Trails II

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Abstract:

Trails II is a live generated audio-visual artwork whose underlying generative mechanisms are driven by a multi-agent simulation. In this paper, the authors reflect about the conceptual and aesthetic aspects of relating a computer simulation to an acoustic and visual composition. From a purely technical point of view, these relations manifest themselves as algorithmic mappings between the different computational processes that underlie the simulation, sound synthesis and image rendering. But on a more conceptual level, the development of these relations can be understood as a semantic transformation. The numerical data provided by the simulation lacks any inherent meaning and tangibility. It is only via the transformation of the simulation into a perceivable output that it can achieve associative and emotional readability and effectivity. Accordingly, composing constitutes a deliberate act of interpretation and categorisation, which assigns significance to certain simulation properties and denies it to others. The creation of music and imagery corresponds to the development of an audio-visual language whose signs refer to these signified simulation properties. From this point of view, the composition process in generative art benefits from a balanced consideration and integration of principles of algorithmic mapping and semiotic organisation. We hope that this paper contributes to a fruitful discourse about the relationship between symbolic and literal approaches in the digital arts in general and in generative art in particular.

Keywords: algorithmic music, generative video, mapping strategies, semiotic transformation, swarm simulation

Introduction

The work Trails II has been realised by the authors of this publication for a concert that took place at the Zurich University of the Arts on March 18 2013. The German title of the concert "vom Nullpunkt" literally translates into English as "from point zero" and is meant as a metaphor for artistic approaches that employ computers for creating entirely synthetic acoustic and visual material. The term "point zero" emphasises the fact that the synthetic material does not derive from previously created material but rather emerges from the nothingness of computational processes. While most of the presented works include a human part, be it a performer who operates the computer in real time or be it a composer who created the artwork in advance, Trails II choses a more radical approach and delegates the role of the performer or composer entirely to the computer. By doing so, both the large-scale structure of the work as well as its details emerge from a synthetic origin rather than from a set of cultural and personal predispositions that are inseparably associated with a human artist.

This approach faces a number of challenges, especially with regard to composition. The term composition refers to the consecutive or concurrent arrangement of different elements or parts of a piece. On a formal level, composition relies on a semiotic system and operates on its syntactic structure and relations (Goodman, 1997). The challenges relate to the fact that algorithmic processes frequently fail to create and maintain a clear compositional consistency and conclusiveness over extended periods of time. Also, these processes often lack the capability to establish aesthetically meaningful correlations between the various elements.

Finally, they sometimes hinder the recipients subjective interpretation through their lack of emotional and aesthetic readability. The authors have chosen to address some of these challenges via a simulation-based approach to composition. This decision is informed by the notion that a composition and a computer simulation both represent sign systems that exhibit many similarities on a semiotic level. Both of them possess a strong syntactic structure but remain semantically indeterminate. And both of them are operationalised via the execution of their computational implementation. The remainder of this paper further elaborates on this relationship and demonstrates its practical significance for the creation of Trails II.

Background

Simulation

The term simulation as it is used in this publication refers to the application of numerical methods in order to automate algorithmic processes that mimic the characteristics of a natural phenomenon. Numerical simulations represent important epistemological tools for the natural sciences in that they render the theoretical and mathematical descriptions of a natural phenomenon accessible to an empirical approach. From an ontological point of view, the capability of simulations to imitate the intrinsic structural and causal relationships of a natural phenomenon assigns the simulated system its own level of reality. From a semiotic point of view, simulations represent formalised syntactic structures that exploit the computer as semiotic machinery (Gramelsberger, 2000). The formal and operational level of a simulation is derived from a natural phenomenon via several successive steps of semiotic transformation (see figure 1). As a first step, the natural phenomenon is transferred into a text-based theoretical description. This description is further abstracted into a mathematical formalism. Finally, the mathematical formalism is transformed into an operational formalism that can be executed on a computer and allows to eventually "run" the simulation. Each of these steps employs its own sign system. Throughout the transformation process, the syntactical aspect of the corresponding signs becomes more significant while their semantic and perceptual aspects are reduced. On the level of the simulation, the signs are entirely decoupled from a semantic and perceptual context and have become purely self-referential and unperceivable entities. The execution of a simulation results in the manipulation of these signs based on their intra-symbolic relationships.

