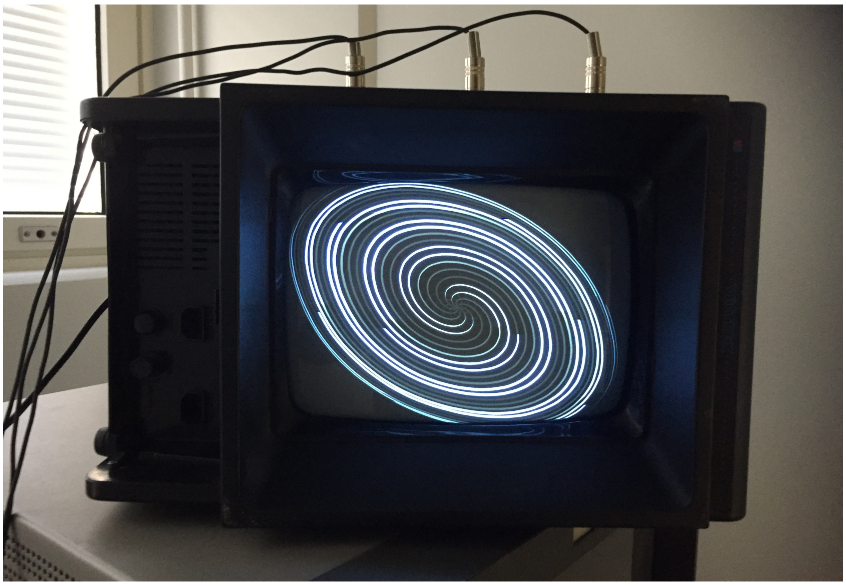
VECTOR SYNTHESIS PURE DATA LIBRARY



Developed by DEREK HOLZER
During the PROCEDURAL AUDIO workshop with ANDY FARNEL
APR-MAY 2017, Aalto University Media Lab, Helsinki FI

ABSTRACT

The VECTOR SYNTHESIS project is an audiovisual, computational art project using sound synthesis and vector graphics display techniques to investigate the direct relationship between sound+image. Driven by the waveforms of an analog synthesizer, the vertical and horizontal movements of a single beam of light trace shapes, points and curves with infinite resolution, opening a hypnotic window into the process by which the performed sound is created.

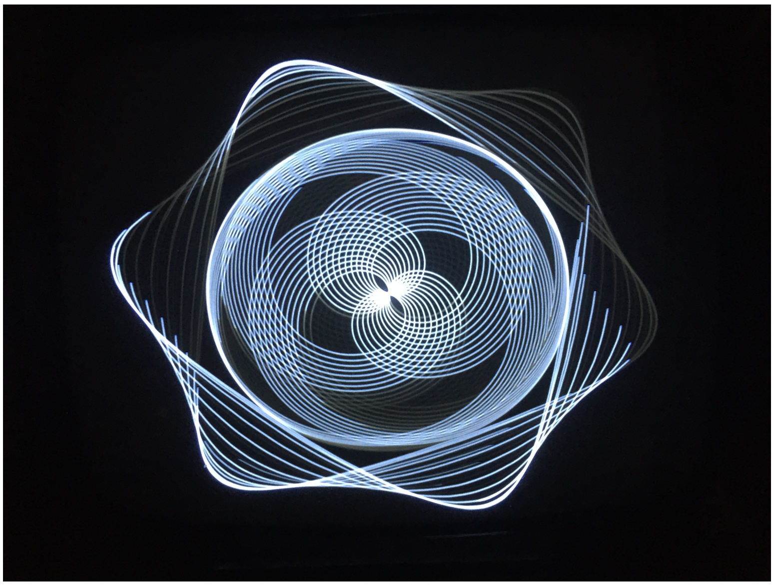
DETAILS

VECTOR SYNTHESIS is based on the well-known principle of Lissajous figures, which are a mathematical representation of complex harmonic motion. Originally displayed by reflecting light between mirrors attached to a pair of vibrating tuning forks, we are most used to seeing them on the screen of an oscilloscope, where they can be produced using pairs of electronic oscillators tuned to specific ratios. The genealogy of this project encompasses 19th century experiments in mathematics and physics, the beginnings of post-war computing on analog mainframes, secret military missile defense stations, the electronic music revolution of the 1960's, the birth of video games as interactive media, and finally the manifest destiny of cathode ray tube monitors as e-waste on a slow boat back to China.

