AHRC ICT METHODS NETWORK

FROM ABSTRACT DATA MAPPING TO 3D PHOTOREALISM: UNDERSTANDING EMERGING INTERSECTIONS IN VISUALISATION PRACTICES AND TECHNIQUES

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MATHEMATICAL VISUALISATION IN THE VISUAL, SONIC AND PERFORMING ARTS

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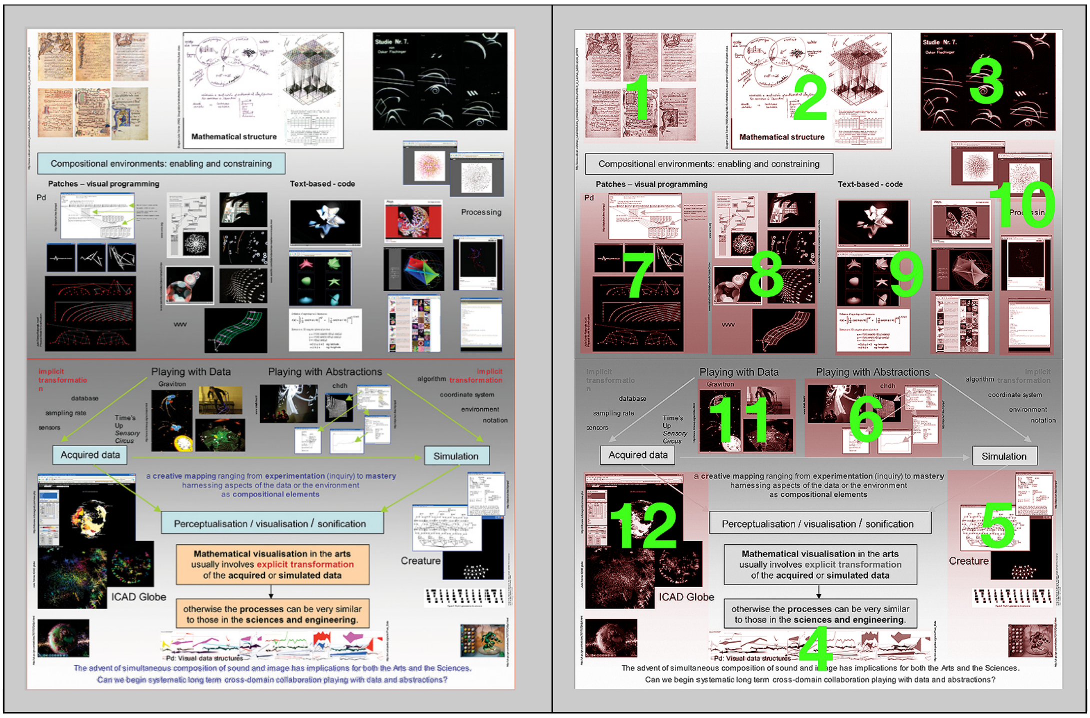
Abstract: The slides present mathematical visualisation in the visual, sonic and performing arts from an interdisciplinary, mathematical, first principles, historical timeframe point of view. The target audience is both visual sonic and performing artists and experts in scientific data visualisation and simulation. The intention is to juxtapose examples and environments demonstrating overlaps with the sciences and to flag the emerging challenge of the simultaneous 'display' and/or composition of sound and image.

Introduction

This paper presents a juxtaposition of examples in mathematical visualisation in the arts, firstly to initiate debate into possible relationships between software based art and abstraction, and scientific and data visualisation, and secondly to raise awareness of the emerging field of simultaneous sound and image, alongside the historical work already undertaken in that direction. The slides were presented at the event *From Abstract Data Mapping: Understanding Emerging Intersections in Visualisation Practices and Techniques*[1], at the Birmingham Institute of Art and Design. This was a follow-up event to *vizNET 2007*[2], and the slides assume prior presentation of the examples at the vizNET[3] event.



Mathematical Visualisation Examples: Dynamic Relationship between Sound & Image

The 'mathematical visualisation in the arts' examples selected highlight mathematical connections and/or a dynamic relationship between sound and image. The focus is therefore on dynamic mathematical visualisation; static visualisation of mathematical form is not considered in this exposition, except as a resource. The focus is further restricted to geometric structures embedded in two or three-dimensional space (plus time) in order to facilitate comparison across the different examples chosen, however this restriction is not strictly necessary; a more algorithmically based set of examples could have been selected. Networked and distributed aspects of mathematical visualisation or live coding in the arts are not explicitly addressed as these areas are covered elsewhere in this series.

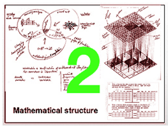
Methodology and the Diagram Block Format

The two slides are combined into a single visual document with blocks of diagrams numbered and traversed in the sequence indicated. Issues discussed as this path is traversed may apply equally to earlier or later examples but are not necessarily repeated for reasons of brevity.

A brief narrative explaining the rationale and interconnections between visual examples in the diagram blocks enables their eventual juxtaposition. Within these diagram blocks, *direct* links to resources are provided along with *extensive* extracts of documentation and brief discussion of the media presented. It is intentional that individuals' statements should be heard rather than presented in summary form as this original material more closely evokes the *nature* of these examples or environments thus facilitating their mutual juxtaposition. It is hoped that provision of this information will make it possible for the reader to follow the overall argument on first reading without the distraction of having to continually access multiple documents in diverse formats. An outline of the narrative is given below. References are given in the narrative traversal of the diagram blocks, rather than the outline.

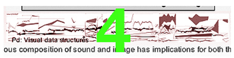
Narrative Outline

The narrative starts with diagrams representing the evolution of polyphony and western musical notation from the 11th to the 14th centuries. The musical notation is considered in the context of its spatial representation, as a visualisation. Instructions for reading the graph or visualisation; development of methods for time partition of the unstructured space; the development of measured music are considered. Most importantly, the historical timeframe over which this example takes place is emphasised.

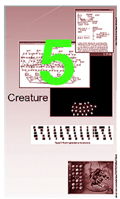


We move next to the late 20th century, to a seminar based on the principles outlined in *Formalised Music* by Iannis Xenakis, but with extension into the visual domain. Mappings of mathematical and stochastic structures into sound and image directly address the topic of this exposition, however the relative maturity of the respective technologies along with their lack of integration, and the first principles approach make this a very different seminar and compositional paradigm to the present situation. Nevertheless this format is more easily identifiable as directly related to the sciences and engineering.

We then move back in time to the abstract and experimental film of the early 20th century. Questions of rhythmic structure and mathematical abstraction, the use of geometric form and of temporal geometry (by which is meant the editing of film according to durations of light and dark or of interweaving of certain types of forms), visual music and attempts at the synchronisation of sound and image are considered.

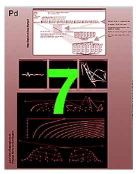


We move forward in time to the 21st century, to the present, to an environment enabling the programming of graphical data structures for audio synthesis and thus enabling the simultaneous composition of sound and image, (so sought after by early abstract filmmakers). The combined environment of Pure data, GEM (Graphical Environment for Multimedia) and pmpd (Physical Modelling for Pure Data) is outlined with direct links to their respective documentation.



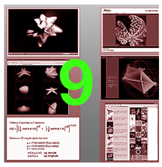
A topological rhythm-generating creature (or structure) is then examined. Notably it is neither its sound output nor its visualisation but can be seen to be defined by its 'abstraction' - its construction of masses connected by links, with some of the masses connected to oscillators which produce a sound when the y position of these masses exceeds a threshold (i.e. when it touches the floor). The creature is in effect an interactive virtual instrument which produces a rhythm, constrained by its topology, and by values assigned to the rigidity and damping of its links. A second example of a creature's procedurally generated motion is then examined. This example is commercial, from the yet to be released computer game *Spore*.

Creating and mapping interactive virtual instruments for live performance and mastering and playing on their idiosyncrasies is the next consideration: playing and performing with abstraction. The choice of mappings is non-trivial. The communication of these new forms to the audience is also a significant task. The pioneering work of chdh in pmpd is showcased.



The instability of the physical modelling environment is both a creative tool and a significant constraint. In the visual dataflow environment, left-right and top-bottom symmetric constructions are not symmetric in a 'physical' sense. Application of an excited membrane of masses and links to a binary tree structure resulted in high instability. However re-conceptualisation using invisible fixed masses led to an interesting physical object.

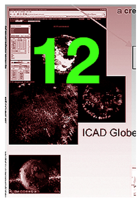
The next environment, vvvv, features high-end 3D graphics, programmable ‘spreads’ of identical objects, multi-screen immersive set-ups, and operates on a runtime only basis, in other words on live coding. Not specifically focussed on sound, it is perhaps closer to the 3D version of pure visual abstraction. Mathematical formulas and objects are appropriated therein as compositional tools. In particular, videos of live performance from Sanch are showcased.