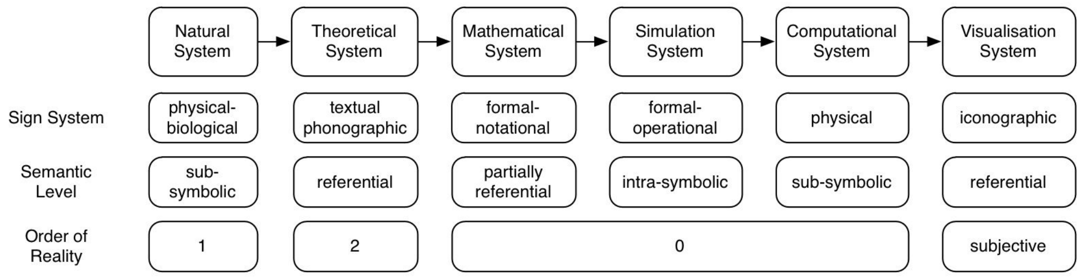

Figure 1. Semiotic transformations

Generative Art

The field of generative art deals with the creation and application of autonomous processes for the realisation of artworks. In principle, any form of output from any autonomous process can be employed to automate an artwork. But in most cases, the output consists of numerical data and the processes originate from scientific research. Examples of such origins are the fields of statistical data processing and pattern recognition, recursive or iterative mathematical equations, probabilistic systems etc. Of particular popularity is the acquisition of numerical data that result from computer simulations of natural phenomena. Accordingly, many of the conceptual and practical aspects of generative art strongly overlap with scientific approaches in computer simulation and visualisation.

Visualisation

In order to render the simulation results accessible to human perception and interpretation, semantic and perceptual qualities have to be reassigned to semiotic signs. The term visualisation refers to the assignment of perceptual qualities that belong to the visual modality. If these qualities belong to the acoustic modality, the term sonification is used. The reassignment of these qualities constitutes a semiotic transformation step (Gramelsberger, 2000). This step results in the creation of an iconographic sign system, whose characteristics are not predetermined by the simulation-based sign system and can therefore be, at least in principle, entirely arbitrary.

Scientific Visualisation

From a scientific point of view, the perceptual and semiotic reassignment is less than arbitrary since it is required to maintain the epistemological value of the simulation-based experiment. Accordingly, the corresponding semiotic transformation needs to preserve the syntactic structure and relations among the signs. Frequently, the transformation is also required to result in a symmetrical relationship between simulation and visualisation or sonification. Such a relationship maintains a one-to-one relationship between the signs of the simulation system and those of the iconographic system. Together, these two requirements imply that the transformation should not introduce any semantic and perceptual elements that are not legitimised by the simulation itself.

Aesthetic Visualisation

Within the arts, the application of visualisation and sonification techniques to simulation-based numerical data resembles their scientific counterpart in the sense that they serve to render a perceptionally and semantically undefined sign system accessible to human perception and interpretation. On the other hand, the artistic motivation for doing so is very different than the scientific one. Rather than to emphasise the epistemological aspects of the simulation-based approach, the simulation itself and its subsequent transformation into an iconographic system become ingredients of an aesthetic process. Iterating the semiotic transformations from concept to simulation and visualisation establishes a mutual feed-back loop between a machine-based form of creativity and the evaluation and re-imagination of an artistic idea. This stands in contrast to the scientific version of such an iteration that alternates between stages of induction and deduction and thereby leads to a more profound understanding of a natural phenomenon (see figure 2). The semiotic indeterminacy of a simulation-based sign system fosters artistic freedom in assigning semantic properties to the iconographic sign system. Rather than being restricted to an assignment that is legitimised by a scientific theory, the semantic properties can be chosen in order to evoke aesthetic and affective interpretations that are highly dependant on the subjective context of the recipient. Similarly, artistic freedom benefits from the perceptual openness of a simulation and the resulting lack of constraints with respect to the range of possible iconographic representations. Here, the options include indexical visualisations that introduce causal relations between simulation-based structures and visual or acoustic elements, iconic visualisations that use naturalism to establish a perceptional similarity between a simulation and its associated natural phenomena, and symbolic visualisations that employ convention-based interpretations of iconographic signs to introduce cultural connotations.