Informed by the discourse of media archaeology, my own personal interest in analog vector graphics isn't merely retro-for-retro's-sake. Rather, it is an exploration of a once-current and now discarded technology linked with specific utopias and dystopias from another time. More info on this project can be found at :

http://macumbista.net/?page_id=4869

PRE-WORKSHOP PROJECT STATUS



Previous to this workshop, I have performed with the VECTOR SYNTHESIS system using three self-constructed “Benjolin” analog semi-modular synthesizers, a DIY DC voltage mixer and a scientific vector monitor. The main benefits of working with analog vector graphics for abstract audiovisual synthesis are as follows:

- Analog vectors are generated by a fairly low-bandwidth, audio-frequency-range signal which can be produced by very common sound hardware and software (as opposed to video signals which require frequencies of 15.625 KHz – 6.75MHz to produce detailed results), thus negating the need to invest in upgraded equipment (an important factor for novices, or for workshop situations).
- As opposed to conventional raster graphics, analog vectors have an almost infinite resolution.
- The control systems for vector synthesis are highly intuitive and the results immediately tangible.
- Vector synthesis maintains a direct, non-symbolic relationship between sound and image due to the fact that both are derived from the same signal.

The disadvantages I discovered of working with a purely analog system stem mainly from the following areas:

- There is great difficulty in obtaining predictable results using analog synthesizers.
- Likewise, there is a similar difficulty in reproducing results.
- The lack of phase locked oscillators in analog music equipment means that the Lissajous figures “spin” without a reasonable degree of control.
- The lack of precise frequency control in the synthesizers being used prevented the fine shape and intensity modulation necessary for highly detailed, “strobe” effects.
- Due to the lack of any multiplexing and blanking signals, only one figure can be displayed at a time.
- It should be noted that most of these difficulties could be overcome by constructing further analog circuits, however I was interesting in prototyping them digitally first.

WORKSHOP ACTIVITIES: HARDWARE

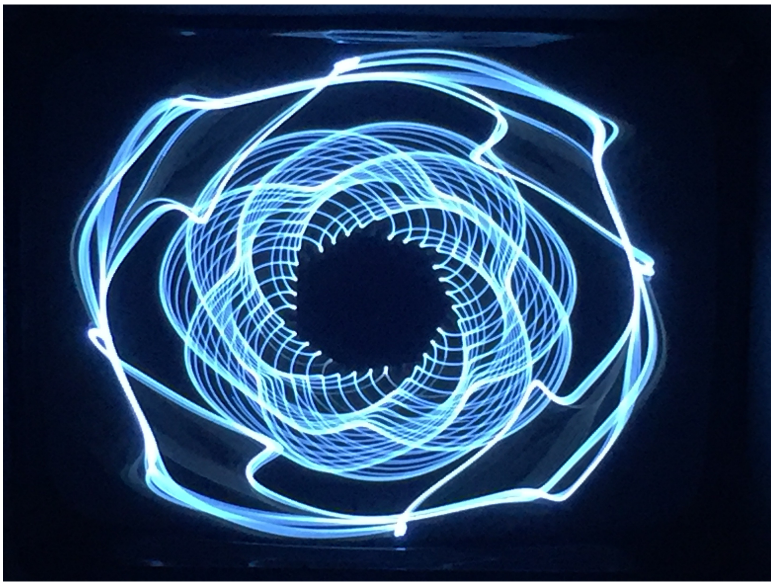
The most important piece of equipment in this setup is the Cathode Ray Tube. One's relationship to the venerable CRT depends very much on their age. So many of us grew up with one constantly around in the form of a television set, while the younger generation live in an era where these objects are rapidly realizing their manifest destiny as e-waste. Unlike modern flatscreens, CRTs draw their image with a single beam of light shot from an electron gun at the back of the tube against a phosphorescent film inside the front of the tube, which gives them their unique visual characteristic.