Mathematically defined objects and processes are frequently used in the creation of audio-visual abstraction. In particular, some artists use scientific visualisation resources, including those of a mathematical nature, directly. A literal application of the 3D supershape in vvvv for visualisation of a song is demonstrated. Mathematical learning objects that border on current visual art in an arts environment are considered.

The next environment is Processing. Significantly, a Processing handbook has just been released (September 2007). It promises to become a text for many new media art and design students. However we go backwards in time to 2003 when ABSTRACTION NOW in Vienna was running simultaneously with the *Code, the Language of Our Time* Ars Electronica in Linz. Early work by Casey Reas, one of Processing’s authors was presented at both events. Catalogue commentary on software based abstraction and complexity is of period interest. A film festival MATHS IN MOTION showed 100 works, many of which came from early abstract and experimental film.

We next move to hybrid reality environments, or extensive multiscale interactive situations, with the Sensory Circus of Time’s Up the example in point: mathematical visualisation; sound; large scale motion sensor data logging, analysis, mapping, and visualisation; integration of different temporal scales across the lifetime of the exhibit; on the fly interactive game design and assignment of meaning to emerging perceivable patterns. Their Sensory Circus’ *Gravitron* and *Lightning District* are showcased.



The final example looks at visual and auditory display of world data. It is artificially constructed to highlight the intention of display: a commercial subscriber interactive 3D globe for viewing world data; a sonification concert based on listening to world data; a 3D globe particle frequency visualisation of world data; a 3D world and its creature inhabitants in the as yet unreleased video game *Spore*.

Summary and overview of slide(s)
The evolution of western musical notation provides an historical timeframe against which profound changes took place. The Design Structures seminar was based on work from a time period in which this musical notation system was no longer at the forefront of compositional environments. Many early abstract films had distinct musical or rhythmic structure. Graphical data structures now enable simultaneous composition of sound and image. Topological structure and physical modelling can create a rhythm whose steps of construction involve implementation of a sound-image creature. Real-time performance with simultaneous sound-image instruments is demanding of both composers and audience in a shift not unlike that faced by early polyphony. Mastering the new compositional environment leads to reconsideration of other disciplines in that new environment, mathematical structures, being the case in point. Parallel developments in high-end 3D graphics are enabling 3D abstract works concerned with pure visual abstraction without narrative. Mathematical structures are employed in much of the visual abstraction and interactive responsive environments. In turn the environments are enabling the mathematical (learning) objects to approach artworks in themselves. Early recent works in computer-based visual abstraction attracted a number of retrospective exhibitions and writings whose content is interesting to juxtapose against the evolution in the short timeframe of just four years. Multi-scale interactive situations attempt to integrate multiple physical installations, simulations, and user behaviour to create an emergent (and tuned) complex system. In this and other such processes, choices are made appropriating features extracted from data streams and real or virtual environments as compositional elements. The resulting transformations of maps can be conventional and easily read, or may be designed to provide underlying structure without being individually identifiable. Compositional environments enable and constrain. Processes can be very similar to the sciences and engineering; intent can be very different.

1. Evolution of Western Musical Notation as a Visualisation: Historical Time Frame
The evolution of western musical notation provides an historical timeframe against which profound changes took place. This example was presented in the talk Visualisation across Domains[4 5] at vizNET 2007 where the extract concerning how to read the graph or visualisation was related to a previously presented historical example (10th century) in data visualisation presented by Brodlie[6].

This historical timeframe example starts in the 11th century with the introduction of a spatial notation system for the representation of music, attributed to Guido d'Arezzo, circa 1025. The musical notation is considered in the context of its spatial representation, as a visualisation. This example addresses the unforeseen implications of a visualisation that was initially employed for the purpose of notation. These changes took place over 300 years. The notation of, initially four, lines and spaces can be thought of as a **graph**. Extracts from Guido explaining **how to read this graph or visualisation** are given:

[7]

[...] The sounds, then, are so arranged that each sound, however often it may be repeated in a melody, is found always in its own row. And in order that you may better distinguish these rows, lines are drawn close together, and some rows of sound occur on the lines themselves, others in the intervening intervals or spaces. Then the sounds on one line, or in one space all sound alike. And in order that you may also understand to which lines or spaces each sound belongs, certain letters of the monochord are written at the beginning of the lines or spaces and the lines are also gone over in colours, thereby indicating that in the whole antiphoner and in every melody those lines or spaces which have one and the same letter or colour, however many they may be, sound alike throughout, as though all were on one line. For just as the line indicates complete identity of sounds, so the letter or colour indicates complete identity of lines and hence of sounds also.[8]
One of the revolutionary imports of this notation was the ability to see the whole and the part across both time and pitch. This framework enabled musical composition of polyphonic works using the spatial representational structure to juxtapose sound in the time dimension. Soundfiles from the 12th -14th century[9] are played with participants asked to listen for the increasing complexity of the rhythmic structure.

Discussion of textual sources then resumes in the 14th century with extracts from Jean des Muris, musician, mathematician, astronomer, University of Paris, Notre Dame in 1319 explaining two times three is equal to six and also equal to three times two, and therefore it is possible to sing multiples of two (imperfect notes) to God. *[...] At the end of this little work be it observed that music may combine perfect notes in imperfect time (for example, notes equal in value to three bréviores) with imperfect notes in perfect time (for example, notes equal in value to two breves), for three binary values and two ternary ones are made equal in multiples of six. Thus three perfect binary values in imperfect time are as two imperfect ternary ones in perfect, and alternating one with another they are finally made equal by equal proportion. And music is sung with perfect notes in perfect time, or with imperfect ones in imperfect, whichever is fitting.*[10]
Of his nine conclusions the final one is an explicit statement of measured music:
That the "tempus" may be divided into any number of equal parts.[11]

Pope Jean XXII issued a Papal Bull in 1324-25 condemning polyphony and measured music, insisting that the measure of musical notes is assigned on the basis of the meaning of the phrase sung to God and not on the measured dividing of time. *Certain disciples of the new school, much occupying themselves with the measured dividing of time, display their method in notes which are new to us, preferring to devise ways of their own rather than to continue singing in the old manner; the music, therefore, of the divine offices is now performed with semibreves and minims, and with these notes of small value every composition is pestered. Moreover, they truncate the melodies with hocket, they deprave them with discantus, sometimes even they stuff them with upper parts made of secular song [...] We now hasten therefore to banish these methods [...] and to put them to flight more effectually than heretofore, far from the house of God.*[12]

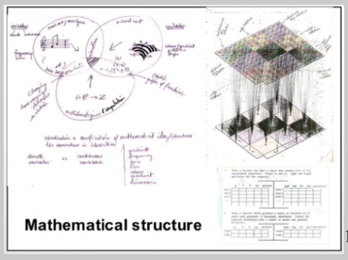
Hughes Dufourt identifies the remapping of music to space and the weakening of its relationship to language as one of the inherent conflicts: *Primacy of the oral, of linearity, the unequivocal deployment of a syntactic order, the absolute reference of the music to the phonetic code: that is the injunction of Jean XXII. The famous bull that contemns the modernist tendencies in music is one of the most significant documents of the period, evidence not only of a conflict between two (poetics) or two antagonistic styles, but above all a disagreement between two conceptions of music. One the relationship to language, the other to space.*[13] *(My translation)*

> The cultural, religious and political upheaval that would be caused by employing a visualisation to notate sound was not foreseen in the 11th century. Neither were the spatial implications. Music represented as space enables use of spatial symmetries, reflection and inversion etc., which do indeed dominate as a compositional tool in some later western music, for example in the works of J.S.Bach in the 18th century. Inevitably the spatial notation system in turn constrained that which could be composed within it, with 20th century graphic music[14] and algorithmic composition not composed within its confines.

In summary, diagram block 1 outlines an historical timeframe of 300 years against which discussion of recent and current developments in visualisation can be set. It showcases the evolution and deployment of rhythmic structure in musical works of this period. Rhythmic structure is further discussed in the early abstract film of diagram block 3 and in the creature examples of diagram block 5.

2. Design Structures: A Seminar from First Principles based on Xenakis' *Formalised Music*
The Design Structures seminar was based on work from a time period in which this musical notation system was no longer the primary compositional environment. The interdisciplinary mathematical first principles point of view applied in this paper to mathematical visualisation in the visual, sonic and performing arts had its origins in the collaborative teaching of the seminar outlined below.

