IEEE, *92*(4), 632-644. doi:10.1109/JPROC.2004.825882

[18] Wang ,G., Essl, G., and Penttinen, H. (2008) Do Mobile Phones Dream of Electric Orchestras? In Proceedings of the International Computer Music Conference.

[19] Wendt, L. (1985). Sound Poetry: I. History of Electro-Acoustic Approaches II. Connections to Advanced Electronic Technologies. *Leonardo*, *18*(1), 11-23.

[20] Werle-Burger, H. (1999). Interactions of the media Storytelling, Puppet Opera, Human Opera and Film. In V. Bordahl (Ed.), *The eternal Storyteller; Oral Literature in Modern China*. Curzon Press.

[21] Wyse, L. (2004). Hierarchies, Tied Parameters, Sound Models and Music (pp. 144-147). Presented at the International Computer Music Conference.

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A STIGMERGIC MODEL FOR OSCILLATOR SYNCHRONISATION AND ITS APPLICATION IN MUSIC SYSTEMS

Andrew Lambert

ABSTRACT

Non-linear and chaotic dynamics, predominantly used in engineering, have become a pervasive influence in contemporary culture. Artists, philosophers and commentators are increasingly drawing upon the richness of these systems in their work. This paper explores one area of this territory: the synchronisation of a population of non-linear oscillators used for the generation of rhythm as applied in musical systems.

Synchronisation is taken as a basis for complex rhythmic dynamics. Through the self-organisation notion of stigmergy, where entities are indirectly influenced by each other, the notion of local field coupling is introduced as a qualitatively stigmergic alternative to the Kuramoto model and noise, distance, delay and influence are incorporated.

An interactive system of stigmergic synchronised oscillators was developed, that is open to be used across many fields. The user is allowed to become part of the stigmergy through influencing the environment. The system is then applied to the field of music, generating rhythms and sounds by mapping its state.

1. INTRODUCTION

Oscillator synchronisation is a potential biological root of musical creativity. Through oscillation, interesting musical behaviour can be achieved.

In section 2, stigmergy, a notion where entities are environmentally influenced by each other, is used as the mode of exploration into self-organisation. The Kuramoto model is introduced as a powerful and elegant mathematical formula describing the phenomena of oscillator synchronisation in the natural world. However, since synchronisation has its roots in self-organisation, the Kuramoto model encounters a problem and falls short of complete plausibility. An alternative model, local field coupling, derived from Kuramoto and other methods of oscillator synchronisation taken from biology and neuroscience, is described to solve this problem.

Section 3 discusses theories from the fields of chronobiology and biomusicology, which use oscillator synchronisation phenomena to explain many forms of behaviours in living systems. A clearly rhythmic, but not necessarily creatively musical behaviour is achievable through stigmergic synchronisation, termed protomusical behaviour.

An interactive system developed by the author, *Crickets*, is detailed in section 4. *Crickets* is an environment in which low-level creativity is achievable through biologically inspired protomusical behaviour. The protomusical behaviour generated by the system is able to be used in many applications across disciplines.

2. SELF-ORGANISATION AND OSCILLATION

2.1. Stigmergy

A self-organising system is a system that forms a pattern or order without a central control mechanism or external influence. The pattern is formed instead via interactions on a local scale, with each part of the system knowing nothing of the global effect of these interactions. Self-organisation is interlinked with two other related terms, emergence and stigmergy, which seek to encapsulate self-organisation from differing viewpoints.

In emergent behaviour, a set of properties or rules are defined through which a sophisticated pattern not present in the design of these rules is revealed [2], [16]. The main criticism of emergence is that an observer must be present. It is only via external observation that emergent behaviour is defined. Agents within the system, by their very nature, cannot intend to produce emergence as that will defeat the point. Furthermore, it is the observer that labels that outcome of the process a 'pattern' prior to being an emergent pattern. This leads to the area being difficult to study with great accuracy.

