HERE IS NOW AND THERE THE SOUND OF THE LAND: *GROUND-BREAKING.*

SCIENTIFIC AND SONIC PERCEPTIONS OF THE AFRICAN SAHEL

Societies are often required to react to extreme events that arise through either anthropogenic or natural processes. Such extremity might be measured is in terms of its immediacy and intensity; it demands comprehension against understood norms. For example, our present-day debate on future climatic change is driven by scientific assertion, reinforced by evidence gathered from both instrument and indirect proxy measurements, whilst the varying societal responses are predicated by everyday cultural experiences. Climatic change denial is one such example of a cultural response. In contrast, places considered to offer experiences at the boundaries of or outside the everyday, e.g. hot and cold deserts, provide a different conception of *extreme*. In this conception, change and the rates of change typically lack context, validation and position within everyday norms. Consequently, it is within such surroundings that the greatest tension occurs between the perception of place and rates of change. While the methodologies of science and art practice are often respectively considered positivistic and non-rational, both are in fact able to investigate the *extreme* in this context. Whether or not such characterisations are legitimate, the obvious epistemological differences both illuminate and problematise our understanding. In this paper we describe and reflect upon a real-time generative installation commissioned from the authors by the UK Research Councils called *Ground-breaking: Extreme Landscapes in Grains and Pixels* that attempts to explore and test these differences[1].

This work offers context and potential validation about change and the rate of change of an extreme environment: this is evidenced through scientific analysis of landscapes and soils and is translated, in a process of critical evaluation, to create an audio-visual installation. The installation seeks to convey the cultural imprints left by societal responses to change experienced in a geographically and socially marginalised area, the African Sahel. By considering a landscape that is both extreme and has long-standing cultural activity, a narrative is developed. To borrow Barthes terminology (Barthes, 1977), the data from scientific analysis provide *functions* to the narrative; they are indices to the landscape and to human conditions. These data also connote *actions* that may be anthropogenic or environmental (such as changes in land management, house building, flooding and desertization). A narrative emerges from the exploration of these data, in which a sequence of actions is deduced from functional descriptions of physical objects, that are in turn offered for evaluation and exploration in sonic and visual forms.

CONTEXT AND INVESTIGATION

In both extreme and non-extreme environments, the fertility of soil is fundamental to the long-term sustainability of human societies. The local management of soils is paramount in agrarian-based societies, whereas nomadic pastoralist societies are reliant at more regional-scales. Soils are, therefore, both an essential source of, and sink for, materials used to sustain basic human existence by providing nutrients for plant growth and receiving material inputs as wastes or fertilizers.

[1] First shown at National Museum of Scotland, Edinburgh 2007. Supported by Research Councils UK, NSW2007 Award.
http://www.sbes.stir.ac.uk/groundbreaking/

Soils subjected to such inputs may retain the imprint of cultural activities. This imprint, commonly microscopic, provides the opportunity to examine how past societies managed their surrounding landscapes. Soils therefore can act as a record of past cultural activities; the examination of such soils - cultural soils – is a major element in the *Ground-breaking* installation.

The soil materials used as a basis for the installation were sampled from within the Sahel region of West Africa from a village called Tiwa. The village is located in the lacustrine plain of Lake Chad in Northern Nigeria (Adderley, et al., 2004) and is representative of many thousands of villages in the region (Magnavita, 2004). The lacustrine plain has experienced extremes of flooding and drought throughout history which may have displaced the human population. The village lies on a raised mound, above the plain which may flood with seasonal rains, with dwellings constructed from mud-brick and thatch. The soil samples were taken within a small field on the village fringe, an area typically cared for by women and small children. This area is subject to intense land management with application of domestic and animal wastes and receives materials washed from the village by heavy rains. A pit, 2 m deep, was dug to expose a profile for sampling. The soil materials were sampled as blocks using rigid open-faced containers called Kubiëna tins. These tins allow the spatial organisation of component materials of the soil to be maintained from sampling, through their subsequent processing in the laboratory and examination by microscope. With the deeper, i.e. older, cultural soils at depths undisturbed by modern-day activities, an intact imprint of past human activities may be retained. The oldest soil materials were subsequently found to be c. 10,000 years old. The materials sampled therefore span this 10,000 year period including the onset of human settlement in the Lake Chad plain c. 4000 years ago (Connah, 1981).