> Design Structures[15] was a graduate seminar in mathematical structures offered at ACAT (the Australian Centre for the Arts and Technology[16]) at the Australian National University in the early 1990s. Unlike similar courses today, the seminar was not based on dedicated software; mappings were constructed from first principles: starting with a theoretical mathematical structure or process and realising it the visual and sonic domains in APL[17]. Students of time-based visual art studied alongside students of computer music composition despite the wide discrepancy in maturity of the technologies developed for the two fields at that time.[18]



[19]

> [The mathematical background of Australian students is different to that of a similar cohort in the UK[20]. In 1995, 78% of year 12 students in Australia were taking some level of mathematics; 14.1% advanced, 27.2% intermediate, and 37% elementary[21]. Intermediate courses included calculus.]
>
> The seminar was loosely based on the approach of *Formalised Music*[22] as outlined by Xenakis but these principles were extended into the time-based visual domain, then as animation and visualisation. Topics covered included: ratio, set, number, relation & group, recursion & automata, Euclidean geometry, vectors, probability, calculus, circular functions and spectral analysis, iterated function systems, fourier transforms, games, fuzzy logic, vector fields & calculus, lindenmeyer systems, genetic algorithms, continuous probability & non-deterministic fractals, chaos theory, deterministic fractals, and topology.
> A cross-referenced index[23] of 2000 terms from mathematics, visual art, music and computing taken from the 700 pages of photocopied notes[24] facilitated navigation of the vastly different notations and representations. Continual exposure to different realisations of the same structures in sonic and visual art enriched the experience for artists, musicians, and mathematicians alike.
>
> Diagrams on the slide include: a venn diagram of the intersections between music, visual art, and mathematics/computation, with animation, visualisation, and sonification being identified as their pairwise intersections; a group table for rotations of a tetrahedron showing its relationships with a group table for addition modulo 3; an assignment that constructs matrices of line segment/tone parameters, where each parameter is normally distributed. These line segments/tone parameters are controlled from a matrix of means and standard deviations.

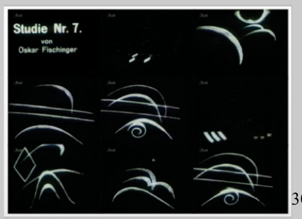
In summary, mappings of mathematical and stochastic structures into sound and image directly address the topic of this exposition, however the relative maturity of the respective technologies along with their lack of integration, and the first principles approach made this a very different seminar and compositional paradigm to the present situation. This early format is more easily identifiable as related to the sciences and engineering; some of the techniques and mappings in use in the computational arts today can be viewed as very similar to the processes in scientific visualisation and simulation.

3. Time-based Visual Abstraction: Rhythmic Structure in Early Abstract Film and Beyond

Many early abstract films had distinct musical or rhythmic structure.

Questions of rhythmic structure, temporal geometry (by which is meant the editing of film according to durations of light and dark or of interweaving of certain types of forms), and attempts at the synchronisation of sound and image arose in the abstract and experimental film of the early 20th century and continued through to the work of the 1960s and 70s. These same questions, with the added dimension of interactivity and thus of dynamic transformation and navigation through the structures, arise in contemporary computer-based visual abstraction. The history of Early Abstract or Absolute Film and its relationship to the Avant-garde, Dada and the Futurists, including The Futurist Cinéma[25] are not addressed here.[26] Instead the focus is rhythmic structure with examples from Fischinger and Whitney. Oskar Fischinger's Studie nr. 7 (1931) was presented in Mathematical Visualisation in the Arts[27] at vizNET 2007 in juxtaposition to the synchronously generated sound and image of *chdh*[28].

In terms of the aesthetics of Fischinger's films of that period, [...] their formal principles rest heavily on the musical analogy: one kind of shape corresponding to one kind of sound, another to another, one kind of movement corresponding to one development in the melody, and so on, repeats in the music being followed by repeats in the animation. [...] The films, even when viewed 'silent' have a clear musical structure: interweaving linear forms, explosions and climaxes, repeats, partial repeats and variations. The films of this time, all the so-called Studies, are best generalised as being a form of abstract choreography, the dance of abstract elements.[29]



[30]

[...] These rectangles are not forms, they are parts of movement. The definition of form refers to one's perception of the formal quality of a single object, or several single objects; but, when you repeat the same form over and over again and in different positions, the relationship between the positions becomes the thing to be perceived, not the individual or single form. One doesn't see the form or object anymore but rather the relationship. In this way you see a kind of rhythm.[31]

When Fischinger arrived in Hollywood, a second generation of artists discovered Visual Music through him. The brothers John and James Whitney encountered him already in 1939, at an art gallery showing his paintings, where Fischinger also screened several of his films. This "influence" contained both positive and negative quotients, since the teenagers both resolved to devote themselves to making Visual-Music, but felt that Fischinger's own films were to some extent old-fashioned in their use of European classical music and tight choreographic synchronization. This inspired them to attempt to create new kinds of music (their pendulum-generated sound) and "modern" imagery that captured a sense of neon, motors and other contemporary phenomena (in the Five Film Exercises, which received a prize in Brussels in 1948, when Fischinger was awarded the Grand Prize for Motion Painting). John and James worked separately, and after the Exercises diverged considerably. John pursued a new technology that could produce both sound and visual imagery "in real time", something like a visual-music piano. This led him to experiment with an oil-wipe screen that could parallel a jazz improvisation, as in Hot House from 1952. John then pioneered computer graphics, and developed a motion-control camera system, which his brother James would use in 1963 to film his Lapis, shooting his hand-drawn dot patterns in multiple exposures that could make 1000 dots from 100, forming intricate mandalas.[32]

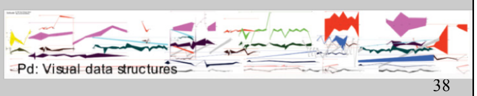
To [John] Whitney, such a direct, synesthetic mapping of music's most basic parameters (pitch, loudness, and so forth) failed to capture the expressive vision of great works of music, which, to him, depended more directly on multidimensional interplay of tension and resolution. Moreover, he advocated an approach in which animation, instead of being a direct representation of music, corresponds to this higher level of aesthetic intention, creating what he termed 'complementarity'.[33] *[…] More particularly, Whitney discovered that if he set a large number of elements into repetitive motion such that the motion of the second was two times the speed of the first, the third three times the speed of the first, and so on, the animation that would result would demonstrate beautiful patterns of symmetry at points corresponding to the same ratios that define musical consonances.*[34] *[…] Whitney intended differential dynamics to provide a set of principles which could be applied compositionally in many different forms, rather than algorithms for visualization.*[35]

The flow of multidimensional rational particle systems[36], arrived at through the process of mathematical visualisation, is not unrelated to the above. Whitney used points of integer frequency, whereas rational particle systems use highly interwoven[37] points of rational frequency.

In summary, diagram block 3 addresses rhythmic visual abstraction. The intent of the works therein differs, as does their technology of construction. The focus on spatially or mathematically defined rhythmic structure relates it to diagram block 1, Evolution of western musical notation as a visualisation, and diagram block 5, Topological structure – rhythm and procedural sound/motion.

4. Pure Data: Graphical Data Structures, Simultaneous 'Display' of Sound and Image
Graphical data structures now enable simultaneous composition of sound and image.
Diagram block 4 introduces the graphical data structures of Pure Data, a visual programming dataflow environment, which enables simultaneous dynamic 'display' of sound and image in definition of the output of structures, or 'abstractions' created within it. Pd was originally developed for audio synthesis, GEM adds OpenGL based 3D graphic for Pd, and pmpd is a collection of objects for physical modelling. Introducing realtime graphical data structures for displaying musical data in Pd offers the possibility to place equal emphasis on the sonic and visual output. Image need no longer be restricted to displaying the actual musical data, but can be employed to map or express other aspects of the 'abstraction' from which it is synchronously generated with the sound.

"Pd is a graphical programming language developed by Miller Pukette in the 1990s for the creation of interactive computer music and multimedia works."



[38]

Pd (Pure Data) http://crca.ucsd.edu/~msp/Pd_documentation/x2.htm#s9
"Pd is designed to offer an extremely unstructured environment for describing data structures and their graphical appearance. The underlying idea is to allow the user to display any kind of data he or she wants to, associating it in any way with the display. To accomplish this Pd introduces a graphical data structure, somewhat like a data structure out of the C programming language, but with a facility for attaching shapes and colors to the data, so that the user can visualize and/or edit it. The data itself can be edited from scratch or can be imported from files, generated algorithmically, or derived from analyses of incoming sounds or other data streams[39]."

