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Tectonic: a Networked, Generative and Interactive, Conducting Environment for iPad

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ABSTRACT

This paper describes the concepts, implementation and context of Tectonic: Rodinia*, for four realtime composer-conductors and ensemble. In this work, an addition to the repertoire of the Decibel Scoreplayer, iPads are networked together using the bonjour protocol to manage connectivity over the network. Unlike previous Scoreplayer works, Rodinia combines "conductor view" control interfaces, "performer view" notation interfaces and an "audience view" overview interface, separately identified by manual connection and yet mutually interactive. Notation is communicated to an ensemble via scores independently generated in realtime in each "performer view" and amalgamated schematically in the "audience view" interface. Interaction in the work is enacted through a collision avoidant algorithm that modifies the choices of each conductor by deflecting the streams of notation according to evaluation of their "Mass" and proximity to other streams, reflecting the concept of shifting Tectonic plates that crush and reform each other's placement.*

1. INTRODUCTION

TECTONIC: Rodinia is a work for four realtime composer-conductors and ensemble. In geology Rodinia is the name of a supercontinent that contained most of Earth's landmass between 1.1 billion and 750 million years ago. Tectonic can mean both 'the study of the earth's structural features' and 'the art of construction' and this works reflects both aspects of the word's meaning. The concept of slowly shifting plates that crush and reform each other's placement is the central paradigm of the work.

Rodinia is the second in a series that began with *Tectonic: Vaalbara* [2008]. In *Vaalbara* five instrumental streams are performed independently, using computer generated metronome pulses to manipulate the tempo of each stream, allowing the blocks of musical material to slide, grate and collide with one another like tectonic plates.

In *Rodinia* four composer/conductors control separate streams of graphical notation and audio (comprising live instruments reading the notation and their processed audio components) that interact through the algorithmically evaluated Mass and proximity of each stream. The work is performed using the Decibel Scoreplayer on multiple iPads via a manually connected network allowing for each participant conductor or performer to identify independently on the network [1]. The manually connected network was first used in Laura Lowthers' work for the Decibel ensemble, *Loaded* [2015]. Previous scores had prioritized synchronization between multiple iPads in order to present uniform representation of fixed scores for all performers. It is made possible by the adoption of the bonjour protocol to manage connectivity over the network. The use of the bonjour protocol also allows connectivity via OSC to stream data to other devices. In *Rodinia* this is used to stream generative data to a dedicated computer using Wave Terrain synthesis to process and spatialise the audio from the ensemble.

2. IMPLEMENTATION

Rodinia employs generative scores for each of the four streams directed by the composer-conductors. Unlike previous generative notation works by Vickery such as *Lyrebird* [2] and *The Semantics of Redaction* [3] *Rodinia* does not use the analysis of a pre-existing audio artifact to generate notation.

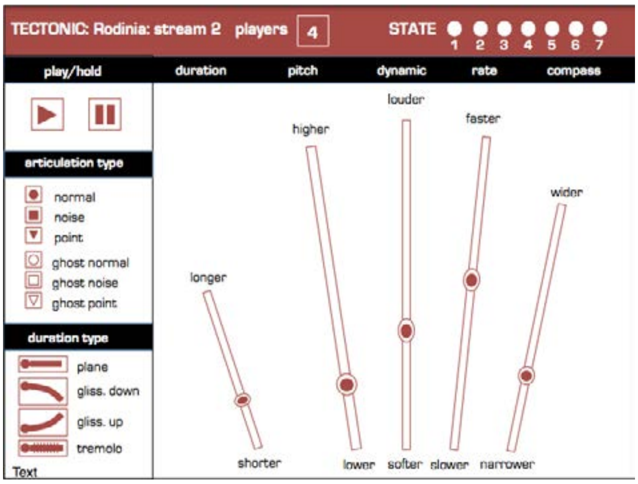

Figure 1. *Rodinia* conductor controller interface

Each composer/conductor in *Rodinia* uses an iPad interface, the "Conductor View", to generate notation for their group (Fig 1.). The controller interface is operated by two hands (the iPad permits 11 simultaneous multi-touch points) [4] allowing parameters to be specified simulteneously by the Left hand (play/hold, articulation, duration type) and Right hand (duration, pitch, dynamic, rate and compass). The variables Conductor View interface are:

- Players – defines the number of performers in each stream and generates a part of varied shade for each performer;
- State – saves a particular configuration of parameters that can be accessed at a later point;
- Play/Hold - stops and starts the generation of new notation;
- Articulation type – defines the graphical shape of the notation events;
- Duration type – generates alters the morphology of the notation events (line, curve up/down and tremolo);
- Duration – generates events of statistically longer or shorter duration;
- Pitch – designates the central pitch of the notation;
- Dynamic – generates larger/louder or smaller/softer notation events; and
- Compass – designates the statistical range that notation events fall within.

These parameters define the boundaries of stochastically generated graphical events which are distributed to the all of the iPads belonging to the same stream on the network. Like many works for the Decibel Scoreplayer, the notation for the performers is scrolled right to left across the iPad screen: in *Rodinia* this is designated the "Performer View" (Fig. 2). The scroll time, the duration between the notation's appearance on the right of the screen and its arrival at the "playhead", is 12 seconds. The playhead is - a black line of the left of the screen at which the performer's execute the notation [5]. This produces a scroll-rate of between 1.1 and 1.8 cm/s depending on the iPad model, falling below the maximal eye-hand span of the average sight-reader (less than 1.9 cm) [6][7]. Therefore, the musicians do not perform the notational event until it arrives – 12 seconds after specification by the conductor. This allows for the performers to comfortably "look ahead" at on-coming notation and for the conductors to evaluate strategies to avoid (or seek) collision with the other 3 streams.

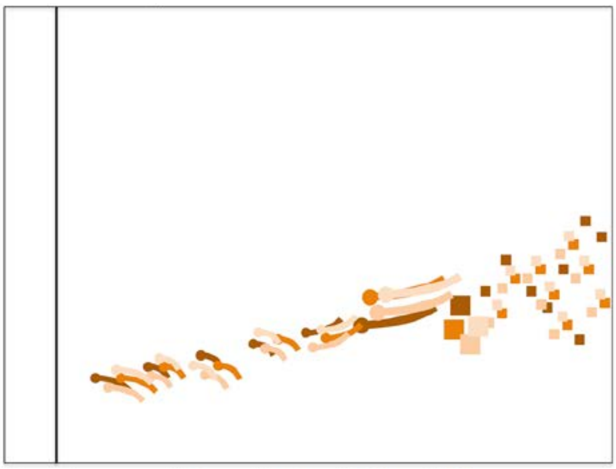

Figure 2. *Rodinia* Scoreplayer "Performer view" of Stream 1.

Rodinia also amalgamates the notation from each stream into a single score, the "Audience View", to be shown on a large screen behind the performers for both the audience and the conductors. Unlike the performer view, audience view shows the streams of notation approaching from four directions (left, right, top and bottom) (Fig. 3). The notation "wraps" around each time it completes the crossing from one side of the score to the other. As notation does not appear until the moment at which it is executed by the performers, the audience see it at the moment that it is heard.

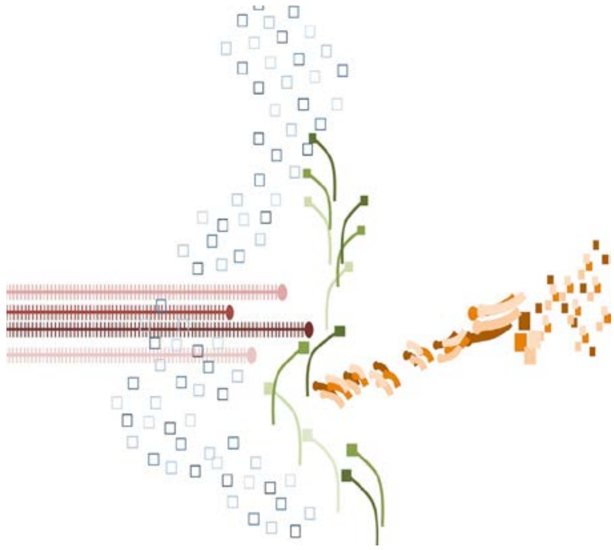

Figure 3. *Rodinia* Scoreplayer "Audience view"

The use of an audience view was first employed for the Decibel Scoreplayer in Vickery's work with Jon Rose *Ubahn c. 1985: the Rosenberg Variations* [2012]. For this and other rhizomatic works [8] the projected Audience View provides an overview of the current position of each player and graphically illuminates the choices taken in each stream.