To allow microscopic viewing, the soil materials were treated to produce glass-mounted thin-section samples suitable for examination by transmitted as well as reflected light using an optical microscope. The soil samples were chemically dried and then impregnated with polyester resin to form solid blocks. Each block was then cut and mounted on glass, followed by wet grinding and polishing with diamond to form the thin-section with a uniform thickness of 30 µm. At this thickness grains of quartz mineral are translucent. In a typical scientific study of such soils, they would now be optically examined and described using an international system of terminology (Bullock, et al., 1985) allowing archaeological interpretation of the materials (Courty et al., 1989). To develop the Ground-breaking installation a more expansive direction was taken to allow a broader cross-disciplinary interpretation. First, by allowing larger, more representative areas of the samples to be examined, a virtual exploration of the microscale features is undertaken. Second, by utilizing the latest digital image-analysis methodologies, a quantitative examination of the materials identifies objects that provide discrete cultural signals; these objects can then be classified and spatially related. This, in turn, allows development of a sonic narrative that draws upon both the measurements and their interpretation as cultural signifiers.

The thin-section samples were observed with a microscope at 80x magnification and images captured using a sequence of different illumination methods: one with incident illumination projected at an oblique angle such that the light is reflected from the sample; and three with light transmitted through the sample: with no polarization, with circularly-polarized illumination and with the sample between crossed-polarizing filters. Each of the optical techniques produces a different resultant image (Figure-1). The oblique incident reflected light image typically shows dark images with colours that can be interpreted as related to cultural activities; specifically burnt materials such as pieces of fired clay and partially combusted fuel materials show clearly as ruby reds and orange colours. The plain transmitted light images typically have a muted colouration, and may frequently show quartz sand grains as an irregular bleached-white “skin” around a near-transparent core. The abrading of these grains through exposure to the natural forces of wind and rain can result in rounded yet irregular shapes. This provides a visual clue to the relative severity of several confounded forces in the natural environment. The images taken using circular-polarized illumination extend this and may show a distinct light blue colouration in areas of the microscope slide where there is no organic or mineral material. It therefore can give a clear indication of the pore-spaces where many environmental and biological processes occur within the soil. With the sample between crossed-polarizers, all empty space in the sample will be shown black, whilst many mineral materials will be shown with a range of vivid birefringence colours. The contrast between this image and the others frequently can reveal textural changes in the soil matrix, which may be related to human disturbance of the soil.

From eight microscope slides a total of thirty-two areas were analysed, each representing a discrete period in the history of the Tiwa village site. For each sample area a large-scale calibrated image was made by capturing a mosaic of smaller images using a high-resolution thermoelectrically-cooled digital microscope camera (Adderley, et al., 2002). This was repeated for all four illumination methods. These images were then examined using image-analysis techniques (Russ, 2006; Adderley et al., 2002) to segment images using colour criteria to identify component objects of interpretative value and then to take measurements of these objects; each group of objects representing the imprint of a different cultural event: construction and destruction of buildings, soil disturbances such as cultivation and periods of flooding. Taking burnt materials as an example, these materials have distinct colour properties under oblique incident illumination allowing a colour-based segmentation of the image. Using image analysis, each object in the image was identified and its size, shape and location analysed. With the object defined as a mass of contiguous pixels that satisfy the segmentation criteria of specific colour properties, the object's area is given by counting the number pixels whilst the outer edge of the mass of pixels is the object perimeter. Holes are identified as pixels outside the segmentation criteria yet bounded by those that are. Shape was estimated by measuring parallel tangents - Feret measurements – at 360 positions around each object (Russ, 2006). The fractal dimension of each object, a derived measure of shape, was calculated from the area and perimeter relationship (Mandelbrot, 1977). By considering the centre of the object as the point with the maximum distance from any point on the perimeter, a set of co-ordinates for each object within an image can be determined. There is therefore a data set for every identified object comprising {x,y} spatial coordinates and a descriptive list; object area, perimeter, count of the holes in the object, Feret mean, fractal dimension and colour hue, saturation and intensity. These and the 10,000 year temporal data form the precursors for the implementation and structure of the installation.

IMPLEMENTATION OF THE *GROUND-BREAKING* INSTALLATION

The macrostructure of the installation (Figure-2) is guided by a master clock that represents the entire period of 10,000 years. The equivalent time interval executed by the installation system varies on each cycle, resulting in presentation of the 10,000 years in periods of between 20 and 50 minutes. Each cycle is denoted by data, interpolated where necessary, that describe the lake-level of Lake Chad at decadal intervals. The levels are indicative of three states; flood, drought or human-populated. These data are interpreted as a probability function that influences the generative processes of the installation. Adaptive probability systems have been applied in other recent work by Young (2007).