Stigmergy on the other hand circumvents this problem through its own definition. It is another term that has its roots in the natural sciences, being devised to explain the control of collective behaviour of social insects such as ants and bees [21]. It is a notion common today in many agent based simulations, in that the agents remain independent entities. Their interactions with the environment affect the behaviour of the other agents, which in turn affects them. Stigmergy is therefore defined as pattern formation in a collective via an interaction with an environmental mediator.

A common example of Stigmergy is an ant following a pheromone trail to a food source. The ant is merely following a trail it senses in the environment. The ant in turn leaves behind a trail of its own, thus strengthening the attraction of that path to other ants. The resultant collective behaviour is that of many ants taking the shortest possible route between the food source and the nest.

Theraulaz and Bonabeau identify two current types of stigmergy: quantitative and qualitative.

> With quantitative stigmergy, the stimulus-response sequence comprises stimuli that do not differ qualitatively [...] and only modify the probability of response of the individuals to these stimuli. Qualitative stigmergy differs from quantitative stigmergy in that individuals interact through, and respond to, qualitative stimuli. [21]

The concepts of stigmergy and emergence are so closely related it may seem to be a matter of semantics. However, stigmergy offers a method that acknowledges the notion of the actively observing agent and therefore offers a more stable ground for the experimentation and exploration of self-organising phenomena.

2.2. Synchronisation

Oscillations can be observed practically everywhere. In nature, behaviour such as a honey bee's activity cycle and a fiddler crab's claw waving are examples of living oscillations. On the microscopic level, every living system is controlled by internal biological oscillators, which affect the organism's physical, emotional and cognitive behaviour. Furthermore, some systems that appear to be one oscillator, can in fact transpire to be constructed of a whole host of oscillators, collectively exhibiting one large synchronised oscillation [8].

The question which then arises in this case is; how do these systems perform their synchronisation? The idea of oscillations in nature possessing identical natural frequencies is unlikely, especially when these oscillations are subject to the random forces of environmental noise. This lead Kuramoto [12] to state that mutual synchronisation could be the only way the oscillation is both produced and maintained.

Kuramoto defines the term synchronisation as, "multiple periodic processes with different natural frequencies [that] come to acquire a common frequency as a result of their mutual or one-sided influence" [12]. However, throughout this paper, the term synchronisation is used in conjunction with the term entrainment. There is a key difference between the two terms regarding the way that the oscillators interact. Entrainment refers to a one-sided interaction where one oscillation, the *slave*, synchronises with a second oscillator, the *master*. In a synchronised oscillation however, there is a degree of mutual feedback where the two oscillators find a common frequency and phase.

Oscillator synchronisation is a self-organising phenomenon. Entrainment, on the other hand, cannot strictly be said to be self-organising, as the master oscillator centrally controls the oscillation. In terms of stigmergy, oscillator synchronisation is quantitatively stigmergic.

2.3. The Kuramoto Model

An artificial evolution study of the firefly, a natural synchronising agent, hinted that synchronisation was achieved via a method where control signal flow was modified in the agent, resulting in a phase shift [11]. In nature, it is unlikely that the exact phase shifting method evolved by this method is occurring. However, synchronisation through shifting phases is not a new discovery and has been explored in great detail in the Kuramoto model.

Kuramoto formulated a mathematical model centred around a generalised oscillator as a basic functional unit, which when combined in some way can output various dynamical behaviours, forming an oscillator *population*. In this way, the exact behaviour of each oscillator is abstracted away, allowing the same model to be used on several different oscillators. A population of many different oscillators can therefore be synchronised.

$$\dot{\theta}_n = \omega_n + \frac{K}{N}\sum_{m=1}^{N} \sin\left(\theta_m - \theta_n\right) \tag{1}$$

(1) shows the resultant formula that has come to be known as the Kuramoto model for synchronised oscillators. $\dot{\theta}_n$ is the change of phase of the *n*th oscillator, θ_n, θ_m are the phases of the *n*th and *m*th oscillators, ω_n is the *n*th's natural frequency and K is the coupling constant. The model specifies a global coupling where each oscillator is inter-connected via a sine interaction function, the output of which is reduced to zero where the phases are identical, or differ by π. The interaction is strongest where the coupled oscillators are in an anti-phase relationship, or differ by $\pi / 2$, as the output of the function is either at one or negative one at this point. This means that the oscillators coupled via this model are attracted to a phase-locked synchronised state [4].

