Graphic Waveshaping

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ABSTRACT

In the design of recent systems, I have advanced techniques that position graphic synthesis methods in the context of solo, improvisational performance. Here, the primary interfaces for musical action are prepared works on paper, scanned by digital video cameras which in turn pass image data on to software for analysis and interpretation as sound synthesis and signal processing procedures. The focus of this paper is on one of these techniques, a process I describe as **graphic waveshaping**. A discussion of graphic waveshaping in basic form and as utilized in my performance work, *Impellent*, is offered. In the latter case, the performer's objective is to guide the interpretation of images as sound, constantly tuning and retuning the conversion while selecting and scanning images from a large catalog. Due to the erratic nature of the system and the precondition that image to sound relationships are unfixed, the performance situation is replete with the discovery of new sounds and the circumstances that bring them into play.

Keywords

Graphic waveshaping, graphic synthesis, waveshaping synthesis, graphic sound, drawn sound

1. INTRODUCTION

Graphic waveshaping may be understood as non-linear distortion synthesis with time-varying transfer functions stemming from visual scan lines. As a form of graphic synthesis, visual images function as motivations for sound generation. There is a strategy applied for creating one out of the other. However, counter to compositionally oriented forms of graphic synthesis where one may assign image characteristics to musical parameters such as pitches, durations, dynamics, etc., graphic waveshaping is foremost a processing technique, as it distorts incoming signals according to graphically derived transfer functions. As such, it may also be understood as an audio effect; one that in my implementations is particularly feedback dependent, oriented towards shaping the erratic behavior of synthesis patches written in Max/MSP/Jitter. Used in this manner, graphic waveshaping elicits an emergent system behavior conditioned by visual features.

The technique expands from two precedents, being graphic synthesis and waveshaping synthesis. As an amalgam of these two approaches, my distinct contribution is towards new performance practices expanding the graphic synthesis paradigm, and not necessarily towards technical progress with regard to longstanding waveshaping procedures. For an introduction to the waveshaping techniques that initially inspired this work, please consult [9] and [14]. Because graphic waveshaping relies upon a dynamic wavetable controlled by the performer, it may be viewed as a variant of scanned synthesis [19], though as positioned here, graphic waveshaping does not aim to model physical phenomena.

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Figure 1: Performance setup

2. GRAPHIC SYNTHESIS

The term graphic synthesis has been proposed to describe the use of images to determine the variables for sound synthesis techniques [15]. An electronic transducer or computer program applies the characteristics of an image towards the creation of sound. A history of graphic synthesis (or drawn sound, graphic sound, etc.) is outside the scope of this paper, but graphic waveshaping may be most clearly linked with precedents where oscillators (or wave tables) are specified graphically and read by a light sensitive apparatus. This principal is evident with light organs [3] [15] [18] and sound-on-film techniques in the early 20th century [6] [10] [11] extending to instruments building on electro-optical technology such as Evgeny Sholpo's Variophone [17], and Evgeny Murzin's ANS Synthesizer [8]. Later in this abbreviated history, Daphne Oram's Oramics stands prominently [5] [12] [13]. Other notable developments include Jacques Dudon's Photosonic Instrument [1] and more recently, Derek Holzer's Tonewheels [4]. Further contemporary comparisons may be made to approaches in digital image sonification such as Jo and Nagano's Monalisa platform [7] and Yeo and Berger's raster scanning technique [20].

