imagination of the composers. So, the development of tools is an essential part of the continuous discussion about what can be created, and what can be expressed—and this discussion is what I call art.

8.3.9 Social and Cultural Creativity

The discussion in this chapter has focused on the individual creative process, even though cultural aspects have been implicitly mentioned in terms of 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 real-time exchanges such as musical improvisation, or in slower processes such as the general artistic discourse within a particular field. Let us look at some examples.

In group improvisation, musicians communicate through the material representation, i.e. the sonic result, communicated through the air. This is possible thanks to the amazing human ability to interpret sound into conceptual musical structures. Once again, creative misunderstandings during this process will result, since the music is always ambiguous. Each musician makes his own re-conceptualisation of what is happening, and reacts to that musically, contributing to the continued material shape of the work.

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

This is interesting, because 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 modify the concept in an unexpected direction, i.e. adjust it to fit his networks, so that he can develop it further along pathways available to him. When the originator is confronted with this re-interpretation, his own network can grow, to also include this kind of output. In this way, we learn from each other, in a continuous development of ideas.

8.3.10 Abstraction Levels

One aspect that has not been directly discussed is the problem of sketches as temporary material form. Sketches are in themselves conceptual and imprecise, but still more precise than the original thoughts that inspired them. The sketch is somewhere between the conceptual representation in your head and the final material result. In many domains, such as drawing, sketches are intentionally vague to allow the testing of ideas without requiring the development of complete detail. How can we account for this? A similar case is the various forms of concept-based artforms, where the final medium for the artwork is ideas. But I suggest that the proposed model can also be applied in these cases. A sketch can still be regarded as a material form in relation to a more abstract conceptual representation. It is the difference in level between the two representations that is important, and the interplay between them when going back and forth—not the exact nature of the material representation. In the case of score-based music, for example, the material representation (the score) is somewhere in between the conceptual and the material level. In the case of concept-based art, we can still think of different conceptual levels, with a number of idea-based tools (idea generation, idea transformation, refinement, deduction, induction, contradiction, etc.) that the artist can use to develop the final work. There are two abstraction levels, and an interplay between them.

The actual material level may also change in the course of the process. First I may work with an interplay between concepts in my head and sketches on paper as the material form. Later, when I am content with the sketches, I proceed to a level where the concept in the head, as formalised by sketches, interplays with the final material medium. Maybe any differences in degree of abstraction between representations would suffice for a creative process, and the transfers between them account for the complexity of the process?

8.4 Implications for Computational Creativity

Many experiments in computational creativity have been implemented within the traditional artificial intelligence (AI) paradigm, using techniques such as symbolic reasoning, knowledge-based systems, statistical models and heuristic search. They usually operate within a restricted domain, and the form of the search target is often strictly defined—a solution to a well-defined problem, a postulate that matches given data, etc. (for a couple of examples, see Lenat 1983, Lindsay et al. 1980). There is an awareness of these problems, and one proposed solution is to add meta-level reasoning to affect the process and domain itself (see e.g. Buchanan 2001). However, the approach at that level is of the same formal nature as the previous one, equally distant from how we think, and from the complexity of real life. And the tasks chosen for modelling are often of a scale that would not be considered particularly creative if performed by humans, such as the harmonisation of a Bach-style chorale (e.g. Ebcioglu 1988; see Papadopoulos and Wiggins 1999 for an overview of similar projects). They are reasonably complex search processes, yes, but more like optimisation processes than an exploration to extend our conceptual world. The form of the solution is known beforehand, and it will give us no surprises.

When going through the AI creativity literature, there is a lack of attention to process as a source for novelty and complexity. The AI approaches are mostly based on logical analysis of the concept of creativity and novelty, and not how a human artist goes about when creating something, at least not the creative processes I can observe in my own artistic practice. As an artist, I seldom know what I am looking for. Sudden ideas are often related to the domain I am working in, but I do not know exactly *what* idea I am searching for. Coincidences play a major role in triggering specific ideas and in shaping more complex creative output.

Maybe the most successful approach so far (according to Boden 2004) has been the use of evolutionary algorithms, i.e. simplified emulations of Darwinian evolution applied to data representations, as search techniques in open-ended conceptual spaces, inspired by nature's creativity. The numerous examples include works by Sims (1991), Todd and Werner (1999), Jacob (1996) and myself (Dahlstedt 2004; 2007; 2009b).