The Kuramoto model has been criticised in terms of its neuroscientific plausibility [4]. The root of the problem is that real neurons and their cortical oscillations are spatially embedded and therefore their coupling should be as well. Thus, Breakspear et al. added a time delay parameter to the model. In (2), α is a mapping function converting a time delay into a corresponding phase offset. Oscillators situated further apart receive the information according to this delay. This delay parameter causes complex synchronisation dynamics in the population. In this circumstance, a stable synchrony becomes difficult, if not impossible, to achieve [4].

$$\dot{\theta}_n = \omega_n + \frac{K}{N}\sum_{m=1}^{N} \sin\left(\theta_m - \theta_n - \alpha_{mn}\right) \tag{2}$$

2.4. A Stigmergic Kuramoto

Stigmergic synchronisation cannot be modelled with the Kuramoto model. In Kuramoto, a single oscillator in the model has a map of the entire collective state, whereas stigmergy relies on indirect communication.

Adjustments can be made to the model, to increase its stigmergic saliency. For example, Breakspear et al.'s addition of a delay parameter (2) goes some way to bringing in a concept of the environment. By spatially

embedding the oscillators, the model now acknowledges the environment. However, even taking these steps we do not alter the model enough to consider it stigmergic. The interaction is still direct and in this sense it is more of an emergent formula than a stigmergic one. The inherent problem in the Kuramoto model in a self-organisational context is that stigmergy was not present in the initial design. To incorporate this, a radical rethink is required.

2.5. Local Field Coupling

The Van der Pol oscillator (VDPO) (4) was inspired by biological systems in that it was used to model an extremely common biologically synchronised rhythm; Van der Pol used three oscillations of this form to model the human heartbeat. More recently, Camacho et al. [5] have used VDPOs to study the circadian rhythm of melatonin in the human eye.

$$\ddot{x} - \varepsilon\left(1 - x^2\right)\dot{x} + x = 0 \tag{4}$$

The VDPO obeys a limit cycle of 2 and is a relaxed oscillator, meaning that voltage or activation accrues over time and releases sharply. The non-linearity coefficient ε, controls the rate of this action and thus the frequency. Since the dynamics of the system obey a limit cycle, natural frequency can be measured by first measuring the period of the cycle.

These systems can be coupled in a multitude of ways (see [5]), though the one believed to be the most useful here is what is referred to as the bath method. Camacho et al.'s coupling of two VDPOs via a bath is illustrated in (5), (6) and (7). Two VDPOs, x and y are coupled via a bath, z. The parameter K represents a coupling co-efficient, much the same as the Kuramoto model.

$$\ddot{x} - \varepsilon\left(1 - x^2\right)\dot{x} + x = K\left(z - x\right) \tag{5}$$

$$\ddot{y} - \varepsilon\left(1 - y^2\right)\dot{y} + y = K\left(z - y\right) \tag{6}$$

$$\dot{z} = K\left(x - z\right) + K\left(y - z\right) \tag{7}$$

This synchronisation method is of interest in a stigmergic sense as it can be easily altered so that each oscillator has a local bath to which other oscillators contribute to a greater or lesser extent. These local baths can serve as a perception of the environment.