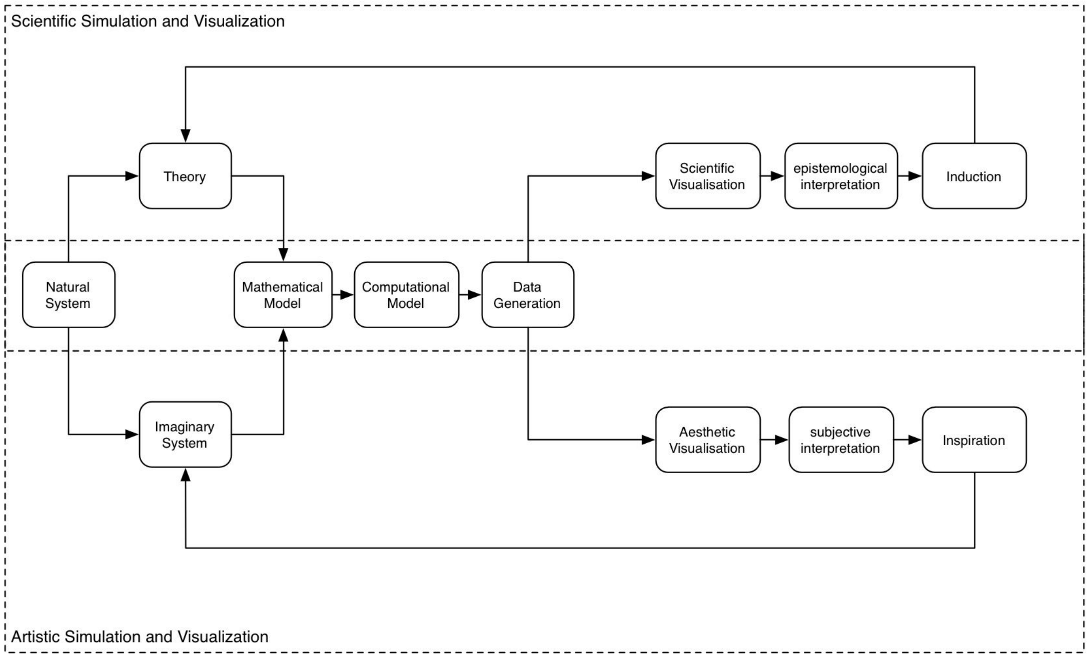

Figure 2. Scientific vs. artistic visualisation

Concept

The realisation of Trails II is based on the premise that computer simulations can be employed as conceptual, aesthetic and technical tools for the creation of an entirely synthetic artwork. The realisation benefits from existing know-how in generative art but also tries to circumvent some of the shortcomings of the field. Algorithmic approaches in generative art have proven to be very fruitful for the creation of visual or sonic material that can later be integrated into a final work. Usually, this selective and compositional work is carried out by a human and it is a rather rare occurence that it is also automated. In the latter case, the compositional work is often assigned to a number of additional and different algorithmic systems, each of which operates on a particular temporal and organisational scale. It is very rare that the application of a single algorithmic system for both the creation of media material and its compositional organisation leads to satisfying results. The reason for this shortcoming lies in the fact that it is much simpler to fine tune a particular algorithm to produce a variety of interesting media fragments than it is to increase the algorithm's flexibility to operate on the structural and temporal properties of a compositional organisation as well.

The following additional compositional aspects would need to be handled by an algorithmic system: the structural organisation and layering of media material, the establishment of correspondences among media both within a modality and across different modalities, the arrangement of media into coherent paratactic structures, and the temporal development of these structures. Traditional approaches in generative art have typically dealt with these issues in one of two ways. They have either committed themselves to compositional styles that are very forgiving with respect to the above mentioned criteria, such as sound scapes. Or they have resorted to compositional styles that are constrained via very narrow and external sets of rules, which can be applied to restrict the range of possible outputs by the generative system. An audio-visual artwork that does not adhere to one of these two stylistic categories faces the challenge of achieving a formal consistency and aesthetic congruency across different modalities and organisational scales. Despite the challenges, the application of a single algorithmic system to control all aspects of a generative work seems very promising. The syntactic variations that a single algorithmic system is able to achieve possess an inherent congruency since they are connected via a single and consistent set of intra-semiotic relations.

This algorithmic level of consistency and congruency can be exploited as compositional mechanisms to achieve a similar level of consistency and congruency on a perceptual and aesthetic level.

For this reason, we have chosen to realise Trails II by employing a single simulation-based algorithmic system. This system generates both the visual and acoustic media as well as their compositional and formal structure. The feasibility of this approach depends on the capability of the simulation to operate on syntactic structures and relations that span a wide range of hierarchical and temporal organisations. A class of simulations that lend themselves to this approach are swarm simulations. These simulations have originally been invented to model the coordinated movement within large groups of individuals such as flocks of birds or schools of fish. Because of this background, these simulations are particularly well suited for organising semiotic entities within groups and for adjusting the syntactic properties of these entities via transformations that depend on formal distance criteria. These grouping mechanisms, distance criteria and syntactic properties can operate on an arbitrary temporal and spatial scale. Furthermore, an arbitrary number of these organisational layers can be implemented and related to each other via operations that traverse these layers. For these reasons, swarm simulations and compositional systems share a similar degree of organisational flexibility for relating groups of semiotic entities across different structural and temporal scales.