I propose that systems involving the preparation of im-

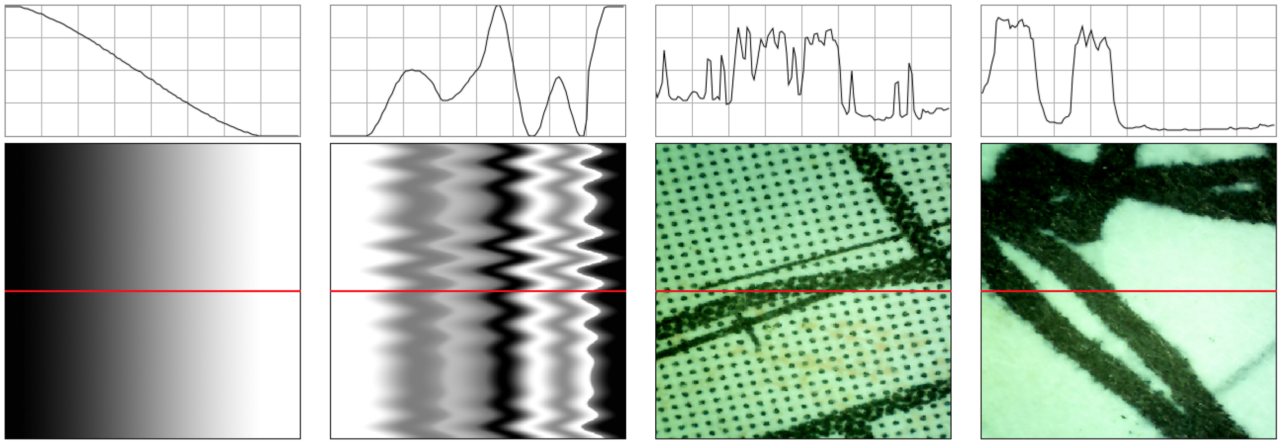

Figure 2: Graphically determined, time-varying transfer functions

ages for machine-conversion to sound generally fall within two categories: transduction and translation. The approaches of transduction and translation involve establishing a system of rules for converting the energy (transduction) or meaning (translation) of the image into an analogous energy or meaning in sound. By learning the correlations between visual specification and resultant sound, a language is learned that can be utilized to evoke predictable results.

Acknowledging that at its core graphic waveshaping distorts an incoming audio signal as a result of visual data, I propose the additional category of interpretation. This framework requires that the rules that determine sound from image are in some way open and allow for sometimes-drastic variability in the outcome. In this case, the visual image is not so much a composed, origin point for sound synthesis, but is instead a guiding influence on a process already underway. Here, the performer may access the variables of conversion, and is therefore responsible for determining the sound of the visual as an instrumental practice. In this framework, there is much in common with patchbay synthesizer performance, where one initiates an electronic process, listens to the output, discovers how gestures relate to the flow, and intervenes in order to access new sounds through learned correspondences between action and output. Sound emerges as the performer troubles the stasis of an electronic system.

3. TECHNIQUE

In graphic waveshaping, the underlying process is related to **movable waveshaping** in which the shape of the transfer function changes or shifts over time [16]. Max/MSP/Jitter has been utilized to implement the technique.

3.1 Basic Implementation

Figure 3 details a patch demonstrating the basic form. Beginning with the top section of the figure, **jit.qt.grab** linked to a live video camera is used to source visual data. One axis of the image will be correlated with time, while the other will be applied as the shaping function. The video passes to **jit.scalebias** where the 4 planes of ARGB char values are summed to create one plane representing luminance. Then **jit.op** inverts those values so that black will have a value of +1.0, white will be the value 0.0 and the grays fall in between. This inversion is optional, but is useful when creating visual images for this process. The data is finally collected in the **jit.matrix** in floating point format and rescaled to 512 x 512 pixels.

In the middle section, **jit.peek∼** facilitates navigation through the linked **jit.matrix** as an audio signal column-by-column. 512 columns are traversed, each having 512 points of data to be used. This is done with a performer-controlled, variable rate **phasor∼** to navigate by column and **count∼** to output the rows at the sampling rate. The **phasor∼** via **jit.peek∼** sends the data to **poke∼**, which in turn updates the **buffer∼** scaling the signal between -1.0 and +1.0 along the way.

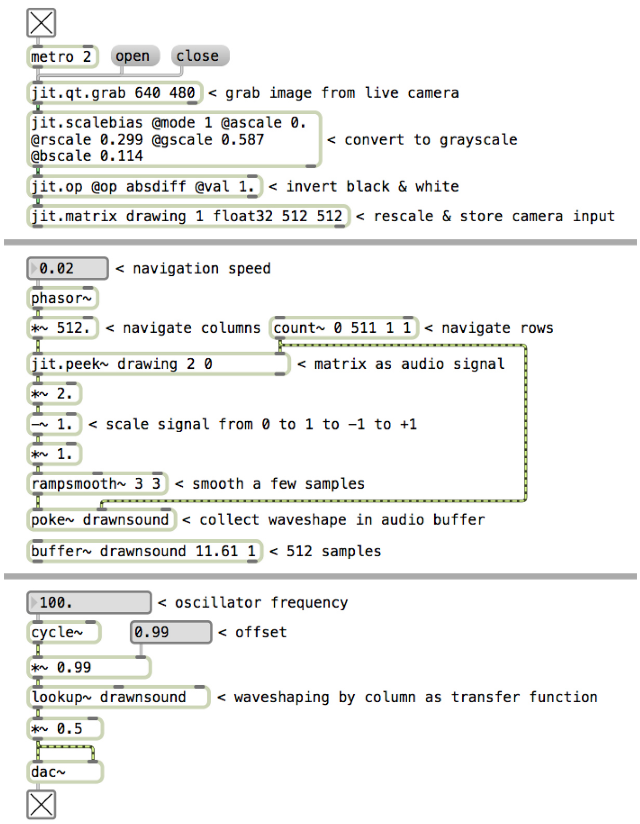

Figure 3: Basic implementation

In the bottom section, **lookup∼** provides the means to utilize the **buffer∼** as the transfer function, distorting the values of an incoming oscillator (**cycle∼**). What differs in this technique from standard waveshaping is that the transfer function is in a state of change. In a standard approach, this function would be static so as to create a specific timbral distortion. In graphic waveshaping, the transfer function is time-varying. It fluctuates according to the rate of navigation through the image.