$$\ddot{x}_n - \varepsilon_n\left(1 - x_n^2\right)\dot{x}_n + x = K\left(z_n - x_n\right) + p_n \tag{8}$$

$$\dot{z}_n = \sum_{m=1}^{N} K_n I_{mn}\left(x_m - \alpha_{mn} - z_n\right) \tag{9}$$

$$\alpha_{mn} = f\left(\tau_{mn}\right) \tag{10}$$

(8), (9) and (10) show an adaptation of the bath method into a stigmergic form. The model has been extended to become *n*-dimensional. In this paper, an *n*-dimensional bath is termed a *field*. Each field is now made local to that oscillator, termed *local field coupling* (LFC). The parameter I is added as a scale or influence factor between oscillators where:

$$1 \geq I \geq 0, \quad I = f\left(D_{mn}\right) \tag{11}$$

D_{mn} is the distance between the *n*th and the *m*th oscillators when placed in the field. This influence factor is a further step to that proposed by Breakspear et al. It arises from the notion in Reynold's *Boids* [19] that a close neighbour will have greater influence on the agent than neighbours further away. It is a form of signal loss linked to distance.

To make this a viable real world model, the coupling must be resilient to noise, which is accounted for by the noise parameter *pn,* a random perturbation.

Furthermore, to satisfy Breakspear et al.'s neurological requirements, a time delay parameter, αmn is added converting a time delay, τ_{mn}, into a corresponding phase offset.

3. STIGMERGIC CREATIVITY

3.1. Chronobiology and Biomusicology

Two scientific disciplines dominate the study of rhythms in biological entities: chronobiology and biomusicology. Chronobiology concerns the study of periodic phenomena in biological systems. Biomusicology, on the other hand, is the study of music and rhythmicity from a biological perspective.

A common feature of chronobiology is the notion of the essential nature of biological rhythms, and often the common acceptance that these rhythms are self-organised [1], [14]. The implications of this are substantial. Life and rhythmicity it seems are coupled together as all living entities require biological oscillators. Many biological sub-systems are linked to the notion of time, such as respiration, reproduction, growth and death.

In addition, Attia [1] states that in the case of certain animals, there is evidence of complex interactions existing with the environment, which in turn affect their biological rhythms. Although the term itself is not used in [1], this is stigmergy.

3.2. Protomusic

Animal calls may be a source of insight into the animal origins of music [15]. Chimpanzees, for instance, engage in pant-hooting, which is a loud, structured, rhythmical hooting used often in chorus to keep in touch with the rest of the troupe in the forest. Early synchronised choral behaviour such as pant-hooting may have arisen from a need to attract mobile females. A synchronised call produces a summed amplitude, and therefore a louder call, meaning passing females are more likely to be attracted to that group of males [17].

However, Marler notes that creativity is a fundamental requirement for the origins of music. The clearly rhythmic, but not necessarily creatively musical behaviour in animals is termed protomusical, meaning that the behaviour exhibits common musical features without being defined as music.

3.3. Rhythmic Behaviour as Self-organised Synchronisation

> Not only is a clear operational definition of 'good' music hard to come by, a definition of 'music' is often arbitrary at best. […] Rhythm essentially refers to timing, both how long events last, and when they are scheduled to occur. […] Music […]

may be beat-oriented or pulsed, but it need not be. […] Even arhythmic music is rhythmic. [3]

Throughout this paper, I have been referring to the notion of rhythmic behaviour, rather than music. This is partly due to the difficulty of defining music and the relative ease of defining rhythm that Biles elucidates above. In the previous section, the term *protomusical* was defined as a rhythmic behaviour, which is the basis for musical behaviour. Biles' second consideration above notes that the concept of rhythm is inextricable from merely events in time, therefore even random temporal events can be considered to be rhythmic. A further step is then needed to make rhythmic behaviour more than random noise: organisation.

Varèse coined a commonly received base definition of music: that it is 'organised sound' (see [9]). Merker notes that the pulse in a piece of human music is most often constant throughout the piece.