Trails II employs exclusively abstract music and imagery. The decision to refrain from an iconic visualisation and sonification is motivated by our intention to emphasise the formal and structural relatedness between a simulation-based sign system and the perceptual sign system. Accordingly, the aesthetic realisation of the piece tries to maintain some of the semiotic characteristics of the simulation. First of all, the abstract media preserve a similar level of semiotic openness as the simulation. Furthermore, the media themselves and their compositional arrangement are discretised into individual perceptional signs that correspond to the discretised signs and transformation rules of the simulation. Finally, the acoustic and visual media are not related to each other via a direct inter-media transformation but rather via the fact that both of them originate from a common simulation via an inter-semiotic transformation. Accordingly, the aesthetics of the piece emphasises syntactical rather than perceptional correspondences among the modalities.

Tools

The computational tools used for the realisation of Trails II consist of several applications that run on three computers: a swarm simulation software that models flocking behaviour, a supervisory control program that manages the large-scale structure and the temporal organisation of the composition, and two programs that handle the visual and the acoustic rendering. The communication between all applications relies on an OSC-based communication protocol and serves to transmit both simulation-based numerical data and global control parameters (see figure 3).

The swarm simulation software that has been developed by the authors (Bisig et al., 2008; swarms.cc, 2013) was originally designed as an open source C++ library and later extended with a graphical user interface (Bisig and Kocher, 2012). The user interface was initially intended to allow non-expert users to operate the simulation but has proven to be equally important for experienced users as a means to rapidly create and experiment with different simulation types. The simulation software allows for the definition and real-time manipulation of a wide range of agent properties and behaviours. Even though the simulation has been conceived to mimic natural swarm behaviours, it is not limited to them. Unusual types and combinations of behaviours and unrealistic agent properties can easily be implemented in order to come up with novel types of simulations that lack any natural correspondence. This flexibility transforms the simulation itself into a tool for the artistic experimentation with artificial realities. These realities become visible via a scientific visualisation mechanism that is integrated into the simulation software (see figure 4).