Rodinia employs a collision avoidant algorithm which may modify the choices of each conductor. As notational streams approach one another they are pushed upward or downward according to their evaluated mass. Mass is defined as the density (duration, dynamic and compass) multiplied by the weight (articulation type and proximity) of each stream. Notation streams with a higher force deflect those of a lower force proportionally, spatially high-

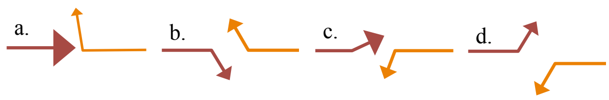

Figure 4. Collision avoidant using force evaluation: a. strong(L)/weak(R) interaction, b. weak(L)/weak(R) interaction, c. medium(L)/weak(L) interaction, and d. spatially higher stream deflects lower stream downwards.

er streams deflect upwards and lower stream downwards, if the streams are of equal height and mass the direction of their deflection is chosen randomly (Fig. 4).

This approach is similar to that adopted in Chappell's "self-avoiding" curve drawings [9], and Greenfield's "Avoidance Drawings" [10]. Chappell describes his process in the following way:

> *To generate a self-avoiding curve, I place "antennae" on the moving point that sense when the path is about to be crossed. . . . If the left antenna crosses the path, then the point executes a 180° reversing turn to the right* [11].

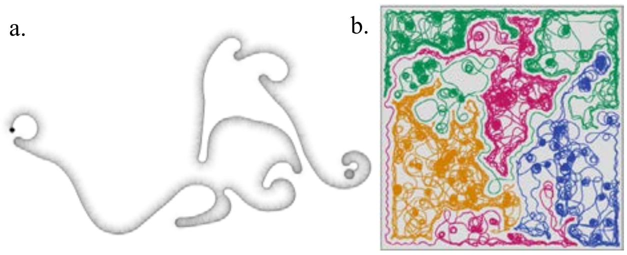

Figure 5. a. example of a point in the plane performing a self-avoiding random walk using Chappell's model. b. Greenfield's "avoidance drawing" (2015).

The key difference in *Rodinia* is that since music is a time-based medium, it can never "double-back" on itself and therefore in a generative score the deflection can never be greater than 90º.

Early studies conducted in Jitter, by Vickery for testing "collision avoidant lines" explored this paradigm, exploring "proximity only" avoidance (all lines were of equal density) to illustrate the kinds of pathways generated by this strategy (Fig. 6).

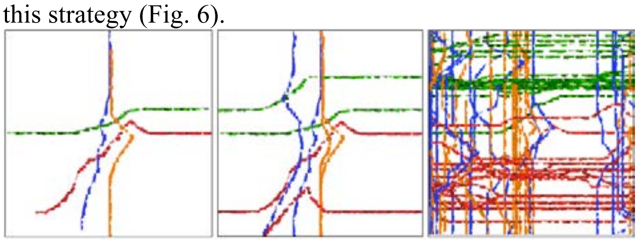

Figure 6. Vickery "collision avoidant lines" study for *Tectonic: Rodinia* (2013): first, second, and twelfth passes.

In Rodinia, a mass is calculated for each stream, M_S, based on its *cumulative density*: that is, based on the positions of the right-hand parameter sliders selected in the conductor view. This is based on both horizontal and vertical density as pictured in the score view.