> We hardly ever encounter music employing discrete, that is, stepwise (from one beat to the next) and frequent tempo changes as a structural device for generating variety. [17]

Therefore in protomusical behaviour, as in measured music, the organising principle is pulse. Here, the same distinction is drawn between two loose categories of music as Merker defines; either music is measured, or it is not, which also echoes Biles' sentiment of arrhythmic music. This does not mean to say that in measured music the pulse is always fixed; Merker acknowledges that retardations or accents exist, but that these are deviations from a base pulse [17].

In many humans the behaviour of tapping along to music is innate, and it provides evidence for an interesting human trait: that we have an extremely wide range of tempos to which we can entrain to, which is not the case in other natural synchronisers such as insects [17]. It is not only the singular individual who has the ability to entrain to a pulse, but many individuals can mutually synchronise their pulses. Hence Merker states, "musical pulse is a cardinal device for coordinating the behaviour of those individuals in a joint, coherent, synchronised performance" [17]. It is a fundamental building block for musical group activity, even individual musical acts such as piano playing require a sufficient level of biologically internal synchronisation to occur.

According to Merker, there is good evidence to suggest that the synchronised chorusing of many animal species in the field is an epiphenomenon, arising out of a competitive strategy the males employ. Each male times their call in competition to be the first, thus causing a synchronising effect [17]. By definition self-organisation is also an epiphenomenon: it is a secondary occurrence, arising out of the primary behaviour.

Merker states that the human notion of music has evolved out of this protomusical synchronised rhythm, just as the human species and chorusing animals such as chimpanzees evolved from common ancestors.

> Such an ancestral adaptation for entrainment to a repetitive beat would supply […] an ancient biological foundation for the musical pulse no human culture has failed to feature among its musical means of expression. […] This adaptation for entrainment supplies an irreducible biological root of human music [17].

What Merker refers to as 'adaptation for entrainment' above can also be expressed as self-organised synchronisation.

3.4. Stigmergic Creativity

According to Merker, the human notion of music has evolved out of protomusical synchronised rhythm processes. He also states that, "synchronous chorusing and dancing to a repetitive beat qualifies as music in the human sense" [17], meaning that a transition from a synchronised rhythm to human-like music may not be that difficult to make.

Etymologically, the Greek term for music originally included not only melody, but also dance and poetry, where the common feature is pulse based rhythmicity. Thus music had more in common with protomusic than a contemporary understanding of the term. Musicians, orators and even soldiers still share this same underlying protomusical synchrony inherent in the classical meaning.

4. THE CRICKETS SYSTEM

4.1. System Aims

This paper presents a system for simulating and generating protomusical behaviour. The system, named *Crickets*, provides an environment in which oscillators are subject to the stigmergic self-organised local field coupling (LFC) model set out above.

Traditionally, the phenomenon of oscillator synchronisation has remained within an engineering discipline: chaotic dynamics. However, this science is now a pervasive influence in contemporary culture, with artists, philosophers and commentators increasingly drawing upon the richness of these systems in their work. SymbioticA's *Silent Barrage* [20] is one such example of an artistic project that integrates many disciplines and has been widely praised in the art world for it. According to Leman, artists are increasingly needing the support of scientists in order to explore these areas [13].

Colton [7] hints that in the case where artists have explored these domains, a lack of skill has lead to the work not realising its full potential. This was certainly realised by SymbioticA, since the group was founded by a cell biologist, a neuroscientist and an artist, arguably giving their work more validity.

Leman goes on to state that,

> Multimedia in art is no longer just a matter of bringing together different arts forms on the scene. Instead, the digital forum offers manipulation and integration of microlevels of information processing. [13]

This suggests that artists may benefit from modular scientific components in their art systems.