Well implemented evolutionary systems are capable of generating interesting novelty; they can be creative in a sense. But there are several problems with this approach. Firstly, while evolution is good at searching spaces, it has been difficult to design really open ended systems. Secondly, the kind of creativity it exhibits is not very similar to human artistic creativity. It uses blind variation directly on the genetic representation, which corresponds to the conceptual representation in my model. In artistic creativity, the variation is instead inferred by extracting a new conceptual representation from the current material form in whatever way this came to be. To understand human creativity, I think we need to base our implementations on a model of human creativity, and not on natural evolution. Evolution is one example of how new things or ideas *can* be created, but maybe not how *we* create. See Gabora (2005) for further discussion about this distinction.

In this context it might be interesting to consider two completely different types of creative processes, both existing in nature, but in different domains. The first is the reiteration of a particular generative process until it is "just right", with evaluation only of quasi-complete results. This is analogous to natural evolution, where each new individual is developed all the way from the blueprint, in each generation. From this perspective every living thing is a generative artwork. The other alternative is the accumulated treatment and processing of a temporary form, exemplified by natural structures such as mountains, rocks and terrain. They record their own history of coming into being, through generative and erosive processes. We may call these *generative* and *accumulative* creative processes. So, one is typical of living things, the other of dead matter exposed to additive, transformative, and destructive processes. Both can be accounted for by the proposed model, with different frequency of re-conceptualisation, and both types of process exist in art. I would say that the accumulative process is a crucial part of human artistic creativity, with the exception of explicitly generative art. Evolutionary algorithms, as powerful as the may be, are limited to generative creative processes, which may indicate that they are not entirely suitable for emulation of artistic creativity.

8.4.1 Implementation of the Model

Implementing the proposed model involves several difficult and challenging problems. They are discussed below, with some preliminary speculation about possible initial approaches.

To fully model human creativity, we would need to successfully model most essential features of the human mind, which is of course impractical. However, there are strategies to make this seemingly impossible problem at least partially tractable. One way is to look for the simplest possible implementation of each required component, still being sufficiently complex for the overall emergent creative behaviour to appear. Certain core features of each component may suffice to arrive at interesting results. It is a research problem in itself to find this level, though, as discussed by Cope (2005). But the more minimal the implementations are—while still functioning—the more general conclusions we can draw.

There are two hard problems involved. Firstly, how do we implement suitable conceptual representations? Secondly, there is the related problem of how to implement re-conceptualisation from material form into new conceptual models. I have stressed the importance of misunderstandings in the parsing process, since they help form a personal expression. Then a rather simple re-conceptualisation model might suffice to start with, or a combination of simple models running in parallel, to widen the repertoire of recognised material. Each model interprets the given material in a particular way, and the choice of models will contribute to the "personality" of the algorithm, in the same way as the characteristic shortcomings of a human artist contribute to his personal style.

8.4.2 Conceptual Representations

Knowledge and concept representation has always been a problem in computing. The conceptual representations in this model need to be flexible and open-ended, but we want to avoid the symbolic approach of traditional AI, for reasons explained earlier. While Pearce and Wiggins (2002) mention the ability to represent musical material as a hierarchical structure (see also Dahlstedt 2004; 2005), McCormack (2005) states that representation and generative mechanism should be on the same level as the material resulting from the process, hence a collapse of hierarchies. This is an important point, and I believe the iterated process between material form and conceptual form bridge this gap between levels, and provides a path between them in both directions.

A conceptual representation has two components: a description of what we want to achieve (e.g. desired properties, list of constraints), and a description of what we want to do (a generative procedure or list of tool actions). Let us call them *description* and *instruction*. In a goal-driven creative process, with a clear vision of the final form of the work, the description component is more important. But the clearest vision may be revised if something unexpected but interesting is found. Also, a determined idea about the description may still lack sufficient detail to form the basis of a full artwork. Hence, flexibility is still needed. On the other hand, a work based primarily on a generative idea may lack an description component, and instead give more weight to procedural instructions. In free improvisation, description may initially be empty, and both are open for change, according to how the process unfolds. So, both components are needed, in a weighted combination, to cover a wide range of processes.