The deflection angle of each stream, θ, is based both on the current mass of each stream calculated individually, as well as the total mass. If the distance between the leading point of each stream is below 175px the deflection angle rises from 0º to 90º exponentially in inverse of the proximity, as the proximity approaches 0px, such that:

$$\theta = \frac{\beta M_S \theta_D}{M_T} \tag{1}$$

where θ is the new angle calculated individually for each stream, M_S is the mass of the same stream, M_T is the total mass, θ_D is the angle scalar, and β is a positive or negative scalar determining a turn in direction either left or right of the current direction of each stream. The height parameter is used to calculate whether an interaction results in an upward or downward deflection. The total mass, M_T, is the sum of all stream masses such that:

$$M_T = M_A + M_B + M_C + M_D \tag{2}$$

3. NOTATIONAL CONVENTIONS

The notational paradigm, semantic spatial notation, employed by *Rodinia* has been developed over a number of projects by composers working with the Decibel Scoreplayer - in particular the approach to presenting notational events used in the generation of scores from John Cage's *Variations I* and *II* by Decibel [12] Fig. 7.

Figure 7. Decibel's scrolling, proportionally notated screen-score for Cage's *Variations I*.

The notation draws on conventions established in works by Cage and his colleagues Earle Brown and Christian Wolfe [13], chiefly proportional notation in which the vertical height of the notational event signifies relative pitch (relative to the range of the instrument), horizontal length its (absolute) duration and thickness its dynamic.

Unlike Decibel's scores for *Variations I* and *II*, in *Rodinia* timbre is indicated by the shape of the notational event rather than the shade. Performers are expected to match the qualities of timbral notational types (such as "normal" tone (rich harmonic sounds), "ghost" tone (harmonically poor sounds) and "noise" tone (inharmonic dense sounds)) within each stream. Each conductor controls a group of instruments of similar range so that register choices by the conductors are mirrored in the ensemble.

The streams, and individual parts within a stream are differentiated using shades of four principal colours orange, red, green and blue. Green-Armytage claims that 26 colours should "be regarded as a provisional limit – the largest number of different colours that can be used before colour coding breaks down" [14]. *Rodinia* is conceived for an ensemble of 16 performers (4 per stream) falling within the limits that of colour differentiation.

4. AUDIO PROCESSING APPROACH

The audio of the live instrumentalists is captured and processed digitally in Max/MSP on a standalone computer that is also networked via the bonjour protocol with the

iPad scores. This processing is informed by the movements of the four user controlled streams in order to generate and gradually deform a two-dimensional terrain map [15].
The terrain is initially generated by a method of perlin noise functions and undergoes both spatial deformation using a 2D spatial lookup process and 2D amplitude modulation. The 2D spatial lookup process involves translating four separate planes from a point of origin $(x_1, y_1), (x_3, y_3), (x_5, y_5), (x_7, y_7)$ translated by the movement of four separate streams $(x_2, y_2), (x_4, y_4), (x_6, y_6), (x_8, y_8)$.
The surface is also modulated by the relative direction and interactions of these four streams. A 2D terrain surface is generated iteratively based on the relative direction and distances between the four streams. Equation 3 describes this process for just two different streams (x_2, y_2) and (x_4, y_4). If the change in direction between these streams brings them closer together, an additive function is applied:

$$f(x,y)' = f(x,y) + \frac{\left(\left(\frac{x_2+x_4}{2}\right)x + \left(\frac{y_2+y_4}{2}\right)y + \sqrt{\left(x-\left(\frac{x_2+x_4}{2}\right)\right)^2 + \left(y-\left(\frac{y_2+y_4}{2}\right)\right)^2} \right)^{\frac{1}{100}}}{2\sqrt{\left(x-\left(\frac{x_2+x_4}{2}\right)\right)^2 + \left(y-\left(\frac{y_2+y_4}{2}\right)\right)^2}} \quad (3)$$

where $f(x,y)'$ is the new 2D function, and $f(x,y)$ is the previous 2D function. The iterative process is also applied subtractively for streams that are moving away from each other.
The terrain surface that is generated is then used to control the audio processing by using Wave Terrain Synthesis to control complex sound synthesis [16]. Similar techniques have been explored using Wave Terrain Synthesis as a framework for controlling timbre spatialisation in the frequency domain [17]. However, in this project, this approach it is used for controlling both granular synthesis and spectral spatialisation [18].

a. b.