This separation between scientific model and creative application was a key aim of *Crickets*. The final system is able to be utilised in a variety of different applications. As discussed above, protomusical behaviour has a variety of different applications in art such as poetry and dance, but it also has applications in science, in areas such as neural oscillation research (see [4])

Crickets is a simulation tool, providing the microlevel of oscillator synchronisation modelling, and as such it is intended to be a component of a larger system. To date, *Crickets* has only been applied and tested in music generation systems.

4.2. System Overview

Crickets encapsulates a qualitatively stigmergic oscillation synchronisation environment and interaction interface for that environment. A user interacts with the *Crickets* interface and the oscillation environment is affected. *Crickets* then broadcasts its data to other applications, known as patches. Each patch parses the data and produces some output as a result, be that audio or other. Thus the user is reacting to the output of the patch but interacting with the *Crickets* system, resulting in a closed feedback loop.

Crickets sits in the same vein as systems such as *IanniX* [6], *StarLogo* [18] and *Silent Barrage* [20]. It is a hybrid of these three systems in that it is an environment for exploring a specific self-organisation phenomenon whilst also acting as an interface for control of an external system, thus becoming a component in a larger system such as an art installation.

The majority of the computation in *Crickets* occurs in an implementation of the LFC model. In the current version, the oscillators in the field are all Van der Pol oscillators. The coupling co-efficient K has been implemented as a global parameter for every oscillator. This is mainly due to simplifying the interaction interface for the system. Allowing for specific coupling values between pairs of oscillators is possible, but creating an intuitive control proved to be a challenge. It seemed overly complex in terms of the usability of the system and so was dropped in favour of the global parameter.

Specific values for K between pairs of oscillators can still be achieved through the use of the influence variable, I. I is used to scale K depending on the distance between two oscillators. This acts as a distance dependent weight between the two oscillators.

Crickets uses the Open Sound Control (OSC) protocol to communicate its state with other programs. The OSC protocol was chosen for its flexibility in being able to communicate with many hardware and software systems.

There are two types of OSC messages broadcast: *update* and *field*. *Update* messages are sent for every cricket in the system on every simulation step, which currently runs at 60Hz. The message contains the cricket's identification number (ID), output level, selected state, and x and y coordinates. *Field* messages are broadcast once when the system starts up and subsequently when a cricket's local field has changed due to movement, change of range, or other interaction that affects the cricket's influence level. A field message contains the cricket's ID and information about the IDs and influence level of each cricket in its local field.

4.3. Results

Crickets' ability to be used for protomusical behaviour has been evaluated through user testing. An informal qualitative study was undertaken in which the system was explained to the users and they were given approximately one hour to interact with the system and some example patches implemented in *SuperCollider*. All the test users who took part were computer literate musicians with varying amounts of experience using other music software. Some were also experts in fields such as performance art, teaching and design. The users were encouraged to talk aloud during their experiences and ask questions when they occurred to them.

A key theme in the users feedback was that of exploration. All users mentioned that by interacting with *Crickets* they felt they were exploring the different sounds and rhythms one could create. Often the results could not be predicted but a sense of order was present in the system. One user even commented on the emergent properties of the system, stating that complexity was achieved through simplicity.

All users said they felt like they understood the system after the demonstration was over, however when asked to describe the system each user had their own interpretations. Some emphasised the idea of it being an interface for generative control, whereas others focused more on the interplay between the oscillator phase relationships.

Some even described it as a potential musical instrument and here it was clear that the point where *Crickets* ended and a patch began had become blurred. Whilst this is an interesting perception by the user and shows a strong connection between interface and sound, it should be discouraged until patches for *Crickets* have fully considered the mapping between data and output (see [10]). This is not an impossible task with *Crickets*, since designers of patches for the system can consider it for each patch they create.

All users immediately saw the potential for *Crickets* to be applied in other fields and most expressed an interest to create their own patch for the system. Interfacing *Crickets* with a video system was a common idea among the user group. Robotics, lighting, and musical effects were other areas of interest.

