# WINDCHIME: DATABASE DRIVEN MAPPING OF COMPLEX DYNAMICAL SYSTEMS

**PETER BEYLS**

CITAR / Universidade Católica Portuguesa
Porto, Portugal

pbeyls@porto.ucp.pt

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This paper documents *WindChime*, a database oriented, web-driven audio-visual installation. In essence, two complex dynamical systems are interfaced, driven by the principle of 'influence' rather than 'control'. Live weather activity in the world, intensity and direction of wind energy, is interfaced with a distributed particle system. Particles interact and, in turn, condition the behaviour of a self-running non-linear audio synth. We address the challenges of mapping and sonification including the aesthetic issues involved. It is suggested that the intricate interplay of the two systems may provide for a rewarding aesthetic experience.



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## 1. INTRODUCTION

Project *WindChime* is a large-scale, real-time, web-driven audio-visual installation, it suggests a digital interpretation/implementation of a classic wind chime; the arrangement of objects suspended from a frame creating tinkling sounds in a light breeze.

*WindChime* challenges the notion of dimensionality; it targets to interface the rhythms of the environment – the world as global found system – with a cultural system of explicit design. Invisible implicit activity in the world is tracked, analysed and converted as to exercise impact on a simple audio patch. The patch is basic, though because of non-linear feedback, it offers a wide palette of responsive options. *WindChime* tracks data from thousand of locations distributed around the globe providing real-time local weather data, information on the intensity and direction of wind is extracted and visualised in an animated world map. Essentially, *WindChime* suggests interfacing two complex dynamical systems; the earth as a found physical system and a sound-producing algorithm as a designed implicit system. Interaction between the many components comprising the global system constitutes a platform for the accommodation of surprising emergent audio-visual complexity. The project explores how the interface of (1) quantitative changes in patterns in wind energy and (2) qualitative changes in musical sound may support a rewarding aesthetic experience.

*WindChime* was initially documented in an introductory paper for ICAD2012 (Beyls 2012). The present paper specifically addresses the aesthetic orientation taken and provides further implementation details.

## 2. CONTEXT AND AESTHETIC ORIENTATION

The expression of deep awareness of the ecological impact of sound on a global scale is documented in *The World Soundscape Project*, a pioneering interdisciplinary research project initiated by R Murray Schaeffer in the early 1970's (Schafer 1970). Creating audio mappings of natural spaces as well as viewing them as inspiring spaces for original musical composition developed the notion of acoustic ecology. A unique approach as it merges the analysis of natural phenomena and the synthesis of cultural ones in a single project. A similar mission is at the heart of the Ear To The Earth project in its expression of concern with the environment, more specifically the effect of climate change. Ear to the Earth aims to convey this concern through the production of environmental works of art and by setting up a social network hoping to raise political understanding (Ear the Earth website, 2013).

New media installation art poses new challenges for long-term preservation, the technology changes, operating systems evolve while live data in global networks available today might be gone tomorrow. This raises difficult questions for the survival of real-time data driven audio-visual installations. However, let us approach the problem as a source of creative design; new versions of the same idea usually offer renewed insight in the context of a given aesthetic implementation. Conservation problems are not confined to digital media; consider the preservation problems with Robert Smithson' s landmark project *Spiral Jetty*. The massive land art sculpture deteriorates facing the impact of nature, though ironically, Smithson acknowledged the exposure of natural forces right from the start.

A few relevant instances follow within the realm of media art. One example is the *Eternal Sunset* project (Stellingwerf 2013), it streams live images from over 100 west-facing cameras across 27 countries for tracking sunset – so, the sunset may be experienced irrespective of earthly location. Experience of time and space is perceived as dislocated.

*Wind Map* (HINT.FM 2013) is a real-time dynamic visualisation project of live wind patterns over the USA; data is gathered in hourly intervals from the national Digital Forecast Database. The beauty of such visualisations follows from the appreciation of complexity in terms of (1) the relative coherence of local wind patterns and (2) the exposure of forceful tension between various islands of distributed wind energy. Complexity is an emergent phenomenon driven by natural forces.

*Sunlight Symphony* by Alexis Kirke connects architecture with nature and sound. A large building is equipped with four light sensors; light intensity is tracked at sunrise and the data is relayed to sound generating patch. Interestingly, this work explores the slow sub-audio cycles of moving from sunrise to sunset, consequently it can be thought of as a sonification of a rotating earth.