The visual component comprises two elements, a library of on-site photographs and the thin-section images of soil samples. At irregular time intervals – determined by a secondary system clock – a thin section is selected and two of the four associated images, along with the relevant soil data file, are loaded into the system. The choice of thin-sections is randomised, but restricted to those relevant to the time period indicated by the current position of the master clock. Images are deployed in pairs to allow for contrasting and complementary perspectives of colour and detail. A number of visual behaviours are deployed stochastically, related to the lake-level state: drought (static image display and minor colouration effects), flood (crossfading and flowing progression between data points, i.e. material fragments) and human population settlement (dynamic zoom activity, onsite photographic material interspersed). Sound materials are also influenced at this macrostructural level, in that the most clearly referential sound materials (i.e. recordings of environmental sounds, human voices, music) are much more likely to be invoked when they are relevant to the historical/temporal scale, unfolded by the master clock. Audio material is generated from the soil data, numbering from some dozen to several thousand objects per thin-section image. Each object's descriptors (area, perimeter, Feret, etc..) are mapped to the sound synthesis algorithm. These data are explored for synthesis as long as the current image selection is in view.

The generation of sound from data obtained from non-musical sources or actions is a well established process (Scaletti, 1994). Pre-existing wave functions (examples: heart monitors, radio-astronomy data) are easily susceptible to such audification through a direct mapping of function to sound synthesis. This approach can be contrasted to higher level mapping strategies, in which an input parameter set is made congruent with the requirements of a specific sound generating system (Hermann & Ritter, 1999). Parameter mapping strategies have been classified as one-to-one, divergent or convergent (Hunt & Wanderley, 2002), indicating the possibilities for data to be directly translated, directed to a multiplicity of parameters, or condensed to fewer dimensions. Often this is a question of physical expression and control (authentic to the gestures of a live performer, for example) rather than the translation of entirely non-musical sources. Designer intervention – whether intentional or not – is common in this mapping process. Model-based sonification (Hermann & Ritter, 1999) offers a more neutral approach, in that the data elements themselves give rise to a virtual physical system that can produce sound, given appropriate excitation (the physical modelling of musical instruments is an example).

In all these cases, the broad aim of sonification is to render data, often complex and multidimensional, susceptible to intuitive or more methodical appraisal and analysis, and the efficacy of user-interfaces and data mining techniques is highly relevant. As Hermann notes, the (self-evident) temporal nature of sound means that both microstructural changes and the global attributes of data can be readily apparent, whereas frequency domain characteristics can provide clear momentary cues and bring together many streams of information. A common question arises from the absence of time information in the data itself, and the consequent need for data to be linearised in time as a stream of discrete events. Given that temporalisation *is*, in effect, sonification, some form of creative decision-making is unavoidable, and must to some extent be predicated on the desired outcome of the investigation.

Our purpose is not user-interactive sonification, or even scientific investigation, but non-rational exploration and narration. Sonic – and visual – production is not intended as a proxy for the actual data, or to be readily perceived to be related either mimetically (or even metaphorically) to it. Instead, there is a new emergent narrative that references data both directly and obliquely. This narrative seeks a structural and syntactical relationship that is consistent and, in theory, comprehensible. Returning to Barthes terminology, the *narrative* constructed in *Ground-breaking* is the result of a stochastic exploration of the soil data sets as cultural indices. The narration is both cyclical and open-ended; because periodic techniques are combined with probability functions, no cycle is repeated. The exploration is in part randomly driven, but, given that the data can be parameterised as a time-based (i.e. rhythmical) function, the narrative is also self-referential. For example, an iterative approach is used in which the area parameter measurements for objects are mapped to the duration between subsequent object inspections. In this way the data sets have a *functional* role in the narrative; they are also a mode of description of the material objects that connotes *actions*. In this case, actions can only be deduced from the description, and may be human or environmental (such as interventions in land maintenance, firing bricks, flooding activity). So, a narrative emerges from the exploration of a data space, in which a sequence of actions can be deduced from functional descriptions of physical objects.

The detail of mapping object descriptions to sound synthesis is problematic, in that the data sets do not suggest any particular context for sonic representation, and conversely, familiar sound parameters (such as pitch, duration, loudness, timbral characteristics) may easily connote a state, behaviour or agency (up/down, near/far, physical excitation and so on) which is not relevant. In *Ground-breaking*, the mapping of data to sound parameters (Figure-2) is arbitrary but consistent in any one cycle of the 10,000 year history. For each iteration of the master clock cycle, the mapping is reshuffled and assigned autonomously by the system with no creative intervention from a user. There are seven data parameters and over twenty sound synthesis parameters, so this reshuffling is decisive and selective in pre-determining the vocabulary and behaviour of sounds. One-to-one, convergent and divergent mapping strategies are used; the strategy and actual assignment map is generated randomly. Two synthesis techniques are employed; subtractive synthesis (multi-band filtered noise) and granular synthesis (or granular reconstruction, the production of extensive and timbrally-rich sound events and textures by the proliferation of tiny sonic fragments or grains). Granular methods offer the possibility of both clear sonic references, and more abstract, acousmatic material, depending on the content, duration and processing of individual grains. The filtering techniques can be employed on both a noise signal and the sound product of the granular synthesis. Sonic parameters include the frequency content, bandwidth and harmonicity of filter banks, the size, content, amplitude, post-processing of grains. Grain content is particularly critical: this is obtained from an existing library of recorded sounds stored by the system. The library sounds are tagged with descriptors denoting their referential content (such as water, work, environment, human voice, music) and their sonic characteristics (such as loudness brightness, roughness, pitch-noise). The tags are assigned as sound parameters, so that appropriate sound sources are looked-up and read into the granular synthesiser as a basis for subsequent events and textures.