The first step in the workshop was to modify a 1980's Vectrex game console. The Vectrex was one of the few home video game devices to use a vector monitor rather than a normal television for its display. Conventional video images are said to be raster scanned, i.e. they have been quantized to a grid of horizontal scan lines traced by this light beam, so that the image you see is drawn one line at a time by a left-to-right motion combined with variations in the intensity of the beam.

In contrast to this, the light beam of an oscilloscope or vector monitor (such as the Vectrex) can freely move horizontally or vertically at tremendous speed responding directly the the amount of electrical voltage sent to control it, and is limitless rather than constrained in its resolution. Similarly, the intensity of its beam can also be voltage-controlled, allowing images to be "blanked" as well as a number of high-speed brightness modulations to be used.

To modify the Vectrex, its internal computer was disconnected from the CRT driver board, speaker and power supply. The connections used by the game computer were then connected to three 6.33mm jacks, one each for the X, Y, and Z controls of the CRT. These jacks were then connected to outputs from a MOTU Ultralite Mk3 soundcard. It should be noted that a DC-coupled soundcard such as the MOTU is necessary for full control of the CRT beam, and that the CRT driver board itself has a safety feature which cuts off the voltage to the beam when the input frequency goes too low in order to prevent holes being burned in the phosphorescent lining inside the CRT screen. The X and Y inputs respond to a bipolar voltage of approximately 2V peak-to-peak, while the Z input responds to a unipolar voltage of 0-1V, and the monitor has a bandwidth of roughly 5KHz.

WORKSHOP ACTIVITIES: SOFTWARE



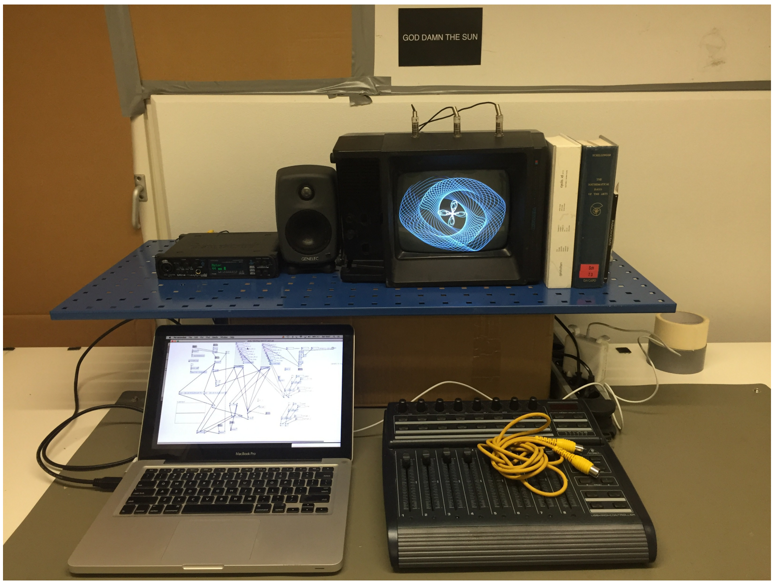
Following the hardware modification phase, I worked with Andy Farnell to develop a phase-locked oscillator system in Pure Data. In the Lissajous-generating patch, all the shape generating oscillators are derived from the phase of a single ramp generator. This phase is multiplied up and used to control a cosine function so that higher harmonics of the time base are derived. An offset to one half of the pair of Lissajous-oscillators allows for phase modulation, affecting the shape of the figure. Differences in the harmonic ratios of the two oscillators (1:1, 3:2, 4:3, 1:2, etc etc) changes the number of nodes seen in the figures. Further multipliers and summing objects allow for modulation of the size and vertical and horizontal position of the Lissajous figure.