A significant early example of viewing the earth as a source of dynamic information is *The Earth's Magnetic*

*Field*. Charles Dodge created a computer music composition based on a chart of the *Kp*-indices (a measure of the average strength of the earth's magnetic field) of the year 1961. Mapping consisted of linking musical pitch to the data thus squeezing almost 3000 data samples for the year into eight minutes of musical time (Dodge, 1970).

*The Pulse of the Earth* is a major piece sound art initiated in 1996 by Lorella Abenavoli, the artist aimed to extract and expose the sculptural qualities of the earth's movements as a form of vibrating matter through the medium of sound. Real-time tracking of seismic activity of the earth is translated into distinct information. Imperceptible vibrations are made audible through a process of sonification; ultra low frequency waves are captured and compressed into the audible spectrum however conserving the overall proportions of the waves (Abenavoli, 2011).

*WindChime*, the system introduced here, exists as a live database driven work of art – thus, by definition – expressing interest in multiplicity of data, availability of massive amounts of data and a qualitative concern regarding complexity of data in a given specific niche. The publication Making Art of Databases (Brouwer & Mulder, 2003) critically addresses the active use of databases in interactive, dynamic works of art. It is stressed that the production of new knowledge only happens when data stored in memory is approached as something dynamic, when information is logically interrelated and recombined.

Database Aesthetics: Art in the Age of Information Overflow (Vesna, 2007) offers a compelling anthology of scholarly essays documenting both the theoretical foundations of database orientation and the hands-on implementation of artistic database productions. The concept of a database embodies many attractive connotations: memory, organisation, structure, change, information, agency… and in a cultural dimension: metaphor.

Artists do not create in isolation; they connect in a continuously evolving conceptual framework – a local cultural context – culminating into a globally extending networked context. Therefore, we might think of databases as extending in the realm of social (co)existence – even viewing art production as a process of shared initiative. An early example is David Blair's WAXWEB, the first online feature film initiated in 1993 (Blair 2013). In recent years, the Rhizome association organised various panels on Net Aesthetics and, most recently, on Post-Net Aesthetics (Connor, 2013). From here on, we reflect on art as the identification and articulation of data-intensive systems.

Let us consider the aesthetic orientation of viewing art and/or art production as a *found system*. The universe is full of 'systems' large and small, systems that are alive and express rhythms in many dimensions: social systems, biological systems, cellular systems, intergalactic systems and systems of the unconscious… systems exist at social, molecular and evolutionary scales, so it seems natural to think of 'systems' as compound articulate micro-universes (perhaps, parallel universes) to be explored with aesthetic objectives. How might their inherent complexity be articulated as a message of creative imagination?

Human observers engage with systems in either intuitive or explicit ways. While witnessing the logic of a given system, a process of anticipation takes place; the system's actual behaviour is compared to certain private patterns of expectation – generally, signified by a personal belief system – the act of responding to the distance of experience and anticipation is considered a source of aesthetic arousal. In other words, the process of adaptation i.e. bridging the conceptual gap between what we expect to happen and what actually occurs, could be the key to aesthetic appreciation. Perception becomes grounded in a dynamic adaptive process. Beyond any specific medium and more generically, we might claim that 'art is a qualitative oscillator'.

## 3. STRUCTURAL OUTLINE

Figure 1 shows a general overview of the main components in the implementation. A JAVA program communicates in XML with a remote data server located at the National Center for Atmospheric Research (UCAR, 2013), in addition, it guarantees real-time display of a complex visualisation showing data analysis and a particle system, to be documented in a moment. The program equally sends information to a sound engine running in SuperCollider, the data is sent via OSC (Open Sound Control) (Schmeder, Freed and Wessel, 2010).

The JAVA program contains classes for data collection, data analysis and visualisation. The main classes are: Stations, Field, Particle and World, all are documented next.

**Stations.** This class holds a uniform data structure containing information on 7961 weather stations distributed around the world. An 80-character entry contains 18 data items including, name of the location, a unique four-letter ID, latitude and longitude, elevation and aviation specific information and country code. For example, the first entry refers to a station in Alaska:

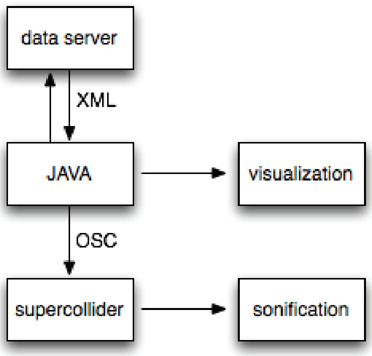
CD STATION ICAO IATA SYNOP LAT LONG ELEV M N V U A C

AK ADAK NAS PADK ADK 70454 51 53N 176 39W 4 X T 7 US

The program instantiates a *Station* object by random selection of a single station from the database. The location data (longitude and latitude) are remapped to Cartesian coordinates to serve visualisation of that location on a large scale projected, animated map of the world. The Station object send a message to the UCAR data server, requesting real-time information for that specific location, when available (not all stations are operational 24/7), the system takes note of the intensity and the direction of the wind at that specific moment in time. The system optimises itself in the sense that, when a data request remains unsuccessful, another station will be selected in the next program cycle. The duration of one cycle is 240 seconds because the system collects, parses and displays data of 24 different stations, the refresh rate being 10 seconds. In the long run, the system will have collected effective 24 stations by random selection using a gradual optimisation policy. Then, the system will further optimise by effectively searching for wind energy thus replacing less effective stations with new more effective ones. Since the weather – looking at it as a complex dynamical system – is in continuous transformation, the optimisation process will never come to an end. Let's consider this a bonus!

In addition, a single effective station will remain active for a certain time interval relative to the amount of change in information it provides (evidence of the dynamics of wind is considered rather than static information) – the data is normalised into time frames lasting between 30 seconds and 5 minutes. The principle of the *appreciation of change* is significant here, our computational structures are driven by fluctuations in data – so is the Field class, discussed next.

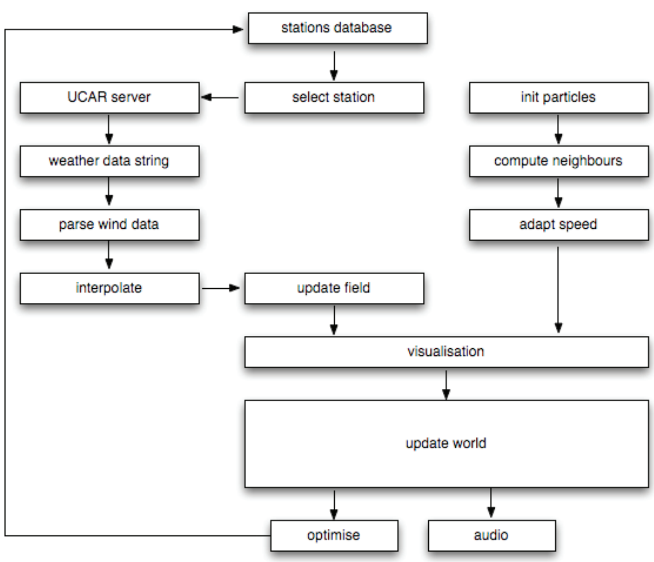
**Fig. 1** Structural components of *Wind-Chime*



**Field.** The Field class is a computational memory construct designed to capture wind energy in an imaginary two-dimensional matrix spanning the whole world. In fact it allows for inference of *changes* in energy because the matrix holds 2 layers: current-data and previous-data, updated in two consecutive time frames. Now, the 2D matrix is projected onto a 2D map is the world. The matrix can be thought of as a low-resolution representation of energy in the world itself, in the current implementation, the matrix is 32 columns by 20 rows. (Considering a distance from Anchorage, Alaska to the South Pole of 16788 km, a single matrix cell corresponds to approximately 839 km.)

After a Station collects data, it will update the matrix at a specific location i.e. where the (normalised) image of the matrix and the station's location coincide. Next, the impact of a single station is computed by interpolating energy for all matrix cells; the effect being inverse proportional to the distance from the original station. Following many process cycles, the matrix will embody a gradually acquired 2D data profile representing contributions of the 24 previously sampled stations. Because of the optimisation process, as explained above, the matrix behaves as a dynamic structure. Initially, large major changes occur since the system starts from scratch. In the long run, more subtle changes appear where newly acquired data assimilates with information yielded in an earlier stage.

**Fig. 2** Data flow in *WindChime*



**Particle.** Multiple particles are a representation of virtual dust, their behaviour being conditioned by actual physical wind – all confined within the inclusive systemic approach of *WindChime*. Particles are imagined to be afloat in 2D space, particle properties (velocity, direction and energy) are influenced by the data accumulated in the Field object; a particle at a particular location in space accelerates/decelerates in proportion to the strength of the wind as reflected in the value at the corresponding matrix cell. In addition, particles interact locally; particles within a critical distance threshold will coalesce into a complex temporary cluster receiving dynamic visualisation. Particles within clusters interact in two ways, (1) a particle will adapt its angle of movement to the angle of one of its (randomly selected) neighbours and (2) a particle's energy level will boost in proportion to its number of neighbours. An isolated particle (no neighbours) will slightly decrement its energy level in every process cycle, energy levels are considered in the audio mapping algorithm documented in section 5. Important, every particle belongs to a specific class, reflected in an instance variable called 'type', valued 0 to 3, type too conditions the mapping scheme (figure 4).