As the process proceeds, the conceptual representation could also include accumulating existing parts of the material form of the work. As an example, consider that when a painting is finished, all we have is the actual material form of the work—the conceptual representation is gradually transformed into a material representation during the creative process. It is then up to the viewer to form his own conceptual representation of it.

8.4.3 Re-conceptualisation

The process of re-conceptualisation is a parallel to what an art-consumer does when observing an artwork—looking at the material result, possibly trying to recreate the process and the concepts behind it. Since the material form *is* the artwork, as it appears to others, nothing can be ignored: faults, context, imbalances, and so on. With both description and instruction included in the conceptual representation, the re-conceptualisation process would consist of an evaluation and modification of the previous conceptual representation, with respect to the material result. The process could involve, for example, perceptually based fuzzy pattern matching and feature detection, such as detecting entities, transitions and regularities in the material. There may be different kinds of discrepancy between description and material:

- Feature extraction may recognise a pregnant idea that is the result of a coincidence between results produced by different parts of the instruction;
- Emergent features in the material may not be explicitly represented in the conceptual representation;
- Computational or human mistakes may have distorted the result;
- The conceptual representation may not be visible at all, due to ambiguity, complexity and the nature of the generative process (an irreversible many-to-one mapping), and the re-conceptualisation step will have to be carried out from scratch.

A useful strategy for the implementation of re-conceptualisation would be to use double-linked representations, with pointers between the part of the implementation components of the conceptual representation and the material result, in both directions. In the material representation, a layer of pointers tell which part of the conceptual representation was involved in generating it: e.g. a node, an object, a branch of a tree, a block of generative code. This could help indicate coincidental material, as detected features or entities consisting of material emanating from widely separate parts of the conceptual representation. Borders between results from subpart of the conceptual representation can help distinguish entities that could form a basis for the next iteration of the conceptual representation, or help indicate which part of the conceptual representation needs modification. However, if implemented too strictly, this could counteract the idea of creative misunderstandings in parsing. But with overlapping of material coming from different parts of the conceptual representation, it may still allow sufficient ambiguity, since the pointers for overlapping material will make things more complex—it might not be, or should not be, a one-to-one mapping.

Such double-linking is probably not possible with all kinds of representations, but in the cases where it is applicable, it can provide valuable information about the morphological relationship between concept and material.

After detection of discrepancies, the conceptual representation needs to be revised, in one of the following ways:

- Extension/addition: adding new details or new source material (themes, motives, source images, "constants");
- Extension/generalisation: conceptually generalising the scope of the representation, e.g. when confronting coincidental material, extracting their core properties and including them in the next representation, to minimise the risk of losing them in subsequent iterations. Or when stagnating, remove hindering constraints, and backtrack;
- Variation: when the conceptual representation is tilted, shifted, or mutated, depending on the form of the conceptual representation;
- Restriction/narrowing: adding further constraints or removing unwanted material;
- Association: when something that resembles some pre-existing material or concept is replaced by a clearer reference, or related material from the same source is added;
- Replacement: when reaching a dead end or when the temporary form is completely reinterpreted into something else, the whole conceptual representation needs to be replaced.

Local implementations of heuristic search, such as evolutionary algorithms or hill climbing, could be used within the component of re-conceptualisation in order to find suitable modifications. As long as these techniques are kept within this component, any shortcomings should not influence the overall process.

8.4.4 Memory and Learning

A fundamental problem of computer-generated art is its relation to the real world—the cultural and semantic content. To be appreciated by humans and to produce meaningful content of any depth, the system must have access to the outside world. This link could be provided on a rudimentary level by an intentionally imperfect associative memory model, where previously experienced material is retrieved by association and incorporated into the creative process. This would account for cultural constraints and generative aspects of culture, such as references, metaphors (Hofstadter et al. 1995) and associations (Mednick 1962). It is also strongly emphasised by Cope (2005). Such a memory model should also include memories of previous results from the system, and in this case it could hold both material fragments and the conceptual representations behind them.

When designing computational models of creativity, it is an important question how to evaluate the success of the implementation and hence how to draw any conclusions from the experiments. As I see it, there are two different cases. Either you make an implementation that tries to generate art that is credible and interesting to human observers, or you make a minimal model and evaluate it if it exhibits the right kind of emergent behaviour in relation to its own context, i.e. its limited amount of data about the outside world.