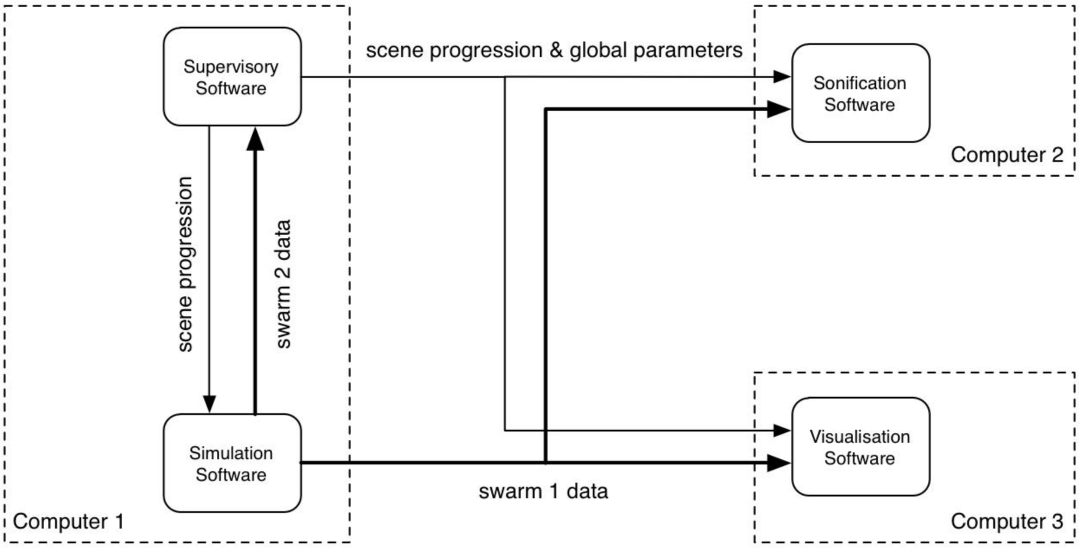

Figure 3. Inter-program communication

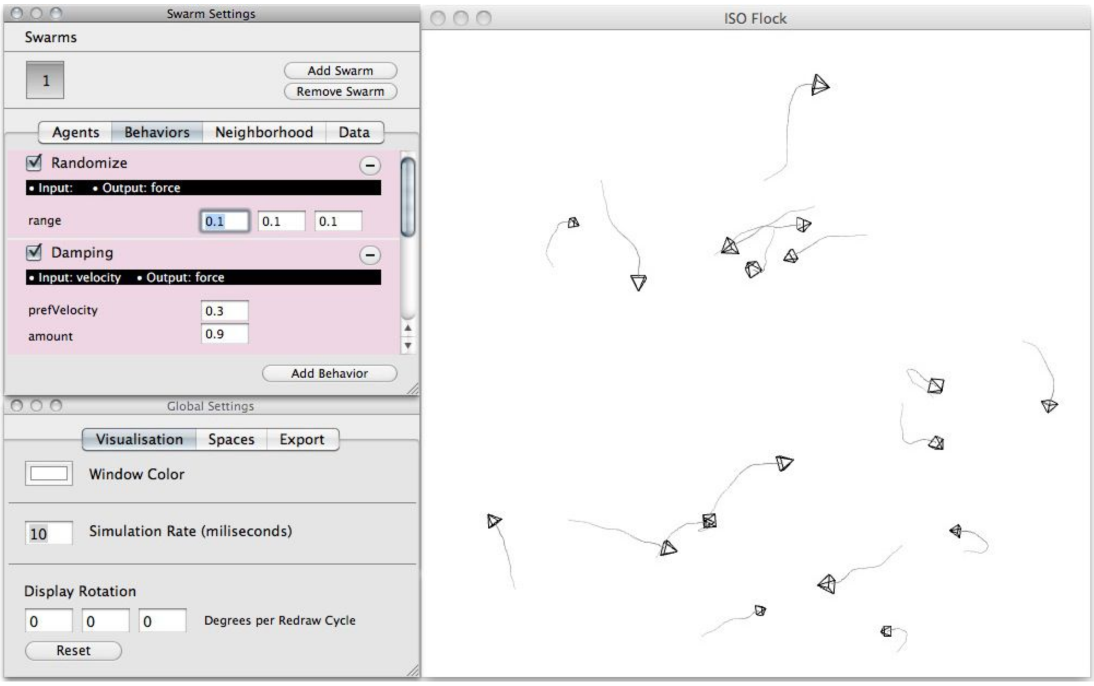

Figure 4. Swarm simulation software with integrated scientific visualisation

The visualisation software is implemented in C++ and realises an OpenGL-based rendering engine that handles polygon meshes and image textures. The software also allows to define arbitrary transfer functions that map the position, velocity and acceleration properties of the simulated agents into parameters that control the visualisation process. The mappings can control the affine transformations of geometrical objects and change their surface characteristics.

The sonification software is implemented in the sound synthesis programming language SuperCollider (McCartney, 2002). It maps position and velocity properties of agents into sound synthesis parameters. This mapping affects either primary synthesis parameters (e.g. frequency of an oscillator) or higher level synthesis parameters (e.g. rhythmical density of a texture).

The supervisory control program is also implemented in SuperCollider. It takes over the role of a human performer or composer in shaping the overall structure and process of a composition. It does so by controlling the chronological order of individual sections of a piece and by manipulating global parameters. The decision when to execute a transition from one section to another is based on an analysis of the swarm simulation data. A section is a distinct state of the entire system that combines a particular set of swarm behaviours with specific visualisation and sonification methods. Thus, each transition is clearly perceivable as a break by which the temporal flow of the piece is structured and the paratactic structure is established.

Realisation

Design of Simulation

Trails II has been realised throughout multiple design cycles as a collaborative work between the authors. The cycles provide the means to iteratively implement and re-evaluate different conceptual and technical ideas via an explorative approach (see Figure 5). The innermost cycle serves to build a repertory of different simulation-based realities. This cycle connects the design and manipulation of the swarm simulation to a scientific visualisation. The scientific visualisation preserves the spatial and temporal patterns of the simulation via a symmetrical mapping to visual properties. The resulting perceptual unambiguity helps to assess the aesthetic potential of a simulation. The simulations are categorised with respect to the characteristics of their spatial and temporal intra-symbolic relations. The categorisation reflects the relevance of different criteria for the acoustic and visual modalities. For the sonification of the simulation, it is mainly the characteristics of the temporal patterns that are of interest, whereas the visualisation benefits mostly from a large diversity of spatial patterns. A further important set of criteria for the classification of simulation behaviours is based on a differentiation of their continuous and discrete characteristics. The terms continuous versus discrete refer to large scale differences in the numerical and temporal output of the simulation, rather than the small scale discreteness that is imposed by the computer hardware itself, since the latter is not translated into a perceivable discreteness via the visualisation and sonification step.