**World.** A single World object incorporates all components introduced above: a single Field object, a continuously optimised collection of 24 stations and a critical mass of 100 particles. The World object coordinates dynamic visualisation and includes an algorithm conditioning sonification. Visualisation includes (1) the ID (label) of the currently selected stations plus the respective values for intensity and direction of wind, (2) the most recent data string retrieved from the remote data server, (3) the Cartesian position of the currently pinged world location is highlighted by a white circle on the world map, and (4) a dynamic animation of the current particle associations as reflected in a number of cluster, clustering particles are connected by straight lines. All this happens on top of two lower layers, first a map of the world showing up as a fixed background image and, second, a visualisation of the field. Matrix cells in the field are drawn as red circles using a radius proportional to cell's value. We think of the matrix as 'being projected' on top of the world, the interpolated matrix values providing a global impression of the distribution of wind energy. Finally, field values above a certain threshold will be highlighted, a blue curve emerges by connecting local maxima in the field's matrix.

Figure 3a and 3b: Snapshots of *WindChime* showing the world, the interpolated field matrix, temporary clusters of interacting particles and the current data collected from 24 live stations.

Figure 3a documents the activity in *WindChime* a few moments after start-up on December 23, 2013 at 15:08:13 hrs. Notice that 13 (out of 24) randomly selected stations actually acquired information. Station data appears at the bottom of the display, station ID is in blue, wind data (direction and intensity) shows in white. Closer observation reveals maximum wind intensity in station KNGP (350/15), the ID refers to a location in Texas, latitude 27 41N and longitude 097 16W. Station CEWB reports a wind intensity of 2 units blowing in an angle of 310 degrees.

Figure 3b displays system status at 15:14:28 hrs. Twenty-two stations show positive data, the current station's ID is RJOW situated in Iwami, Japan. Notice, the coordinate conversion algorithm is not totally perfect; the displayed XY-position on the world map is approximate.

## 4. FIRST PRINCIPLES

Let us briefly consider a number of first principles underpinning the work documented here. *WindChime* is based on a first principle implicit in my artistic practice; the principle of influence. Initially, this refers to the principle of *mutual influence*, i.e. a policy of open conversational human-machine interaction where both parties express social pressure on one another given the absence of a supervising agent. Influence is opposite to 'control' i.e. typically, the instrumental manipulation of a control structure (in hard- or software) allowing precise control over a given process. Control implies predictability and absolute certainty of outcome.