GEM (Graphics Environment for Multimedia)
http://gem.iem.at/documentation/manual/manual/referencemanual-all-pages
"GEM was originally written [ ] to generate real-time computer graphics, especially for audio-visual compositions. [ ] GEM is a collection of externals which allow the user to create OpenGL graphics within Pd, a program for real-time audio processing. [ ] Because GEM is an add-on library for Pd, users can combine audio and graphics, controlling one medium from another.[40]"

Extending Pd http://puredata.info/
*"It is easy to extend Pd by writing object classes ("externals") or patches ("abstractions"). [ ] Recent developments include a system of **abstractions for building performance environments**; a library of **objects for physical modelling**; and a library of objects for generating and processing video in realtime[41]."*

pmpd (Physical Modelling for Pure Data) http://drpichon.free.fr/pmpd/
*"pmpd is a collection of objects for use with pd. These objects provide real-time simulations, especially physical behaviors. pmpd can be used to create natural dynamic systems, like a bouncing ball, string movement, Brownian movement, chaos, fluid dynamics, sand, gravitation, and more. It can also be used to create displacements thus allowing a completely dynamic approach of pd computing. [ ] These objects are designed to be used with pd.
[ ] In the provided pmpd examples, GEM is used for the movement visualisation[42]."*

This is effectively a new form. It is not an evolving response in the image triggered by an event in the sound, or an evolving response in the sound triggered by an event in the image, which is often the case for so-called 'responsive environments'. The synchronisation of sound and image occurs at a 'calculation at each timestep' level. Composing in this new form is an emerging challenge not unlike that faced by the composers of the 11th – 14th centuries.

The next three diagram blocks address different aspects of examples in the Pd-GEM-pmpd environment: topological structure and procedural rhythm, composing and performing live with virtual physical objects, and responding to the instability of the environment, whether it be artistically or mathematically.

5. Topological Structure: Rhythm and Procedural Sound and Motion

Topological structure and physical modelling can create a rhythm whose steps of construction involve implementation of a sound-image creature. Diagram block 5 addresses the procedural generation of rhythm based on a constructed abstraction. Two examples are given. The first, a *rhythm creature*, created by Cyrille Henry in Pure data, the second, a creature from the yet to be released computer game *Spore*, shown in a demo video at the vizNET 2007 event. The first creature is relatively transparent with its (topological) construction visible in pmpd. The second creature is commercial; the model for the family of creatures will not be provided with the game. Nevertheless it is evident that parameters from its geometric and topological structure have been used to determine its (rhythmic) gait.

In pmpd[43], the physical modelling environment for Pure data, the two basic building blocks are masses, and links connecting the masses. Masses act as point particles; they have no volume. Individual masses can be made to interact with an ambient environment or mutually interact when they come within specified radii of one another, neither of which requires links. Masses can also be coupled together with links to create a topological structure. *A structure and its components can be modelled according to the topology, that is a defined set of interactions: different dynamic systems can be modelled using different topologies.*[44]

The patch for the 'rhythm creature' is included in the Pd browser documentation under examples / pmpd / 12_excitation. Its behaviours are determined and constrained by a number of factors including its topology, the values assigned to its masses, and the rigidity and damping assigned to its individual links. By opening the subpatch, *pdstructure*, the visual construction of this object can be seen, visually.

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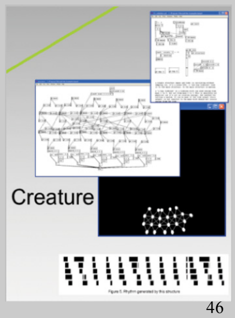

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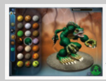

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It is composed of 23 masses and 48 links and exhibits a line of horizontal symmetry through its right most mass. There are two rows of masses below this line. The lowest 5 masses are each connected to an oscillator. When the position of one of these masses satisfies a certain condition – when its y coordinate is the same as that of the floor – the oscillator connected to this mass emits a sound. The user can interact with it exerting a further external force up, down, left or right. **The creature is a virtual instrument designed to generate a rhythm**; it is in constant movement or excitation due to the choice of a non-physical value for a parameter:
It is possible to choose non-physical values for pmpd parameters. For example, you can set damping to a negative value, which mean energies creation. This is not physical and can lead to instability or saturation of the model, but can be useful for artistic reason.[48] *The main rhythm corresponds to the structure moving by itself while the internal deformations of the structure create the small rhythm variations.*[49]

The second creature example is from the computer game *Spore*[50], not yet released. *Spore* has a number of phases: cellular, creature, tribal, civilisation and space. The screenshot shown above is from the creature editor in the creature phase. This is an *outside game time* part of the game where the player is able to design, not just the surface appearance, but the movement or gait of the creature, based variations of its toplogical and geometrical structure defined by the number and position of body parts, and by relative scaling and orientation of these components. *At E3 2006, Wright showcased the creature editor. It allows the player to take what looks like a lump of clay with a spine and mold it into a creature of their choosing. Once they are done molding the main form, they can then add legs, arms, feet, hands, eyes, mouths, decorative elements, and a wide array of sensory organs like antennae. Many of these parts affect the creature's final abilities (speed, strength, diet, etc.), while some parts are purely decorative. Once the creature is designed to the player's satisfaction, they can paint the creature using a large number of textures, overlays, colors, and patterns. After the player feels their creature is complete, it can be tested in a small enclosed area, showing how it would move around, fight, interact, etc.*[51]

To some extent this second example relies more on satisfying predictive models, (it has to work) and is thus perhaps closer to scientific simulation, but it may be constrained quite artificially by other factors at other levels of the game. These editors are effectively used to **design a structure or form that** (one hopes) **will enact specific game strategies**. As the game has not yet been released, it is not known how direct the mappings are between choice of shape of body or body parts and behaviour, and whether or not some level of randomisation is introduced in the process.

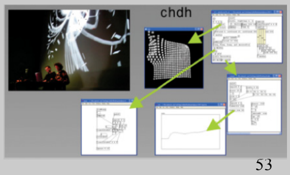
In summary, diagram block 5 addresses procedural rhythm obtained in real time from topological or geometrical structure. It can be juxtaposed against diagram block 1, the evolution of rhythmic structure of early polyphony, and with diagram block 3, abstract film based on rhythmic structure.

6. Playing (and Performing) with Abstractions

Real-time performance with simultaneous sound-image instruments is demanding of both composers and audience in a shift not unlike that faced by early polyphony.

chdh developped a body of work from theoretical principles which makes possible the creation of a live, real-time, audio-visual performance based on about thirty instruments. These instruments are made of generative, stochastic or physical modelling algorithms and each of them control a sound and a visual. With mathematical algorithms as well as physical modelling for the real time generation of control data of an audio/video synthesis, chdh brings a new vision of the data-processing use of tools in musical creation.

[52]



[53]

The use of instruments having an audio component and a video component, controlled by the same parameters, allow an effective management of the audio-visual relations. This project required the development of a virtual world made of abstract creatures, more or less autonomous. During a performance, chdh plays with these « instruments », in order to make them react both visually and aurally. Two musicians, connected through a network, interact on the same interface with motorized MIDI faders. Each instrument, or « patch », can then be played by one of the two musicians or both simultaneously. They handle the instruments by using an abstract layer which modifies the parameters of the algorithm. Each algorithm then creates data used for the synthesis of video and sound, giving a strong cohesion between the two media. Aesthetic of video and sound is minimalist: sines, diracs and noises interacts with cubes, spheres and other 3D primitives forms in a black and white environment. The different instruments make possible the creation of a solo / accompaniment musical structure; to let the audience discover the intrinsic bonds between image and sound as well as to create a polyrythmy by playing on the visual and sound space granted to each instrument[54]

In the video of Improvisation[55] instruments are first introduced separately and then combined in an increasingly complex structure. The gradual introduction reveals a clear audio-visual grammar and is similar in strategy in to some abstract film: *[...] their formal principles rest heavily on the musical analogy: one kind of shape corresponding to one kind of sound, another to another […]*[56]

However the choice of mappings is highly non-trivial:
[.] Only few input parameters can generate lots of different data flows (a musician can play with only few control parameters on the whole structure, and then generate lots of data to control any audio synthesis). Moreover, the control parameters are intuitive because they correspond to physical values. […] Another important specification is that all data coming out of the physical model are not independent. The relation between them can be adjusted regarding the topology of the structure.[57]

In the example patch […], two-dimensions of user input data control different part of the patch. First, a [pmcloud 2d] object is used to generate two different two dimensional data streams. These two streams are used to control two instances of the same subtractive synthesis algorithm. This audio material is sent to separate audio delays looped in a Karplus-Strong topology. The delay times are controlled by the output of a [repulsor 2d] object. The (0,0) point corresponds to a singularity in the audio process (zero delay will cause a null loop), but also in the pm object as it acts like a repulsion of the output mass. Finally, the amplitude of the sound coming from the Karplus-Strong loop is modulated by a pmattractor 2d] object. When user does not send any data, the envelope goes to zero, and the sound stops. This very simple instrument offers a complex interaction with the sound synthesis thus allowing for more expressive audio exploration from the musician.[58]

The Mapping Library for Pd is a fledgling library of mapping primitives with the aim of cataloging existing mapping methods. […] As part of the process of generating a catalog of fundamental building blocks for mapping, we are creating a software library of mapping methods based on both research and real world projects.[59] [60]

In summary, diagram block 6 addresses virtual instruments created using pmpd, questions of mappings and musicians' live performance, and communication of these audio-visual relations to an audience.