The time and space continuity of a simulation is affected by the integration of what we call “density behaviours”. These behaviours cause agents to cluster among each other (cohesion behaviour), scatter away from each other (evasion behaviour), or gather at a global attractor point (position target behaviour). The continuity is also affected by the integration of so called “coherence behaviours”. These are behaviours that cause agents to move locally (alignment behaviour) or globally (velocity target behaviour) along similar trajectories at particular speeds (damping behaviour and inertia behaviour). The time and space discreteness of a simulation is achieved by establishing thresholds or boundaries that need to be crossed by the agents. Furthermore, it is also achieved by configuring continuous behaviours in such a way that they lead to an exaggerated dynamics, for example via a rapid and very strong repulsion among the agents.

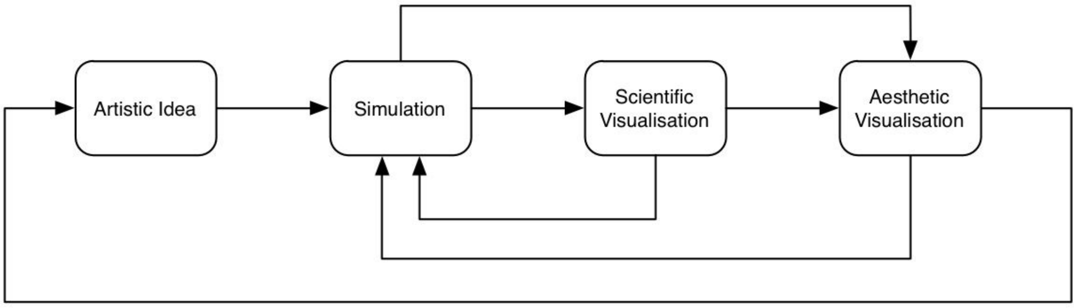

Figure 5. Artistic cycles

Design of Renderings

The second design cycle links the simulation to an aesthetic visualisation and sonification. During this cycle, the properties of the simulations that are part of the repertoire might be fine-tuned but their main characteristics remain unchanged. The goal of this cycle is to establish a correspondence between each simulation and its sonic and visual rendering. As part of this, a repertoire of rendering scenes is established. Each scene is related to a particular simulation and encompasses a specific visualisation and sonification technique together with a corresponding method of mapping numerical simulation data to rendering parameters. Since the designs of the simulations were informed to different degrees by musical or visual ideas, not all of them lend themselves equally well to a transformation into both modalities. This is not necessarily a drawback and can be exploited for translating artistic ideas among different media. This aspect relates to the outermost design cycle. This cycle leads to a repeated reassessment of the creative process and helps to establish an awareness for the semiotic and aesthetic relationships between simulation, music and imagery.