5. CONCLUSIONS

The phenomena of oscillation synchronisation is observable in countless places in the natural world. Living and non-living systems entrain and synchronise microscopic oscillators to form one large oscillator on the macroscopic level, which can in turn be synchronised. The way these oscillators achieve their synchronisation is largely accepted to be via self-organised processes. However, the neurological plausibility of Kuramoto's synchronisation model has been questioned and the self-organisation aspect, in particular in terms of stigmergy, is not present. It has thus been reworked here into a stigmergic model for oscillator synchronisation: local field coupling (LFC).

The fields of chronobiology and biomusicology further elucidate oscillator synchronisation in living systems and the phenomena has been used to explain many forms of behaviours in those systems from their activity cycles to their development from birth to death. Even the animal origins of music have been suggested to arise out of synchronisation phenomena: a clearly rhythmic, but not necessarily creatively musical behaviour is achievable through synchronisation. This behaviour is termed *protomusical*.

This paper proposes that protomusical behaviour can be achieved through self-organised, stigmergic synchronisation, or in other terms: LFC. *Crickets* was developed to achieve low-level creativity through biologically inspired protomusical behaviour. This system is interactive and acts at Leman's microlevel of information processing [13], enabling the protomusical behaviour generated by the system to be reused in many applications across disciplines.

6. REFERENCES

[1] Attia, J. (2004): 'Behavioural Rhythms of Land Snails in the Field', *Biological Rhythm Research*, 35 (1-2), pp 35-41.

[2] Beckermann, A. (1992) 'Introduction – Reductive and Nonreductive Physicalism', in Beckermann, A, Flohr, H and Kim, J. eds. *Emergence or Reduction? Essays on the Prospects of Nonreductive Physicalism*. Berlin, Walter de Gruter.

[3] Biles, J.A. (2007) 'Evolutionary Computation for Musical Tasks', in Miranda, E.R. and Biles, J.A. (eds.) *Evolutionary Computer Music*. London: Springer, pp 28-51.

[4] Breakspear, M. Heitmann, S. and Daffertshofer, A. (2010) 'Generative models of cortical oscillations: neurobiological implications of the Kuramoto model', *Frontiers in Human Neuroscience*, 4, pp 1-14.

[5] Camacho, E., R and, R. and Howland, H. (2004) 'Dynamics of Two Van der Pol Oscillators Coupled Via a Bath', *International Journal of Solids and Structures,* 41, pp 2133-2143.

[6] Coduys, T., and Ferry, G. (2004) 'IanniX aesthetical/symbolic visualisations for hypermedia composition', *Proceedings International Conference Sound and Music Computing.* Paris.

[7] Colton, S. (2009) *Seven Catchy Phrases for Computational Creativity Research*. London, Imperial College. Available from: http://www.doc.ic.ac.uk/~sgc/papers/colton_dagstuhl09.pdf (accessed 05th September 2011)

[8] Foster, R. and Keirtzman, L. (2005) *Rhythms of Life*. London: Profile.

[9] Goldman, R. F. (1961) 'Varèse: Ionisation; Density 21.5; Intégrales; Octandre; Hyperprism; Poème Electronique. Instrumentalists, cond. Robert Craft. Columbia MS 6146 (stereo)', *Musical Quarterly* Vol. 47(1) pp 133–34.

[10] Hunt, A., Wanderley, M. M., and Paradis, M. (2002) 'The importance of parameter mapping in electronic instrument design', *Proceedings of the 2002 Conference on New Instruments for Musical Expression (NIME-02).* Dublin.

[11] Knoester, D. B. and McKinley, P. K. (2009) 'Evolving Virtual Fireflies', *Proceedings of the 10th European Conference on Artificial Life, Budapest, Hungary, September 2009*. Berlin: Springer.

[12] Kuramoto, Y. (1985) *Chemical Oscillations, Waves, and Turbulence.* Berlin: Springer.