7. Enabling and Constraining: Instability of the Compositional Environment

Mastering the new compositional environment leads to reconsideration of other disciplines that new environment, mathematical structures, being the case in point. This diagram block looks at applying environments from the visual sonic and performing arts to modelling structures in mathematics, both abstractly and physically. The instability of the audio synthesis environment, demonstrated in the string and corde examples shown from Pure data, forced an iterated reconceptualisation of the mathematical structure to be modelled.

One relatively simple object used in pmpd is the corde or string. The patch shown in the diagram block is the elastic string example given in the pure data pmpd examples, examples/pmpd/02_string.pd This example produces sound output but its visualisation occurs only in the sliders in the patch itself. Moving the first or last slider demonstrates the propagation of a wave through the string.

The example 05_corde2D.pd demonstrates a corde of masses fixed at both ends. The example 50_scann_synth.pd again shows a corde, fixed at both ends, but this time the links have been visualised along with the masses. The patch contains sliders for the rigidity and damping of the links.

Playing with the rigidity and damping can produce unstable structures such as those shown in the second image set in the diagram block. A video of this instability used as a compositional tool by chdh (Corde[61] 20061111) demonstrates the liaison between sound and image across these instabilities.

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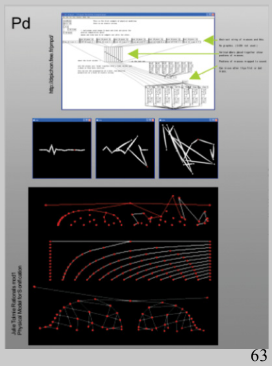

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You should also take care while changing parameters like rigidity. This can lead to energy creation or lost, depending of the deformation of the structure.
The most important problem using physical modeling is the instability.[64]
In the visual dataflow environment, left-right and top-bottom symmetric constructions are not symmetric in a 'physical' sense. An attempt at physical modelling of a binary tree structure through rational points, initially down to a denominator of 13, led to a stable structure on the left and a highly unstable structure on the right (see the top structure in the third image set); theoretically identical halves were behaving very differently physically in this environment. Tuning or stabilising the system was one possible strategy. Reconceptualising it was another.

By remodelling the vertical binary tree structure as an excited 2D membrane of masses and links, with transverse links included for stability, it was necessary to choose how these transverse links would be defined. Starting with the Harmonic Sequence 1/1, ½, 1/3, ¼, … successive 'rows' of masses were connected as shown in the middle structure in the third image set. This operation was then performed from the other direction: 0/1, ½, 2/3, ¾, … , again for successive 'rows'. Links were put in without connecting their responses to the masses, thus temporarily fixing the masses, again for stability during construction. Next 'equivalent' masses, such as 2/4, 3/6, 4/8, .. were made invisible and the vertical links of the binary tree structure were implemented through the appropriate remaining masses. Finally links from invisible masses were made invisible and these masses left fixed. The remaining visible masses and links had their responses connected and the structure started to respond to the excitation of its visible masses along visible vertical and transverse links.[65]

Varying parameters for rigidity and damping according to the type of link and its associated masses, and varying the value of the mass according to the denominator of the rational, while scaling the structure up, emerged as new directions for visual investigation.

In summary, working within the constraints of an environment developed for audio synthesis led to the creation of a different physically based model to that originally envisaged for a mathematical structure. It provided the motivation and opportunity to remodel. The process was somewhat akin to puzzle solving where the primitives available in pmpd were masses and links, and the mathematics suggested, rather than determined, visibility and allowable links between masses. Other solutions are possible.

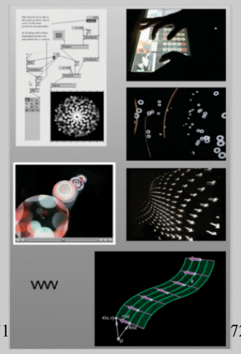
8. Enabling and Constraining: Spreads & Multiple Projection, Immersive Visual Abstraction
Parallel developments in high-end 3D graphics are enabling 3D abstract film concerned with pure visual abstraction without narrative.

vvvv[66] is a toolkit designed to facilitate the handling of large media environments with physical interfaces, real-time motion graphics, audio and video that can interact with many users simultaneously. It uses a visual programming interface, providing a graphical programming language for fast prototyping and development. vvvv is run-time only. There is no edit mode.

Spreads
A defining feature of vvvv is the handling of multiple objects with spreads. Individual values in the spread are called slices. *Spreading is an abstraction that refers to the act of distributing different values across a set of objects. [ ] vvvv contains many spread generators that make it easy to program complex behaviours for a large group of objects.*[67]

The three screenshots top right in this diagram block are from the video of the Sanch live set in Heilige Liga club in Nurnberg[68]. The second and third screenshots (and the video) demonstrate the use of spreads.

Spreads of spreads can also be created. Perusing the list of node reference by category[69] gives an indication of the type of spreads available.

[70] [71] 

[72]

Boygrouping
One of the things vvvv was originally designed for is the possibility to control any amount of render computers from a single server to create multi-screen systems or seamless multi-projection setups.[73] This technique is called 'boygrouping'.

A video of a performance, again by Sanch[74], at the Festival Paysages Electroniques[75] in Lille demonstrates a multi-screen immersive setup. Multi-screen still images indicative of a live visual set are presented on his promotional page, where he states his emphasis on a *realtime 3d abstract / graphic live set , there is no messages , no story , it´s a study around esthetic / mathematic and motion* . [ ] *I´m always researching about mathematic formula , scientific simulation , to generate new shape , new motion , in the best quality and speed as possible.*[76]

These examples show high-end 3D visual abstraction in active use and emergence in clubs. There is a return to abstraction on the part of a generation and conventions for reading and authoring these works is developing, albeit tacitly. Awards are being given:

The "Visual Music Award" is designed to honour young creative talents for artistic visionary music visualisations in the spirit of "paintings in time" and "symphonies of light and sound" or "visual music". The award honours visionary experiments of the avant-garde of the "Absolute Film" movement, for example by Oskar Fischinger, who anticipated since the first half of the 20th century with their visual compositions the aesthetics of todays music-video clips.[77]

Novel Display Technologies
The use of seven inflatable motorised cones as projection surfaces[78] is documented in video, an outcome of Hyperwerk[79] at the School of Art in Basel.

The future impact for science and engineering and of a generation focused on 3D dynamic visual abstraction should not be underestimated.

- Mathematical formulas and objects, and computational processes & data structures, are appropriated therein as compositional tools.
- Ambient data streams are combined and perceptualised in sound and image.
- Fast visual association within sequences of diverse visual material, often with multiple overlays, is the norm.

An historical timeframe is likely to be necessary before anything like mastery of this environment is achieved, but it is already in the making.

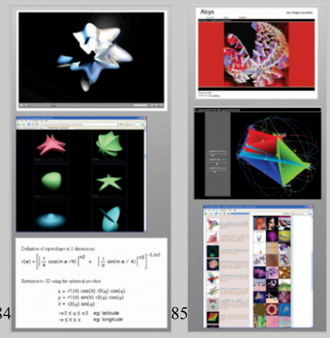
9. Appropriating Mathematical Structures and Known Objects

Mathematical structures are employed in much of the visual abstraction and interactive responsive environments. In turn the environments are enabling the mathematical (learning) objects to approach artworks in themselves. Mathematically defined objects and processes are frequently used in the creation of audio-visual abstraction. In particular, some artists use scientific visualisation resources, including those of a mathematical nature, directly.

Mathematical resources and visual abstraction
Mathematically defined objects or processes are frequently used in the creation of audio-visual abstraction. Paul Bourke[80] of the University of Western Australia has maintained an extensive site of scientific visualisation and mathematical resources for more than ten years.

All of his pages on mathematical objects include one or more visualisations. The page on Surfaces and Curves[81] is especially popular. [An exercise[82] based on Paul Bourke's The Blob surface, can be viewed on tonfilm's blog.]