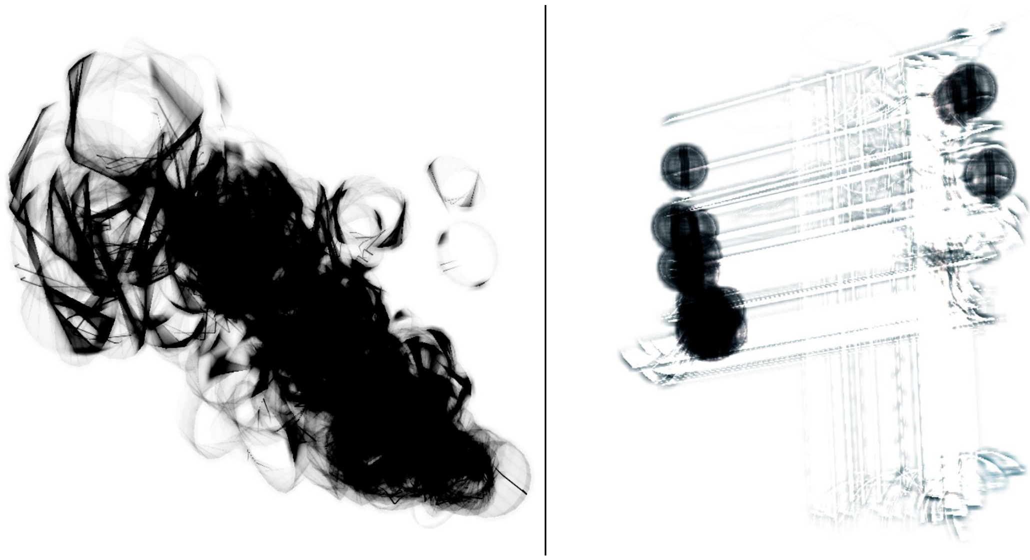

Figure 6. Visualisation examples

Design of Composition

The main challenge in the realisation of Trails II concerns the development of an automated mechanism that results in an aesthetically meaningful structure for the overall form of the artwork. As stated earlier, the goal is to mandate these compositional aspects to the simulation itself. As part of this approach, two processes are established. The first process controls the temporal progression of the sections by using the time-discrete characteristics of the simulation to trigger scene transitions. The second process employs the continuous characteristics of the simulation to control the change of overarching and scene independent global parameters. These parameters are mapped to secondary properties of the visualisation and sonification. These are properties such as colour or texture that are of an accidental nature in a sense that they may vary while the character of a scene remains unambiguous. Finally, a particular state of the simulation is defined to act as termination condition that ends the performance of the piece.

Results and Discussion

The aforementioned realisation process resulted in a first version of Trails II. This piece is characterised by two main aesthetic elements: it consists exclusively of abstract audio and video and it favours a time-discrete compositional structure over a continuous form. The high level of audio-visual abstraction serves as a means to convey the semiotic and perceptional openness of a simulation-based generative work on an aesthetic level. The focus on time-discrete elements helps to accentuate the perceptibility of the simulation driven correlation between music and video on a macroscopic level. This complements the perceptibility of correlations between the two modalities on a microscopic level. The latter correlations are less evident due to the fact that they tend to be partially masked by peculiarities of the rendering processes which are different for each modality. The introduction of macroscopic events for the creation of perceptually strong correlations among the modalities requires a magnification of the temporal discretisation of the simulation. It is only via this magnification that the temporal discontinuity becomes perceivable. For Trails II, this magnification is based on a simple mechanism that triggers discrete events whenever the value of an agent property or its derivative exceeds a certain threshold. This approach of deriving an aesthetic discretisation provides a certain level of artistic freedom without abandoning a perceptual proximity to the syntactic and temporal organisation of the simulation. In addition, the aesthetic discreteness and clarity of event-based synchronisations among the modalities helps to balance the spatial and temporal complexity of the perceptional patterns that exist within each modality. Finally, the event-based synchronisation creates a temporal proximity between audio and video that forms an important basis for their multimodal integration.

Visualisation

With respect to visualisation, an approach was chosen that extends beyond a direct interpretation of the simulation-based syntactic entities as geometrical objects that exist in a Euclidian space. While such an interpretation is attractive due to the fact that it manages to achieve a close relationship between syntactical and perceptional elements, it fails to capitalise on the aesthetic freedom of this semiotic transformation. It was therefore decided that the composition of the piece should progress through a wider range of aesthetic manifestations that employ additional visualisation strategies. The strategies that were finally employed for each of the different sections of the piece can be distinguished based on the structural and perceptional characteristics of the resulting visualisation and the amount of relatedness that these characteristics share with the simulation. A direct relation between structural and perceptual aspects of the visualisation and structural aspects of the simulation is achieved by directly mapping agent positions and velocities to the positions and orientations of graphical elements and/or by modifying the shape of the graphical elements based on these properties (i.e. the extrusion of a profile along an agent‘s movement trajectory). This type of direct relationship maps the discreteness of the simulated entities into a similar discreteness of a graphical depiction. Those visualisations that maintain a direct relationship with the simulation on a structural level but abandon it on a perceptional level introduce new aesthetic properties but preserve their structural organisation. Examples of such relationships are the velocity-based scaling of graphical objects or changes in the transparency of graphical objects based on the spatial density of the agents. Such a visualisation still manages to convey the structural characteristics of the simulation but it does so in a more qualitative and continuous manner. Finally, if the visualisation abandons a direct connection to the structural characteristics of a simulation on both a structural and perceptional level, the visual aesthetics partially hides its simulation-based origin. Examples of such visualisation include the depiction of spatial discontinuities in the agents movements, the animation of graphical textures, and the visual fragmentation of graphical objects via masking patterns.

Sonification
With respect to sonification, the mapping of simulation data to sound synthesis parameters is always to be understood as a translation. Whereas the signification of an agent as an entity in a Euclidian space permits a one-to-one visualisation, there is no such immediate path available in the realm of musical or acoustic rendering. In its most elementary sense, the agent position in a Euclidian space is directly converted into a position in a parameter space. This interpretation establishes a very strong relationship between the structure of the simulation and perceptual elements, especially when they connect to metaphors from spatial geometry that are familiar to us since we use them to describe acoustic or musical properties such as “high–low” for pitches or “left–right” for stereo-panning. More subtle effects are achieved when the simulation data are mapped to secondary parameters such as timbral properties or textures. This approach to sonification renders the structural qualities of the simulation audible without depicting the continuous nature of the data in obvious ways, e.g. as permanent pitch glissandos. The sonification of time-discrete data turned out to be most fruitful since it conveys a temporal shape which is a crucial property in music as it is a basic building block for rhythm, phrasing and form. Time-discrete data can be mapped to any sonic parameter resulting in well perceivable changes in sound quality, or used to trigger a synthesiser to play a note.