The frequency of the incoming oscillator (**cycle∼**) is a performer-tuned variable, as is its amplitude (***∼**), which limits the range of the transfer function used. Importantly, this method allows other input signals. However in the basic implementation, to achieve the most salient correlation between visual image and sound, the sinusoidal waveform at high amplitude is preferable, because it will read the full contents of the transfer function. The result of this process is a shifting timbre tied to the visual, yet allowing a change in perceived pitch as the frequency of the incoming oscillator is altered. Aliasing effects that may result from waveshaping are encouraged rather than suppressed.

Figure 2 shows a series of visual images with the corresponding time-varying transfer functions. A central scan line in the images show which pixel row is active as the waveshaper. From the left, the first two images are digitally composed gradients; the last two are from live camera input. The first of these images shows a static curved, diagonal waveshaper going between +1 and -1. This will cause the output of a sinusoidal oscillator to be inverted with a slight sharpness in timbre. In the other figures the distortions are dynamic and more pronounced. When the image has variation in the time axis, the transfer function fluctuates and the distortion becomes the dominant characteristic.

3.2 Situated Implementation

A critical step in the evolution of this technique has been expanding the basic implementation by situating graphic waveshaping within larger synthesis and signal processing networks. These are largely idiosyncratic creations that also make use of additional oscillators, phase distortion, frequency modulation, and feedback in differing configurations. This gives the performer more variables to explore and increases the unpredictable factors due to the complexity of interacting signals and the utilization of feedback in the signal paths.

Figure 4 shows a subpatch where graphic waveshaping is situated in such an erratic network. The method for arriving at the **buffer∼**, utilized by **lookup∼** is identical to the basic technique in Figure 3. Five inputs are shown determining signal values, which based on the performer's decisions dramatically alter sonic outcomes in conjunction with the time-varying, graphically derived transfer function.

4. INTERFACING

Initiated in 2012 with development ongoing, my performance work, *Impellent*, centers on the graphic waveshaping technique situated in synthesis patches with erratic and temperamental behavior, as in the situated implementation discussed in the previous section.

Particularly defining this work are two live visual inputs to the system, Bodelin digital microscopes (ProScope HR2) [2]. These microscopes have variables that can be adjusted during performance, including changes to magnification (from 10x - 400x), focus, and lighting. The microscopes are mounted on microphone boom stands and pointed down towards a table surface. On the table, the performer shifts what is visible to the microscopes using precomposed, mixed media works on paper that function simultaneously as graphic score and performance instrument (Figure 1). Due to the magnification, rich textures and patterns suitable for use as transfer functions are conveyed to the software for interpretation. The play of positioning objects beneath the microscopes and adjusting manual image acquisition variables (magnification, focus, lighting) are significant interface components. Each microscope is tied to its own synthesis procedure, which allows mixing and fading between two distinct voices.

Other critical inputs are multitouch trackpads, which are utilized to tune the sonic interpretation of the visual images by setting frequency variables for signal inputs to the respective synthesis patches linked with each microscope. Finger movements also configure the bounds of image acquisition and zoom, permitting a wider (or narrower) field for exploration, and the directionality and speed of the image navigation, which is visualized on screen for the performer as a short-term map of the evolving performance (Figure 5). This tuning and retuning of the system is vital as part of the performer's play, allowing him to dramatically alter outcomes by upsetting or balancing the emerging behavior.