Once we had stable and modulatable Lissajous figures, the next challenge was to create more than one on the screen. This required a system for multiplexing and blanking. The multiplexer switches between two (for a start) independent figures at a rate of 50Hz, effectively switching off the gain of the signals creating the figure being multiplexed out, and switching on the gain of the figure being multiplexed in. To prevent small “traces” from appearing between the two multiplexed figures, a pulse with a width of approximately 99% is applied to the Z axis control, with the 1% “off” section of the duty cycle corresponding to the moment when the multiplexer switches between the two figures.

This multiplexing system should easily be scaleable to a greater number of figures appearing on the screen, perhaps by scaling the multiplexing frequency appropriately. Even when the Lissajous figures overlapped in screen-space, this system effectively keeps rendering of them completely separated and without any interference.

The final abstraction we produced was designed to rotate the vector image in 2D space. Depending on the speed of its modulation and where it is placed relative to the scaling and X/Y offset of the Lissajous figure, a great number of visual transformations can be achieved. The vector rotator abstraction follows the formula *Xout=(Xin*cos)-(Yin*sin), Yout=(Yin*cos)+(Xin*sin),* and uses a quadrature oscillator derived from a ramp generator for the sin/cos modulation.

AUDIOVISUAL INTEGRATION



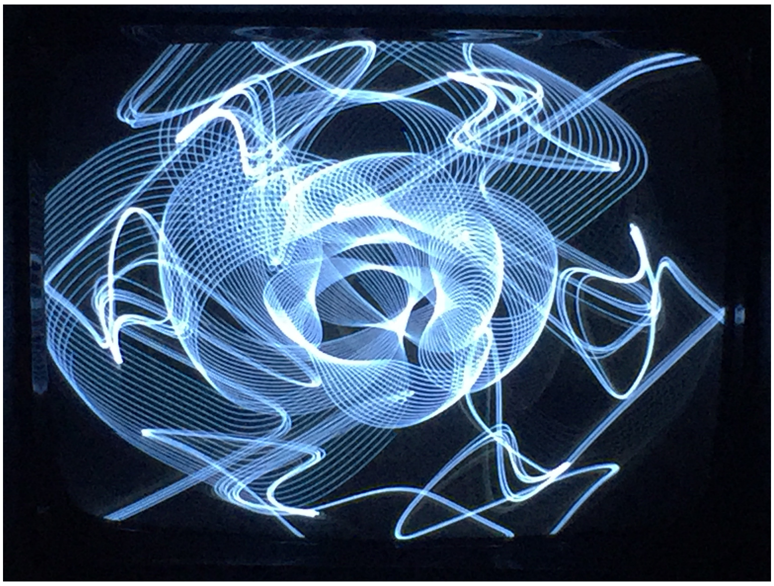
For realtime manipulation and live performance in general, I have found that this method of vector synthesis maintains a direct, non-symbolic relationship between sound and image due to the fact that both are derived from the same signal. In many of the existing works of contemporary “oscilloscope music” surveyed, such as those by Robin Fox, James Connolly and Kyle Evans (as Cracked Ray Tube), Jerobeam Fenderson, Benton C. Bainbridge and others, the artists employ a very literal, 1:1 relationship of left channel=horizontal axis and right channel=vertical axis. This allows the images to be reproduced by anyone using only the digital sound file and any oscilloscope on hand with X and Y inputs.

However, to produce the stable shapes and fixed images seen in the photos in this paper, relatively stable and unchanging sound frequencies are required. Also, while the clearest images tend to come from the simplest waveforms of basic geometry (sine, triangle, square), these shapes may not be the most interesting in sonic terms. And finally, the multiplexing frequency used is constant and can be heard in the output signal sent to the vector monitor. For all of these reasons, some intentional decoupling of the sound and the image may be creatively expedient.