Composition
The compositional structure of the piece is divided into individual sections that are organised into a sequential arrangement. The syntactic structure of the simulation is transformed into an aesthetic structure via visualisation and sonification strategies that are specific for each section and by a statistical mapping that controls the progression among these sections. The properties of the two different modalities are correlated due to the fact that they result from the semiotic transformations of a single simulation that is unique for each section. Simulation types that combine large spatial and temporal changes among their elements have proven to be suitable for both visualisation and sonification. Examples include simulations that exhibit highly synchronised fast global movement patterns or simulations in which the density of the agents‘ spatial distribution alternates frequently. A second compositional element that is controlled by the simulation are global parameters. Throughout the entire piece, these parameters influence the visualisation and sonification methods. The exact characteristics of this mapping depend on the particular properties of the currently active rendering methods and changes in each section. But despite these changing relationships, it is the application of these global parameters that give the piece an overarching aesthetic structure. For the purpose of this mapping, it has proven useful to simulate two swarms at the same time. The first swarm serves to control the rendering process and contains a larger number of agents than the second swarm. A large number of agents helps to generate a high level of perceptual density even if a symmetric semiotic transformation is applied. The second swarm exclusively controls the global parameters and the scene progression. The numerical data that are obtained from this second swarm are processed differently for these two control purposes. The global parameters are updated via a direct mapping. The scene progression on the other hand relies on a threshold mechanism to identify events in the incoming simulation data. These events are statistically analysed in order to decide which scene transition should be triggered. Typical criteria for this decision include the number of events that have occurred so far or the time

interval between these events. The two swarms can be interrelated with each other by transformation rules that connect agent properties across swarm boundaries. It is via the semiotic transformation of these inter-swarm syntactic relationships that the aesthetic characteristics of each scene, the scene progressions and the overarching compositional structure become correlated. Or put differently, the simulation-based consistency between two different swarms can be translated into a consistency among the macroscopic and microscopic aesthetic elements of the piece. Finally, it is important to note that the combination of a simulation-based repertoire of scenes with a simulation-based progression of scenes results in a synthetic performance resembling an improvisational setting. The probabilistic characteristics of a swarm simulation gives raise to random perturbations that manifest themselves during a performance as manifold variations and as spontaneous rearrangements of an audio-visual vocabulary.

Conclusions

In the case of Trails II, the incorporation of semiotic concepts fulfilled a valuable function as they helped to inform the artistic realisation on a very fundamental level. The swarm simulation that underlies the organisation of synthetic music and video as a generative mechanism represents a highly abstract formal system. Hence, the notion of a simulation as a semiotic machinery that operates on the syntactic structure and relations in a sign system seems to be a viable method to gain an appropriate understanding of such a system. The identification of a semiotic equivalence between simulation, media and composition allows to assess the artistic potential of a simulation and guides the translation of the system’s characteristics into the aesthetic properties of an artwork. Such an approach proves to be vastly more promising than treating a simulation as a black box mechanism. The latter tends to be limited to an enforcement of a numerical compatibility between simulation data and media rendering parameters and a reliance on a perceptual and/or metaphorical similarity between a simulation’s original scientific context and the aesthetic result.

In addition, the conceptually precise characterisation of a compositional process as a chain of semiotic transformations between different sign systems helps to differentiate between stringent and flexible relationships among the formal and aesthetic aspects of the compositional elements. Our approach to employ a single simulation-based algorithmic system to control both the compositional aspects and the media generation of a work is mostly based on the identification and exploitation of semiotic similarities among the various components of a generative composition. Without the identification of these similarities, such an approach would hardly have been possible. Accordingly, it is clear that semiotics can help to identify and expand the range of compatibilities between a single algorithmic system and a variety of media modalities and organisation principles. The presence of a strong coherence on a structural level can be exploited to achieve a similarly strong coherence on an perceptual level without forcing the contributing artists to renounce their aesthetic freedom. For this reason, we believe that semiotics provides powerful conceptual and strategic tools for conducting collaborations among artists.

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