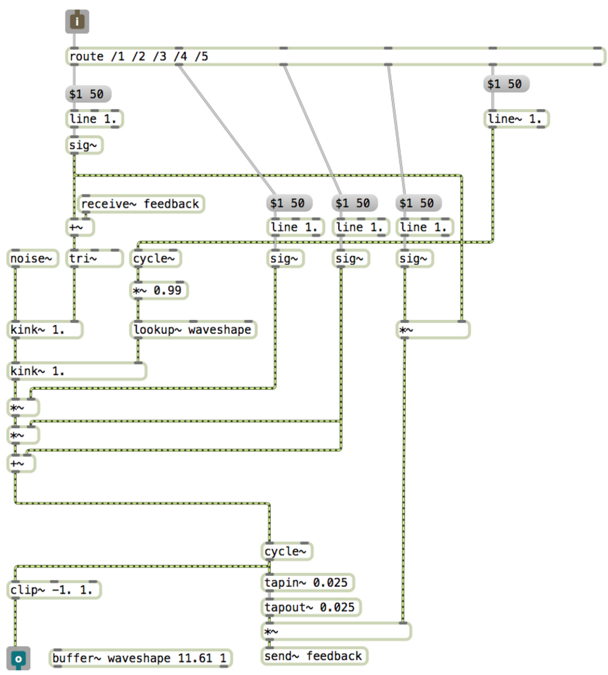

Figure 4: Situated implementation

So far, luminance data has been most often utilized to determine transfer functions. In expansions of *Impellent*, other simultaneous image features have been used to control additional effect parameters, such as linking Hue, Saturation, Lightness (HSL) values or detected visual features to determine delay lines, spatialization, or system states. I describe this related work as **graphic actuation**, a more open concept whereby analyzed image data drives a broader scope of control parameters.

5. FUTURE WORK

There are several directions for future work. First is the refinement of the graphic waveshaping technique including further analysis and development when situated in complex synthesis patches. A better understanding of how to design systems with erratic tendencies conditioned by visual images would be an advantageous result. Careful study is

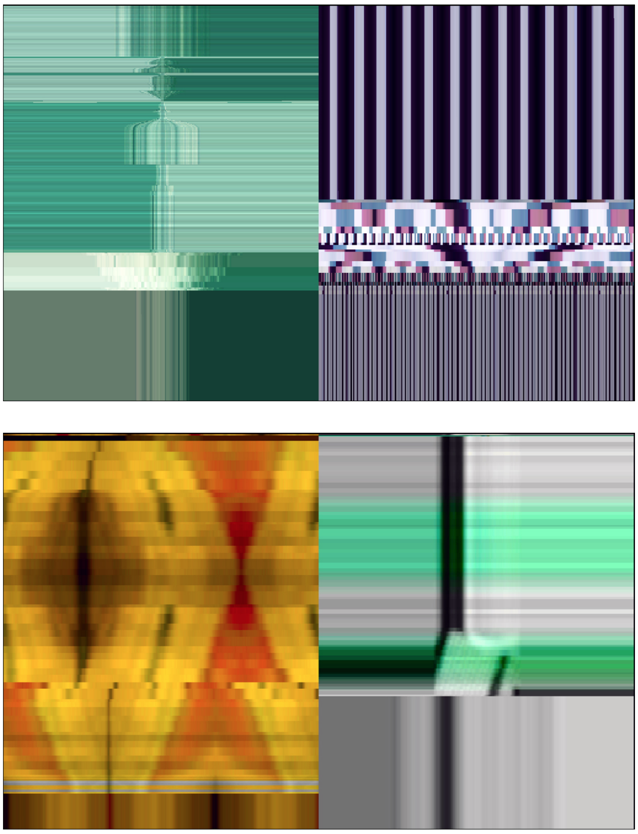

Figure 5: Screenshots, visual interface

needed on links between waveshaping synthesis and visual correlates so as to better explicate the technique and to articulate new paths for research.

As the understanding, refinement, and iteration of these techniques is contingent upon the visual input, further work may be done with regard to the composition of works on paper. Thus far, these visual images have been created based on experience with the system in development, and largely are a result of trial and error and my inclination towards aleatoric approaches. New directions may become clearer by studying correlations between the visual input and sonic output, and therefore give rise to more diversity with regard to purposefully elicited, unpredictable outcomes.

Certainly there may be notable gains in reconsidering image acquisition in terms of resolution and other input devices, partnered with further investigations in applying image analysis and computer vision techniques.

In related research I have utilized simultaneous, extracted visual features to drive control parameters of audio effects, spatialization, and system states. This work, which I describe as graphic actuation in this paper, may be further expanded in the context of graphic waveshaping.

6. CONCLUSION

Graphic waveshaping stands as a combination of graphic synthesis and waveshaping synthesis techniques. When situated in larger, erratic synthesis networks, it is particularly useful in giving a means to tangibly influence systems with purposely-temperamental behaviors. The technique has been a center point around which to build systems that do not enable a language of prescription, but instead one of suggestion or influence. Instability in the rules of image to sound conversion removes the ability to predict exact results, which is viewed as an asset to solo improvisational performance where a spontaneous interaction with the system is desired.

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