One example on this page is the **Supershape in 3D**[83] based on equations by Johan Gielis and intended as a modelling framework for natural forms.



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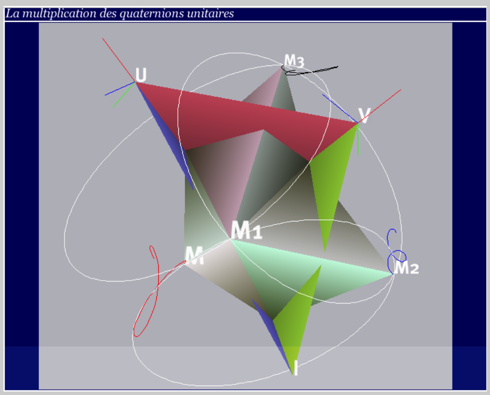
Supershape
The equation for the 2D Supershape produces a value for a radius that depends on an angle and another four parameters. The first of these parameters corresponds to a type of frequency m, the others correspond to the type of root taken n_1, or the type of powers to which two different components are raised, n_2 , n_3.
In 3D, there are two such radii, each depending on four parameters that can be individually varied. In other words, two 2D supershapes are 'combined' to make a 3D form. A family of related forms can be obtained by varying these (eight) parameters. Bourke's Supershape in 3D page gives more than fifty different examples, including for non-integer values of the frequency.

3D supershape in vvvv
A animation using the fast fourier transform data of a song to create the parameters for an animated family of 3D supershapes was created in vvvv by tonfilm[87]:
For this little project the FFT data of a 3 minute song was recorded with 60 fps into more than 10000 text files, where each text file got a timestamp in its file name. During the rendering the text file with closest timestamp to the current rendering time was read and processed into parameters of a 3D-object which is based on Johan Gielis superformula[88]

Quaternions in Processing
The visualisation of quaternions and their relationships to computer graphics is generally considered difficult to understand[89]. This site by Alcys, *les images sensibles*, is included because of the elegance of the quaternion learning objects. In *La multiplication des quaternions unitaires*[90] (Image: The multiplication of unitary quaternions), the object is in continual movement tracing its path at three points. What is notable in this particular example is that Processing[91] is employed as drawing machine[92], one of the main reasons it was authored for artists in the first place [93]. (See next diagram block.) *HOT BALL: utiliser les quaternions*[94] (using quaternions).



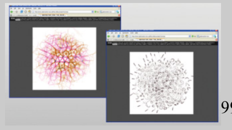
In summary, the two examples given in this diagram block juxtapose artists using mathematical or scientific visualisation resources directly, and science and engineering using artistic environments directly. The directness and transparency of these particular maps enable us to see that each has taken something of the sensibility of the other into the work created. tonfilm's work can be understood as a path through Paul Bourke's Supershape in 3D page and Alcys' *quaternions drawing themselves* in Processing is exquisite.

10. Responsive Visual Environments: Rationale for Processing, Early Works

Early recent works in visual abstraction attracted a number of retrospective exhibitions and writings whose content is interesting to juxtapose against the evolution in the short timeframe of just four years

Processing
Casey Reas' discussion of the Processing[95] environment, at least since 2003[96] [97] is framed by the following four statements: **software is a unique medium with unique qualities; each programming language is distinct material; sketching is necessary for the development of ideas; programming is not just for engineers.**

Processing was showcased at Ars Electronica in 2003 and won a Golden Nica Award in 2005. Dynamic form, gesture, behaviour, simulation, self-organisation and adaption were included in its discussion in 2003 and it is informative to revisit Reas' early work *Articulate*[98] in the ABSTRACTION NOW Exhibition held in Vienna during the same period: *Structure emerges through the interaction of autonomous elements, /Click the mouse to restart /Press the space bar to change representation*. The first representation draws leaving a continual trace. The second erases its trace after a given number of timesteps and instead animates worm-like forms. Toggling between the two reveals aspects of underlying structure.



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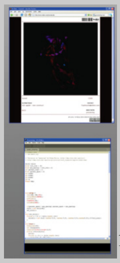


100

Processing is open source and extensive resources are available on the Processing website. *Processing, A Programming Handbook for Visual Designers and Artists* by Casey Reas and Ben Fry was released 28 September 2007: *Processing relates software concepts to principles of visual form, motion, and interaction. It integrates a programming language, development environment, and teaching methodology into a unified system. Processing was created to teach fundamentals of computer programming within a visual context, to serve as a software sketchbook, and to be used as a production tool. [ ] The Processing language is a text programming language specifically designed to generate and modify images.*[101]

ABSTRACTION NOW[102]
Lev Manovich, compares abstraction now to early modernist abstraction in his review of the exhibition ABSTRACTION NOW, *Abstraction and Complexity*[103]. He characterises the online section of this exhibition (still available online[104]) as *animated or interactive works that begin with an empty screen or a few minimal elements that quickly evolve into a complex and constantly changing image*[105], in contrast to the reduction of the visual experience in modern art.
The aesthetics of complexity which dominates the online works selected for the show ABSTRACTION NOW *is not unique to it; scanning works regularly included in other exhibitions such as Ars Electronica 2003, or Flash Forward Festival demonstrates that this aesthetic is as central for contemporary software abstraction as reductionism was for early modernist abstraction. This is the larger ideological importance of software driven abstraction – at its best it quite accurately and at the same time poetically captures our new image of a world seen as the dynamic networks of relations, oscillating between order and disorder, always vulnerable and ready to change with a single click of the user*[106].

Norbert Pfaffenbichler[107], in his review, From *Panel Painting to Computer Processing*, *Notes on the Phenomenon of Abstraction in Contemporary Art*[108] comments *The abstract representation always refers to itself and hence to the conditions of its own existence. In other words, what it negotiates is the conventions and, as a result, the states of representability in the various (visual) media*[109].

He further reflects on interface differences between illusionistic and abstract works and on the evolution entailed by emphasis on user input: *The possibilities offered by interactive and reactive applications are in principle independent of whether their visual elements are illusionistic or abstract. As conventional user interfaces are normally absent from non-representational applications, navigation itself becomes a component of the composition. The existing conventions relating to the utility of digital data and the logic behind them are thematized and subjected to experimentation. The events and modulatory parameters that can be triggered as a result are often unpredictable for the user. Trial and error is the only method available for eventually comprehending a complex work. The moment of the work's intended mutability through the user's input represents a paradigm change in artistic production. Artists now provide a certain framework for action and define the aesthetic parameters within which the user can operate; the work itself is a variable*[110].

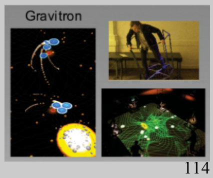
Maths in Motion[111] Mathematische Konzepte im experimentellen Film und Video
A film festival/series was held in conjunction with the ABSTRACTION NOW exhibition. 100 abstract and experimental works were shown, organised in ten themes: CALCULATED MOVEMENTS, THE PROCESS OF ABSTRACTION, STRUCTURAL LANDSCAPES, VEKTOREN & KOORDINATEN, ZUFALL, CHAOS UND ORDNUNG, STRUKTURIERTE DOKUMENTE, DIE LIEBE ZUR GEOMETRIE, SEE THE RHYTHM!, DIE GEFORMTE ZEIT, ELECTRONIC LINGUISTICS.[112]

In summary, this diagram block looks at software based abstraction (and complexity) somewhat retrospectively, from the viewpoint of 2003. It is useful to have access to a sequence of views 1995, 2003, 2007, where the first two are separated by eight years, and the last two are separated by half that amount.

11. Playing (and Performing) with Data

Multi-scale interactive situations attempt to integrate multiple physical installations, simulations, and user behaviour to create an emergent tuned complex system. In this process, features extracted from data streams and real or virtual environments are appropriated as compositional elements.

Time's Up[113]
The user is central in Time's up's **Sensory Circus**, a multiscale interactive situation, integrating numerous installations of different temporal scales across the lifetime of the exhibit. Locally mathematical visualisation and sound are embedded alongside physical architectures and physical interfaces. Globally large-scale motion sensor data logging, analysis, mapping, and visualisation aid in on the fly interactive game design and assignment of meaning to emerging perceivable patterns.