[13] Leman, M. (2005) 'Musical Creativity Research', in Kaufman, J.C. and Baer, J. (eds.) *Creativity Across Domains: Faces of the Muse*. London: Lawrence Erlbaum Associates.

[14] Lloyd, D. (2007) 'Ultradian rhythms and clocks in plants and yeast', *Biological Rhythm Research*, 37 (4), pp 281-296.

[15] Marler, P. (1999) 'Origins of Music and Speech: Insights from Animals', in Wallin, N. L., Merker, B. and Brown, S. (eds.) *The Origins of Music*, Massachusetts: MIT Press, pp 31-48.

[16] McCormack, J and Dorin, A. (2001) 'Art, Emergence, and the Computational Sublime', *Proceedings of Second Iteration: a conference on generative systems in the electronic arts.* Melbourne, CEMA.

[17] Merker, B. (1999) 'Synchronous Chorusing and Human Origins', in Wallin, N. L., Merker, B. and Brown, S. (eds.) *The Origins of Music*, Massachusetts: MIT Press, pp 31-48.

[18] Resnick, M. (1997) *Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworld.* London, MIT Press.

[19] Reynolds, C. (2001) *Boids: Background and Update*. (s.l.):(s.n.). Available from: http://www.red3d.com/cwr/boids/ (accessed 5th September 2011).

[20] SymbioticA. (2010) *About Us*. Perth: The University of Western Australia. Available from: http://www.symbiotica.uwa.edu.au/home/about (accessed 5th September 2011).

[21] Theraulaz, G and Bonabeau , E. (1999) 'A Brief History of Stigmergy ', *Artificial Life*, 5 (2), pp 97-116.

WALK WITH ME - A WORK OF POINTLESS CURIOSITY

Jeroen Strijbos *Rob van Rijswijk* *Niels Bogaards*

Strijbos & Van Rijswijk
www.strijbosvanrijswijk.com

Stedekestraat 53
5041 DM Tilburg
The Netherlands

Elephantcandy
www.elephantcandy.com

Rapenburg 91c
1011 TW Amsterdam
The Netherlands

1. ABSTRACT

In this paper sound artists and composers Jeroen Strijbos & Rob van Rijswijk and programmer Niels Bogaards present a musical smartphone app they designed, which (using GPS data) adds layers of sound and music to a circumscribed area to be listened to via headsets: specific sound events are triggered by the position of a listener relative to spots within that area determined in advance by the artists. The article gives an outline of the effects and the workings of the app, which combines elements of composition and installation, and which they have so far adapted to a variety of areas.

Figure 1. app icon

2. INTRODUCTION

Walk With Me is a complex of topographic compositions performed by means of a smartphone-app, operating within and designed for predetermined environments. Technological developments have opened up possibilities to create compositions that are shaped into unique and personal electronic realtime musical experiences connected to a specific geographical area by the audience through the use of smartphones. New compositions are made for each environment. In this app, devised by Jeroen Strijbos and Rob van Rijswijk, the integrated use of GPS-triggered non-linear composition and realtime Digital Sound Processing (DSP) of environmental sounds, elements that are here combined for the first time, it creates a soundscape in public spaces. This soundscape changes for the individual listeners wearing earpieces with their movements around the area, and with chance events occurring in the area for which the app has been devised.

Figure 2. splashscreen app

Composing music for an urban or rural environment (as opposed to a closed architectural space) offers new perspectives, and raises questions regarding the interaction and the structure of the electroacoustic composition in relation to the audience and their surroundings.

Walk With Me presents an opportunity for a poetic exploration of a city or an area in the countryside. The composition fuses fiction and reality by superimposing environmental, musical and vocal sounds, and realtime processing of sounds occurring in the surroundings. It evokes an experience akin to walking in a movie, in which the imagery consists of the scenery that the audience walks around in.

What Strijbos and Van Rijswijk have set out to do is