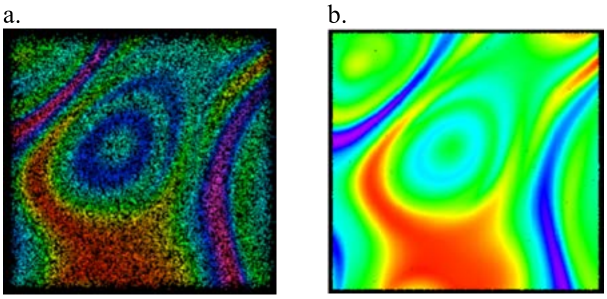

Figure 8 a. A trajectory of white noise reading values off the terrain after 1 second. b. A trajectory of white noise reading values off the terrain after 10 seconds.

The audio-rate trajectory that is used to read information from the terrain is a random 2D signal (white noise, as shown in Fig. 8), a curve that is considered to have effective space-filling properties. This means that details of the contour can be mapped to spatial details of the processing with great precision and resolution. The control information generated, in the way of 8192 individual parameters, those being 352,800 parameters generated per second, are used to control the relative distribution of grains and spectra across 8 loudspeakers.
Controlling granular synthesis via such an interface may take grain time or grain size into consideration. In order to control 1000 simultaneous grains, parameters would be updated at 44.1Hz. Depending on the implementation of the synthesis model, parameter assignments are multifarious. For example 2D data could determine the grain pan and grain length of individual grains.
Swarm-based spatialisation is also used where 2D data is mapped to the spatial position of individual grains. In this case the space-filling properties of the 2D trajectory signal will also correlate with the level of immersion of the resulting sound spatialisation.
Spectral spatialisation is also explored in Rodinia. Each spectral bin is assigned an independent spatial trajectory. 1024 simultaneous frequency bands are updated at lower-dimensional audio rates, that is, at approximately 43Hz. This is used to create complex immersive effects that would otherwise be more cumbersome if using standard control-rate methods.

5. CONTEXT

Preistly defines generative music as

> indeterminate music played through interaction between one or more persons and a more or less predetermined system, such that the players control some — but not all — performance parameters, and relinquish choices within a selected range to the system [19].

Tectonic: Rodinia conforms to this broadest definition of generative art work, through its use of algorithmically determined modification of the intentions of human conductors. The term most specifically refers here, however to the use of generative “emergent: non-repeatable” [20] music notation, a category of the emerging genre of animated notation [21].
It is an interactive form of generation that has game-like aspects to the conductors’ interactions with the algorithmic modifications: a dynamic obstacle game. In this sense it resembles “4-way-confusion (4 agents)” games structure in which “four agents traveling in four opposing directions, meeting at nearly the same time [22] or (form the individual conductors perspective) a “Frogger”-like structure in which “one agent encounters many perpendicular crossing agents” [23].
The game analogy is perhaps amplified by the inclusion of an Audience View, allowing the audience both to hear and view the interactions of the streams, and the conductors' attempts to maintain control under conditions in which their choices are undermined and their ability to utilise the algorithmic modifications to subvert the control of the other conductors.
Musically, the work is something of a concerto for conductors themselves are silent but create sound through their gestures. The Rodinia environment gives significant freedom of choice to the conductors, which is curtailed only by the interactions between their choices.

6. CONCLUSIONS

Tectonic: Rodinia adds a series of new capabilities to the Decibel Scoreplayer. Many of these advances have been dependent upon the adoption of the Bonjour network protocol and the subsequent ability to stream data between a variety of devices.

There is arguably some value in engaging the audience with a visual representation of the sound they are hearing, but the requirements of the performer are quite different to those of the listener and displaying the performer's score to the audience and allowing them to "see what is coming" may reduce the effectiveness the musical discourse when it is actually heard. Delaying the audience score until the moment of its execution by the performers goes some way to alleviating the issue.

Rodinia is somewhat unusual in its combination of generative and interactive qualities in the context of notated music for live instrumentalists. Although the "tectonic" concept is distinct, the implementation of this work provides a framework capable of accommodating a wide range of generative and interactive/generative works employing varied conceptual approaches.

Acknowledgments

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