[114]

Gravitron and The Lightning District are two local installations in the **Intergame Balance Space**:

In **Gravitron**[115] *By the use of one of the input devices the user is able to affect the gravitational field. Shortly after an actor clambers on one of the input devices, she/he lowers the gravity around her/himself with the exercised pressure of her/his mass, which leads immediately to a disturbance of the orbit of the circling planets and hurls them from their centric position. [ ] A circular or oval area, minimum 5m in the diameter, accessible over six different inlets; a floor projection, bordered with a loudspeaker system and six accessible input devices build the game scenario of Gravitron. […] The strength of the gravitational field is not only acoustically and visually perceptible; the passing planets also attract to the control platforms physically via force-feedback.*

In **The Lightning District**[116], *projected upon the ground, a flexible, reactive grid reacts optically and acoustically to the movements of the visitors. […] the fields change colour upon contact and begin to rotate. Simultaneously a sample or a tone is played. A surround sound system enables the positioning of acoustic elements around the playing area.*

Over the whole environment there is a global system that manipulates the parameters of local interactions, the perspectives and other visualisations. The summed effects of all actions and reactions in all the local interactions in the total space feed into a collective system that reacts to this massive data input in various ways. This system attempts to order, categorise, analyse and perhaps even control the localised interactions and to pass on this analysis to be visualised in certain spaces that are set apart from the localised interactions. This global 'mood' (mood is to interaction as climate is to weather) changes slowly over longer time frames as a kind of learning system and becomes apparent only after spending some time within the space[117].

For example, globally, *as a part of the Proto Cognitive System, the Paranoia Engine scans inside Sensory Circus for foreign bodies and, depending on the mood of the whole system, it bothers, guides, tracks or plays with them. The Paranoia Engine uses lots of cameras as input-devices and even more moving spotlights spread over the whole situation and sound to output to the situation. Inside Sensory Circus it should become clear that one moves inside a cognitive system. We use the Paranoia Engine to give a feeling of observation and - more important - to communicate and transport the mood of the system to the visitors.*[118]

In his discussion of defining *the relationships of sensor data to actions to allow a visitor and the system to co-structure the behaviour of a mutually defined space*[119], Boykett speaks of the moment when the world building role of the puppeteer is reimplemented in software and circuits: *The simplest end of these world-rules starts off with a reaction: if X then Y, push button – ring bell; turn knob – adjust light. Once a process starts to have an internal state, complexity is added: the knob controls the rate of flashing of the light, the button adds a beat in a sequencer, the lever offsets the pneumatic cylinder. Before we know it we have rolling patterns of light, sound and action feeding from the multiple control mechanisms enabled by the sensor systems, levers affecting tones and rhythms, dials adjusting tempos and intensities, camera-based body tracking systems allowing subtle actions in the space to effect broad sweeps of change in the audiovisual environment. Somehow the visitor is no longer causing reactions, rather the entire system takes off on its own and the input systems available allow only general changes to timbre and the direction of development; the world has a mind of its own and the puppeteer can only affect its mood*[120].
However interaction begins at the local level where installations function as small interactive environments, often formulated as games with short term clear goals requiring physical action: *[…] play at a local level must be intuitive and simple to grasp. Once this interaction has been achieved, we can begin to introduce longer term relations between events. Interlocal interactions are a direct way to underscore that the total environment is not just an exhibition of items but that the items and their interrelations build a coherent world.*[121]

In this process, features need to be identified and extracted from data streams and real or virtual environments, and redeployed as compositional elements. Time's Up's research activity in this area includes Data Ecologies[122] *a symposium series investigating the connections between data systems, processes, physical systems as well as constructed and natural ecologies.*

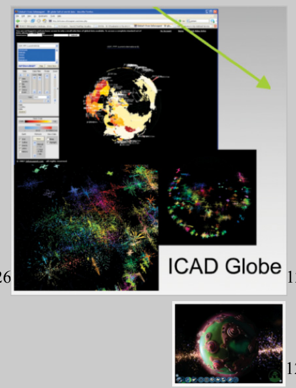
In summary, this diagram block addresses the creation and tuning of multiple data driven mixed reality worlds using visualisation, sonification, lighting and physical and non-contact sensor interfaces. It is a work at the theatre/game interface, playing with the data streams to create a coherent whole. The intent is not objective analysis of the data streams but their remapping into a user-robust evolving system.

12. Appropriating Aspects of the Dataset as Compositional Elements

The resulting transformations of maps can be conventional and easily read, or may be designed to provide underlying structure without being individually identifiable.

Global-i[123] *is a 3-dimensional interactive globe that displays information about the world in your browser. The Earth can be rotated and inspected and displays can be changed to see information in the most appropriate form. Colours, cone sizes and cone colours all represent the same information in different formats - each has a use in finding useful information quickly.*

This commercial globe view of world data[124] closely respects existing conventions. For example it transposes the bars of bar charts to cones orthogonal to the surface of a sphere[125]. Viewing the cones directly from above, the area of their cross-section gives their magnitude. We look now to less conventional visual and auditory display of world data.



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Global Music - The world by ear[129] was a concert of sonifications based on sociological global data at the Institute of Contemporary Arts in London.
Call for sonifications[130]: *As a common reference point, we have compiled a basic dataset that includes 190 countries with geographical data (capital location, area), population numbers, and is extended by several basic social indicators such as GDP, access to sanitation and drinking water, and life expectancy. Using this reference dataset is mandatory: All submissions must include countries, capital locations, population and area data. This dataset can be extended with extra dimensions, and in fact this is strongly encouraged; the extensions included in the reference dataset (such as GDP) are given as examples only. [ ] The countries/regions represented have very different sizes and population numbers; one result we hope for is that very different strategies for representing these frame dimensions will be applied in the submissions.*

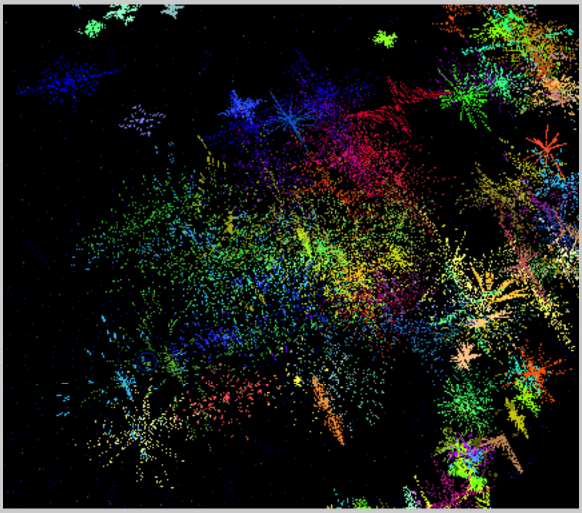
Sonification or Musical composition?

Depending on one's perspective they can be listened to as sonifications or as pieces of music, Bennett & Hogg commented about two sonifications for the ICAD 2004 concert dataset, ***Listening to the Mind Listening***. *Both pieces lie at the Ars Musica end of the continuum being designed as performance pieces for a concert, yet they are also sonifications of a 15-dimensional dataset*[131]. We meet *[] works that possess to a greater or lesser extent attributes of both musical composition and non-musical sonification. The really interesting point is where it is hard (or even impossible) to discern the origins of a piece: composition or sonification. This implies that the distinction between the two pairs of indexicality polarities – musical (tonal) sonification & abstract music, and non-musically sounding sonification & concrete music – become blurred. By shifting perspective, we can transform the way we listen so that an unmusical sonification becomes a piece of musique concrete, and a musical sonification becomes a piece of musique abstraite (and visa versa).*[132]

The following two pieces demonstrate very different strategies for transforming world data to sound. These sonifications are available on the Proceedings section of the ICAD 2006 website[133], along with short papers on their methodologies and/or structure.

In ***Navegar é Preciso***[134] by Alberto de Campo and Christian Dayé, a sonification based along the path and timing of the 1519-1522 voyage of Magellan was constructed:
Every country is represented by a complex sound stream composed of five resonators; all parameters of this sound stream are determined by (a) data properties of the associated country and (b) from the navigation process, i.e. the ship's current distance and direction towards this country. At any time, the 15 countries nearest to the route point are heard simultaneously.
[…] The mapping choices in detail are
Population density of country: density of (random) attack triggers in the sound stream
GDP per capita of country: frequency center (and most prominent resonant pitch) of the stream)
Ratio of top to bottom 10% percentile of incomes: pitches of the outermost two 'satellite' resonators
Ratio of top to bottom 20% of incomes: pitches of the inner two satellite resonators
Water access: decaytime (short tones mean less access (drier), long tones mean more access to water)
Distance from the navigation point: volume and attack time (far away streams are softer and more 'blurred')
Direction: the spatial direction of the stream in the loudspeaker rendering (North is kept constant)
Ship speed, direction, storm and calm: spatial direction, brightness, intensity, and liveliness of wind-like noise

Construction of ***Schnappschuss von der Erde***[135] by David E. Spondike takes places in two phases. Sonifications are made of interesting combinations of three data categories, based on the following rationale: *Rising and falling melodic lines, crescendo and decrescendo are useful in music composition, but they are not sufficiently complex to sustain aesthetic interest. However, what has been generally disregarded as being unable to provide useful information, the zero-correlations, are exactly the place to look. These data sets are not uniform in their distribution. There are places in the graphing space where dots are more likely or less likely to accrue. […]Since creating the sonifications with the algorithm essentially meant typing in three names and executing the code, it was like a bead making machine. […] Results that were aesthetically pleasing were kept. Those that were not were discarded. Fifty (50) sonifications were retained in the final pool. A total of fifteen different combinations of data ended up in the final composition.*



ICAD Globe Abstract visualisation: From the global world dataset for the ICAD 2006 sonification select the geographical data: capital location, area, and population and append the first social indicator GDP. Construct a visualisation mapping GDP, population, area and their ratio/frequencies as a visual form. For each country, locate this form at the position of the capital. View 190 countries as abstract visual forms executing independent motions on a rotating globe.