One could argue that a computational model that produces results interesting to human observers, having been exposed to a very small amount of human art, could not be a faithful model. A human with such limited experiences and limited contact with the outside world would certainly not produce very interesting art. So, the creator of such a system simply must have put in a lot of his own experience into the model, consciously or not, in the form of informed design choices.

On the other hand it is difficult to evaluate a minimal model, since it will not be possible to judge the output as art in itself. The novelty, complexity and interest of it must be valued in some way in relation to the context and scope of the program. Creative behaviour may be there, but we may fail to recognise it, since it does not appear as anything we are used to. Only if a computational model can perceive and internalise substantial amounts of humanly produced artistic material, combined with human feedback on its own output over an extended time, can we judge the output by human standards.

8.5 Final Remarks

I have presented a model of creative artistic processes that is founded on artistic practice. There is a long way to go before it can be implemented fully in software, but it is my firm belief that it could help us create more believable artistic results and behaviour from computational creative systems, and it may form a foundation for discussion, analysis and increased understanding of human creative processes. In my own artistic practice as composer and improviser, I can clearly see how it fits a wide variety of creative activities, and I present it here to be tested by others in relation to their experiences from art practice and in future computational implementations.

Though preliminary, the model already provides a framework for analysis, discussion and possibly emulation of a number of important concepts and phenomena directly related to creativity:

- of the relationship between the theoretically, practically and conceptually possible; between material, tools and ideas;
- of the relationship between the artist and his tools;
- of ideas, concepts and generative processes as guiding mechanisms for realisation of a work;
- of choices, and how we navigate the space of the possible;

- of the realisation 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-conceptualisation as an essential part of the iterated process of realising a work;
- of personal style as characteristics of the personal topologies in material space.

In this chapter, I have mostly discussed how we go about realising the artistic artefact and give it form in a particular framework or context. The model does not cover what *we* want to express, depict or give form to as artists, or the value of the outcome, which is included in some definitions of creativity. According to this view, the result not only has to be new or novel, but valued by the community where it appears—or else it is not judged as creative. If we speak about value as in good art vs. bad art, then value is not intrinsic in the work, but relative to the observer. It lies in the consistency of ideas, depth and detail of implementation; in the relevance to the observer of the ideas conveyed. As long as it can provide an adequately complex reflective surface for the observer, to enable her to make her own re-conceptualisation and arrive at something which resonates with her thoughts, it can be good art. I think this kind of value and meaning in a computer-generated artwork may emerge from a faithfully implemented creative process.

Based on thorough observation of my own creative processes, and experience from artistic teaching, from development of creative tools, and from my research into applications of creative algorithms, I am quite convinced that the proposed model could provide the basis for such implementations, providing a deeper understanding of artistic creative processes: in humans and in machines.

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References

Barron, F. (1972). *Artists in the making*. New York: Seminar Press.

Barron, F. (Ed.) (1997). *Creators on creating*. Tarcher.

Boden, M. (2004). *The creative mind: myths and mechanisms* (2nd ed.). London: Routledge.

Buchanan, B. G. (2001). Creativity at the meta-level: AAAI 2000 presidential address. *AI Magazine Volume*, *22*(3), 13–28.

Cope, D. (2005). *Computer models of musical creativity*. Cambridge: MIT Press.

Dahlstedt, P. (2001). A MutaSynth in parameter space: interactive composition through evolution. *Organised Sound*, *6*(2), 121–124.

Dahlstedt, P. (2004). *Sounds unheard of: evolutionary algorithms as creative tools for the contemporary composer*. PhD thesis, Chalmers University of Technology.

Dahlstedt, P. (2005). *Defining spaces of potential art: the significance of representation in computer-aided creativity*. Paper presented at the description & creativity conference, King’s College, Cambridge, UK, 3–5 July 2005

Dahlstedt, P. (2007) Evolution in creative sound design. In E. R. Miranda & J. A. Biles (Eds.), *Evolutionary computer music* (pp. 79–99). London: Springer.

Dahlstedt, P. (2009a). Ideas and tools in material space—an extended spatial model of creativity. In M. Boden, M. d'Inverno & J. McCormack (Eds.), *Dagstuhl seminar proceedings: Vol. 09291. Computational creativity: an interdisciplinary approach*. Dagstuhl: Schloss Dagstuhl—Leibniz-Zentrum fuer Informatik. http://drops.dagstuhl.de/opus/volltexte/2009/2198.