In my performances using analog equipment, I solved this issue by using the core triangular and square waveforms of my analog synthesizer to generate and modulate the Lissajous figures, but then sent these waveforms further along through a number of voltage-controlled, resonant low pass filters before making them audible. This allowed a “carving up” of the audio signal in sonically interesting ways, while preserving the basic integrity of the visual aspects.

In the workshop with Farnell, I tried applying various procedural audio models to the overall sound and image impression. The most successful involved applying the same dynamic envelope to noise sources which were either displayed on the monitor or heard through the speakers. The combined effect, especially in a darkened room, was that of explosions, lightning or fireworks. A great deal of future research with this system will be in developing individual, series or sequenced envelopes of amplitude modulation to enhance the compositional possibilities. Other options for audiovisual integration could include generating basic shapes digitally and modulating them with external, analog signals.

VISUAL DOCUMENTATION



A number of images illustrate this doument, however because of the high rates of continuous size, shape, position and brightness modulation of these shapes in motion, it is extremely difficult to capture and reproduce the visual effects they have on the eye using digital cameras. The fact that so many of these effects are unique to this particular medium convinces me that the effort in developing this project is worthwhile.

An HD video clip displaying multiplexing and rotation of two distinct vector shapes can be viewed at the link below. Please view it with HD1080p and fullscreen settings in dark surroundings for maximum retinal afterimage.

https://player.vimeo.com/video/217155061?quality=1080p

FUTURE DESIGN GOALS

- Increased number of multiplexed and blanked figures
- Preset system for saving specific shapes and their modulations
- Event and envelope generators for compositional use
- MIDI control of all parameters
- External audio input to modulate shapes
- Anti-aliased/bandwidth-limited audio output
- Expanded palette of waveforms
- Templates for generating and manipulating specific 2D and 3D shapes
- The use of physical models to modulate the parameters of each shape (with inspiration from vintage scientific visualizations)
- The ability to import, manipulate and morph three-dimensional .OBJ files, such as those produced by Blender
- All code running on Bela microcontroller through the Heavy compiler
- Built-in, high resolution DAC, with discrete audio outputs and International Laser Display Association standard connection, plus lowpass filtering to common beam angle and kpps ratings
- Further physical interaction hardware to be considered

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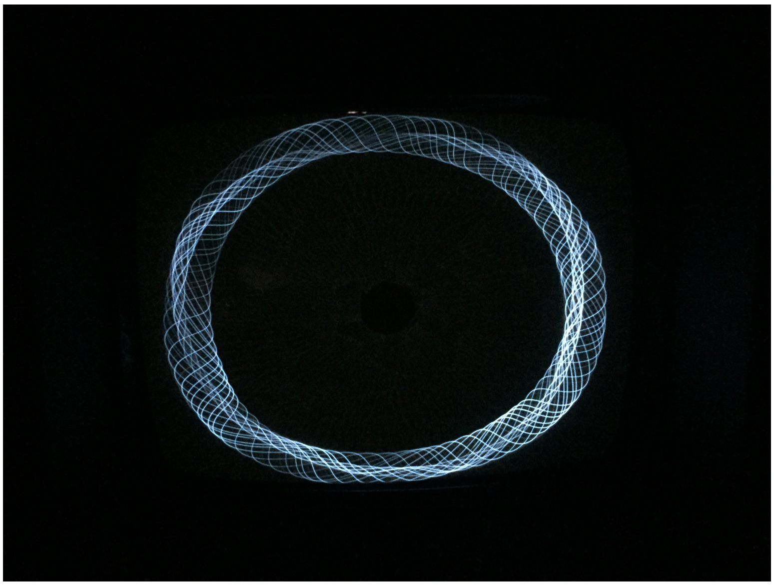

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