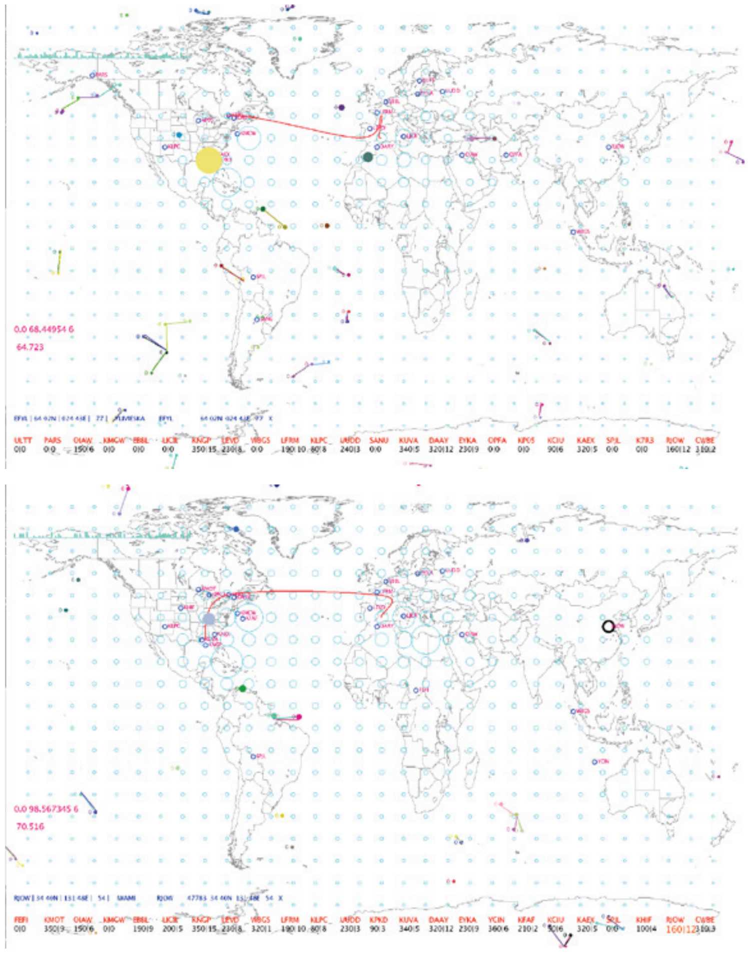


**Fig. 3a** System status at start-up (image inverted for printing). **Fig. 3b** System status after approximately 6 minutes (image inverted for printing).

The principle of influence acknowledges the relative autonomous existence of an artificial system; it exhibits an internal logic but remains open to outside impact from an unpredictable environment. Organisms in biological workspaces and complex dynamical systems in science are inspiring examples, such entities develop non-linear yet coherent behaviour and cannot be approached as something under control – therefore, they incorporate the potential for offering rewarding aesthetic experiences.

In *WindChime*, the principle of *coexistence* is complementary in the present argument; a number of systems subsist within a given common, shared environment. The installation interfaces weather data, quantitative and qualitative information on wind as a distributed global system, and a digital sound synthesiser in software. In other words, it associates a found implicitly natural system (the earth) with a constructed cultural system (the DSP algorithm). In addition, a human observer witnesses the ever-evolving complex animated audiovisual behaviour.

## 5. MAPPING, SONIFICATION AND EMERGENT AUDIO

Scientific sonification (Kramer, 1994) usually aims the induction of hidden knowledge from typically massive amounts of data using the medium of sound.

Sonification is distinctive of composition because the objectives and artistic motivation is different. Nonetheless, a thin line might exist between (1) formal data sonification, for example, in the context of meaning extraction in a data mining engineering application and (2) mapping an instrumental gesture to sound i.e. the creation of a musically significant link between grounded action and critical parameters in algorithmic composition. Musical mapping typically aims to convey a meaning implicit in high-level expressive bodily gestures into low-level instrumental control structures, sometimes resulting in exceedingly virtuoso performances (Waisvisz, 1985).

In the present study, mapping is seen as conveying *changes* in the environment to changes in a DSP algorithm conceived and implemented as a complex dynamical system. Notice, very few data items are tracked (only two; strength and direction of wind energy) and only two control parameters impact the sounding patch (conceptualised as a spot on map, identified by a location i.e. the X and Y coordinates).

*WindChime* implements an experimental mapping scheme, representative of our first principles of *influence* and *change*. The mapping strategy proposes a functional association between complex behaviours in two independent parallel universes that coexist within their private domains.

In addition, *WindChime* acknowledges a massive step in dimensionality – wavelike patterns in wind energy (macro-time) communicate abstract information that is accommodated by the DSP algorithm to result in qualitative gestures in musical micro-time. The purpose of mapping is not to create musical structure as such but to provide a sounding platform to articulate environmental changes. We avoid direct linear mappings between cause and effect in favour of the non-linear influence of environmental forces on a black-box software synthesiser. A synth is considered a network of DSP-modules, complexity issues from the kind of modules and their interconnection. More important, unexpected non-periodic and near chaotic behaviour may result from the application of specific parametric settings to a given synth because the global effect is nonlinear interaction between the synth's individual components.