Dahlstedt, P. (2009b). Thoughts on creative evolution: a meta-generative approach to composition. *Contemporary Music Review*, *28*(1), 43–55.

Dahlstedt, P. (2012). Ossia II: autonomous evolution of complete piano pieces and performances. In *A-Life for music:music and computer models of living systems*. Middleton: A-R Editions.

Denton, R. (2004). The atheism tapes: Jonathan Miller in conversation (TV program), episode 6, interview with Daniel Dennet. London: BBC, TV program.

Ebcioglu, K. (1988). An expert system for harmonising four-part chorales. *Computer Music Journal*, *12*(3), 43–51.

Gabora, L. (2005). Creative thought as a non-Darwinian evolutionary process. *Journal of Creative Behavior*, *39*(4), 65–87.

Gibson, J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing*, Hillsdale: Erlbaum.

Gregory, R. L. (1981). *Mind in science*. London: Weidenfeld and Nicolson.

Harrison, A. (1978). *Making and thinking*. Harvester Press.

Hofstadter, D. (1985). Variations on a theme as the crux of creativity. In *Metamagical themas*. New York: Basic Books.

Hofstadter, D., & The Fluid Analogies Research Group (1995). *Fluid concepts and creative analogies: computer models of the fundamental mechanisms of thought*. New York: Basic Books.

Jacob, B. (1996). Algorithmic composition as a model of creativity. *Organised Sound*, *1*(3), 157–165.

Karmiloff-Smith, A. (1994). Beyond modularity: a developmental perspective on cognitive science. *Behavioral and Brain Sciences*, *17*(4), 693–745.

Klein, G., & Ödman, M. (Eds.) (2003). *Om kreativitet och flow*. Bromberg.

Konecni, V. J. (1991). Portraiture: an experimental study of the creative process. *Leonardo*, *24*(3).

Lenat, D. (1983). Eurisko: a program that learns new heuristics and domain concepts. *Artificial Intelligence*, *21*, 61–98.

Lindsay, R. K., Buchanan, B. G., Feigenbaum, E. A., & Lederberg, J. (1980). *Applications of artificial intelligence for organic chemistry: the DENDRAL project*. New York: McGraw-Hill.

McCorduck, P. (1990). *AARON'S CODE: meta-art, artificial intelligence, and the work of Harold Cohen*. New York: Freeman.

McCormack, J. (2005). Open problems in evolutionary music and art. In F. Rothlauf et al. (Eds.), *LNCS: Vol. 3449. EvoWorkshops 2005* (pp. 428–436). Berlin: Springer.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220–232.

Nachmanovitch, S. (1990). *Free play: improvisation in life and art*. New York: Jeremy P. Tarcher/Penguin-Putnam Publishing.

Norman, D. A. (1988). *The psychology of everyday things*. New York: Basic Books.

Papadopoulos, G., & Wiggins, G. (1999). AI methods for algorithmic composition: a survey, a critical view and future prospects. In A. Patrizio (Ed.), *Proceedings of the AISB'99 symposium on musical creativity*, Edinburgh, UK.

Pearce, M., & Wiggins, G. A. (2002). Aspects of a cognitive theory of creativity in musical composition. In *Proceedings of 2nd international workshop on creative systems, European conference on artificial intelligence*, Lyon, France.

Sims, K. (1991). Artificial evolution for computer graphics. In *ACM SIGGRAPH '91 conference proceedings*, Las Vegas, Nevada, July 1991 (pp. 319–328).

Todd, P. M., & Werner, G. M. (1999). Frankensteinian methods for evolutionary music composition. In N. Griffith & P. M. Todd (Eds.), *Musical networks: parallel distributed perception and performance*, Cambridge: MIT Press—Bradford Books.

Valkare, G. (1997). *Det audiografiska fältet: om musikens förhållande till skriften och den unge Bo Nilssons strategier*. PhD thesis, University of Gothenburg.

Wiggins, G. A. (2006). A preliminary framework for description, analysis and comparison of creative systems. *Knowledge-Based Systems*, *19*, 449–458.