CONCLUSION

The *Ground-breaking* installation was commissioned to raise awareness of the scientific aspects of how people have coped with extreme modifications, regardless of causation, of the environment of the African Sahel. The work has problematised notions of data representation, such that it offers a critique of data-sets rather than a simple audification. In doing so it has attempted to breach the barriers presented by different temporal and spatial scales: between landscape and the production of artefacts, between the scientific analysis of artefacts and their manufacture, between the perception of visual and sonified representations, and between micro-scale information and macro-scale evidence of extreme climatic change. Direct deduction of the human processes or environmental events is not explicitly sought such that the installation remains an unresolved generative work; in this form it promotes the audience towards a liminal space, an understanding of place and of rates of change.

The narrative developed explores a data space which contains as set of deduced actions from functional descriptions of physical objects; this has revealed the possibility that a yet more detailed data analysis and deeper data space exploration can produce further novel insights into the nature of the cultural imprints held by the soil. This also highlights the transferability of the meta-constructs of the narrative to other domains including other geographical environments with other cultural imprints.

Adderley, W.P., Simpson, I.A. & Davidson, D.A. (2006) Historic landscape management: a validation of quantitative soil thin section analyses. *Journal of Archaeological Science,* 33, 320-334.

Adderley, W.P., Simpson, I.A., Kirscht, H., Adam, M., Spencer, J.Q., & Sanderson, D.C.W. (2004) Enhancing ethno-pedology: integrated approaches to Kanuri and Shuwa Arab definitions in the Kala-Balge region, North East Nigeria. *Catena,* 58, 41-64.

Adderley, W.P., Simpson, I.A. & Davidson, D.A. (2002) Colour description and quantification in mosaic images of soil thin sections. *Geoderma*, 108: 181-195.

Barthes, R. (1977) *Image, Music, Text*. London: Fontana Press.

Connah, G. (1981) *Three Thousand Years in Africa: Man and His Environment in the Lake Chad Region of Nigeria.* New York: Cambridge University Press, 268.

Courty, M-A., Goldberg, P. & MacPhail, R. (1989) *Soils and micromorphology in archaeology*. Cambridge: Cambridge University Press, 344.

Hermann, T. & Ritter, H. (1999) Listen to your Data: Model-Based Sonification for Data Analysis. In G. E. Lasker (Ed.) *Advances in intelligent computing and multimedia systems*. Int. Inst. for Advanced Studies in System Research and Cybernetics, 8 Baden-Baden, 189—194.

Hunt, A., & Wanderley, M.M. (2002). Mapping performance parameters to synthesis engines. *Organised Sound*, 7:2, 103–114.

Magnavita, C. (2004) Zilum - Towards the emergence of sociopolitical complexity in the Lake Chad region (1800 BC- 1600 AD). In M. Krings & E. Platte (Eds.). Living with the Lake. *Perspectives on History, Culture and Economy of Lake Chad* Cologne: Rüdiger Köppe Verlag, 73-100.

Mandelbrot, B.B. (1977) *The Fractal Geometry of Nature.* San Francisco: W.H. Freeman, 365.

Russ, J.C. (2006) *The image Processing Handbook* (Fifth Edition) CRC Press, Boca Raton, Florida.

Scaletti, C.(1994). Sound synthesis algorithms for auditory data representations. In G. Kramer (Ed.) *Auditory Display: Sonification, Audification, and Auditory Interfaces*. Addison-Wesley. 223--251.

Young (2007) NN Music: Improvising with a ‘Living’ Computer. *Proc. of the International Computer Music Conference*. ICMA: San Francisco, 508-511.

Dr Paul ADDERLEY, British, 1967. RCUK Academic Fellow. University of Stirling, UK. School of Biological and Environmental Sciences. http://www.sbes.stir.ac.uk/people/adderley.html w.p.adderley@stir.ac.uk

Soil scientist with publications in geoarchaeology and environmental history specialising in long-term societal-climatic interactions including the sustainability of societies in extreme environments, land degradation and environmental risk.

Dr Michael YOUNG, British, 1968. Lecturer. Goldsmiths, University of London, UK. Music Department. www.myoungmusic.com m.young@gold.ac.uk

Composer with interests in computer music, interactive performance systems and generative media. Recent works include Argrophylax (2005), Aur(or)a (2006) and Piano_Prosthesis (2007). Co-director of the Live Algorithms for Music network www.livealgorithms.org