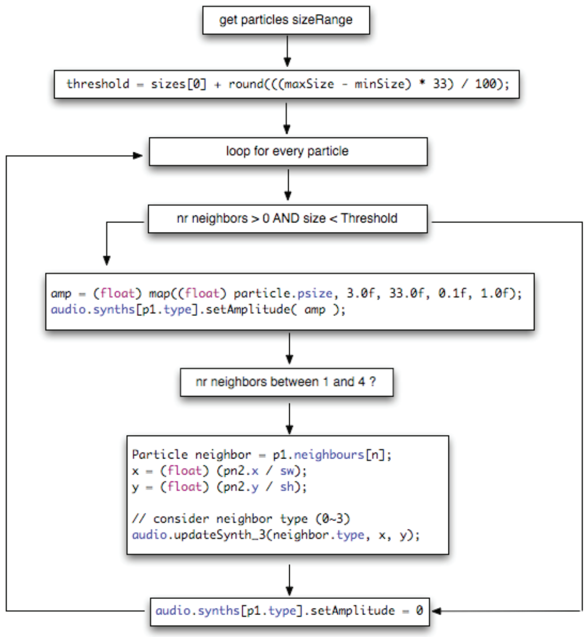



**Fig. 4** Information flow in the mapping algorithm.

The notion of mapping is a challenging one, we aim to create a sensible correlation between some abstract behaviour in a specific universe – *WindChime* combines real-world phenomena with dynamic invented artefacts – and an unambiguously designed sounding apparatus. In practice, we avoid simplistic one-to-one relationships, yet we also aim for an *intuitively* perceptible correlation, a relative induction of meaning from the perception of fragmented data. Fragmented because the global audio-visual system is in continuous change and different aspects of its behavioural space are being exposed over time.

Implementation of a non-trivial mapping scheme is typically a process of generate-and-test, not unlike trying patches on a modular voltage controlled synth. Definitely, it also links with the current musical practice of experimental live coding. Our mapping structure is detailed next.

The black-box synth in the most recent implementation consists of a hierarchical network of Frequency Modulation UGens (synthesis modules) written in SuperCollider (Wilson, Cottle and Collins, 2011). Since modules interact in non-linear ways, we consider the modules being pushed (influenced) into chaotic orbits. Remarkably, the overall musical character of the system remains clearly identified, the structure of the algorithm does not change but the implied behavioural space supports a rich palette of expressive sounds.

The output signal of the SuperCollider program results from the multiplication of three simple frequency modulated sine wave generators, triggered by an additional cubic sine shape. The patch features eight ‘entry points’ i.e. control plugs which accept normalised floating-point values between 0 and 1.

Because the generators interact in non-linear ways, the output signal may engage in chaotic behaviour, in practice, a whole range of sonic phenomena can potentially be synthesised, from simple sine waves to complex audio spectra. We get the impression of relatively independent behaviour in the patch, we loose the notion of ‘control’ and involve in the appreciation of relative autonomy; the audio patch is definitely influenced but surely beyond explicit external control. As explained above, this approach is implicit in the project’s aesthetic orientation.

Figure 4 displays the mapping algorithm. There are four software synthesisers running in SuperCollider, corresponding to four types of particles, visualisation size of a particle is portioned to its energy and equally echoes its type.

Any particle may trigger a sound when its the contents of the Field matrix at the particle’s present location exceeds a given adaptive threshold AND it does not live in isolation i.e. it currently sports at least one neighbour within its range of sensitivity. The threshold increases while facing overstimulation. In contrast, the absence of accumulated wind energy will lower the threshold thus increasing the probability of audio responses. Adaption contributes to global emergent behaviour in *WindChime*. Amplitude is further mapped according to the particles size.

Next, particles engage in social collaborative coordination; more neighbours will exercise more control. The highest-ranking neighbour is selected from the current list of neighbours, its XY-location is considered and, according to its type-value (0~3) the x-coordinate and y-coordinate is sent to the corresponding synth in the block of four free- running synths. Finally, any particle momentarily without neighbours and of low energy will switch off a particular synth. Mapping indirectly reflects the interaction between the particles (virtual dust) and captured (physical) wind energy as continuously reflected in the field structure.

## 6. CONCLUSION

*WindChime* recommends a perception format of intuitive (partial) understanding of audio-visual behaviour unfolding in a live data driven installation. We appreciate the intricacy in the interface between two complex dynamical systems: firstly, an implicit, found system (the weather) impacting on a dynamic particle system and, secondly, a set of explicitly designed digital sound generators in software. All components are considered complex as they consist of a mass of tiny components interacting in non-linear ways. The notion of 'mapping' is challenged by exploring the first principle of 'influence' rather than 'control'. Globally, *WindChime* suggests a synthetic space effectively influenced by physical real-world features; a complex hybrid universe results affording an unpredictable yet coherent emergent aesthetic experience.

The work reported in this paper took place in the context of the Media Arts and Technology (MAT) project in which CITAR at UCP is a partner organisation. MAT research fuses emergent media, computer science, engineering, and electronic music and digital art research, practice, production, and theory. *WindChime* is an interdisciplinary project proposing novel ways to connect a diversity of aesthetic objectives and technical (implementation related) components, including the notions of database, experimental sonification, dynamic visualisation and perception in an original, innovative presentation format.

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