The mapping: GDP, population and area have a wide range of values across the 190 countries given. Take logs of these values to reduce the range. These will become radii of three (circular) dimensional particle systems. Effectively particles will be travelling in three circular directions.

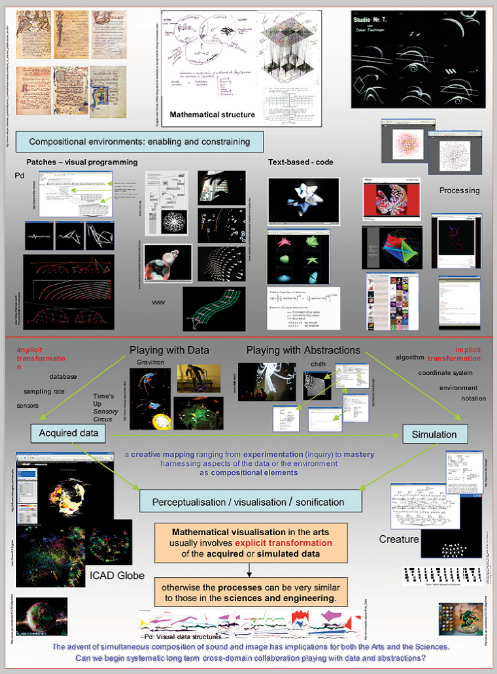
Next take the ratios GDP/pop GDP/area and pop/area. Again take logs to reduce the range. These values will become the frequencies of the three (circular) dimensional particle systems. Particles can travel in these three circular directions at three different frequencies. Because the directions are circular, or cyclic, alignments will occur from time to time in one, two, or three dimensions.

'*Countries*' as these visual forms are juxtaposed spatially according to the location of their capitals. Depending on parameters chosen their radii may overlap. The larger 'countries' may obscure the smaller ones (in GDP, population, or area). Yet each 'country' will exhibit unique three cyclic dimensional behaviour according its GDP, population and area. When the particle systems of larger countries pass through rational alignments, the smaller ones they obscure are revealed. There is no particular 'reading' of the data intended in this visualisation. Yet there are patterns that emerge. 'Countries' who share similar sets of ratios of GDP/pop GDP/area or pop/area will exhibit similar cycles in those dimensions.[136]

Spore planet
The planets in the space game of *Spore* are also globes displaying data, of sorts. The planets and their lifeforms are procedurally constructed from systems evolved by other players. It is easy for us to identify and interact with the mimetic world-like aspects of these structures; their stylised representation is essentially conventional.
An interesting development would be if, given sufficient time and exposure, we come to think of these increasingly procedural game objects as ambient visual forms of data such as in the example above. And if, given an historical timeframe, we are able to 'listen to' such procedural forms as both **sonifications and pieces of music**, metaphorically speaking of course. If so, the representations thus developed are likely to be very different to those we read with today's conventions.

In summary, this diagram block addresses display & analysis vs appropriating aspects of a system or data as compositional elements.

Discussion
Returning now to the visual juxtaposition / spatial configuration of the slide(s):



Vertically, consider the slide(s) as four rows:
The top row contains examples from the historical and recent past.

The second row contains examples from current environments. The 2003 early Processing example is located midway between the two. In the second row, visual programming environments (or patches) are presented on the left and text-based environments (or code based) are presented on the right. Works based around mathematical structures are located towards the middle of both top and second rows.

The third row contains two real time performance examples, Time's Up's Sensory Circus, in which user data is central, and chdh, in which abstractions control / simulate virtual visual objects and audio synthesis.

The bottom row contains two groups of examples, the globe/sonification (data driven) and creature (simulation driven) each of which *transform aspects of their internal structure into compositional elements*.

Horizontally, the lower slide is split left right between 'acquired data' driven works and 'simulation' driven works. Most of the data driven works also involve a considerable amount of simulation within their models. The graphical data structures of Pd lie in the centre at the bottom.

There were two main points of discussion raised: one from the Arts, the other from the Sciences. Briefly,

1. Artistic communities of practice using shared multiply-modified patches may not have any reason to map their ideas onto a mathematical framework for composition and/or analysis. (raised by author)

~ Slide 1. Compositional environments enable and constrain.
The separation between recent past environments and current environments is quite significant in terms of actual practice, for compositional environments and frameworks both enable and constrain those who use them. The sciences and engineering may also not recognise mathematical or scientific resources re-purposed in the arts because of the venues, contexts and language within which those works are performed or discussed. In contrast, issues related to current software environments, for example, their instabilities and their networked aspects, are likely to have strong overlap across those using computer-based abstraction in the arts and those working in information visualisation and scientific visualisation in the sciences and engineering.

In the historical and recent past examples we have seen the how the implications of a spatial notation caused representational conflict 300 years later, how new technical environments that could produce film changed abstract visual music, and how different the current converged environments for production of audio synthesis and reactive graphics are from that available in the 1990s. Mathematical resources have remained throughout as a resource, including those based on topological and geometric structure of combined primitive elements. Recent environments in the arts that market themselves as 'data-driven' are often, and to a very large degree, running on underlying simulations and the rise of the user therein is still very much controlled by the designed available options. Thus the emerging challenge of mastering simultaneous composition / display of sound and image gives us motivation to bring those using computer-based abstraction in the arts and those working in information visualisation and scientific visualisation in the sciences and engineering together. To the author, whose view of mathematical visualisation in the arts evolved out of that early seminar based on Xenakis' *Formalised Music*, the relationship between (some) computer-based abstraction in the arts, and information visualisation and scientific visualisation in the sciences and engineering, is not only close, but could be remapped and documented in a rigorous way. We would, however, need to re-negotiate the language.

2. The author referred to a transformation of some aspect of the structure as a compositional element for an artistic work, as an *explicit transformation*, in contrast to an *implicit transformation*.

~ Slide 2. Processes can be very similar to the sciences and engineering; intent can be very different.
The use on slide 2 of the terminology *explicit transformation* was problematic for some in science and engineering, for it is the case that every visualisation involves transformation and choices of representation, and it can indeed be argued that *every transformation is explicit*. While the author recognises that every mapping is a transformation of some sort; the term *explicit transformation* was used in the slide to delineate the act of *harnessing aspects of the data or environment as compositional elements*. This precision of terminology became a useful starting point for later discussion. In the group session for data/scientific/mathematical visualisation, a *twist in the transformation* was canvassed as a possible alternative terminology for an *explicit transformation* in the sense it was intended on the slide. On later reflection, the terminology *creative mapping* may prove to be less contentious.

Another starting point for discussion was differences in intent between the arts, and the sciences and engineering raised by Avis[137], in particular with regard to an artistic mapping not necessarily being bound by fidelity to a predictive model, whereas in scientific modelling this is generally the requirement. The value of playing with data, and playing with abstractions without being bound by such requirements was then discussed quite extensively within the group. Both its possible value to new representations and pattern discovery, and its limitation by the current restrictions on what is considered to be valid research activity (that which is RAE-able) were raised. The author considers that while mapping a system as a predictive model is clearly different in terms of intention and rigour, investigating behaviours by playing with aspects of mathematical structures, data, representations, or environments as compositional elements, may not be so different in terms of process, and that this common ground offers strong potential for collaboration between the arts and the sciences and engineering. A possible constraint, or barrier for re-negotiation, lies in the arts practice of not generally making such mappings available to an audience[138]; focussing on the end result rather than the process. This point was addressed later in the data/scientific/mathematical visualisation group.

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6) *La mensie fauveline* (Martyn Hill, Paul Elliott, Geoffrey Shaw), Anonymous, Ars antiqua
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[138] With the exception of course of artists and programmers dedicated to Free/Libre/Open Source Software (FLOSS) and digital arts, for example GOTO10 http://goto10.org/