"WaveLoom", software to help create photosonic disks.

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***Abstract** : Photosonic synthesis uses computer-designed and fabricated disks. Here we present a new software program to aid in the design of photosonic disks: "WaveLoom," along with other research and creation tools. This software is based on a compilation of a language developed by the Atelier d'Exploration Harmonique (Harmonic Exploration Workshop).*

1. Photosonic disks

The photosonic discs developed by Jacques Dudon within the framework of the Harmonic Exploration Workshop are semi-transparent media designed to pulse light rays passing through them, which are converted by a sensor into electrical signals that are directly amplified [Dudon, Arfib 1990]. Sounds covering the audible spectrum are thus generated, the sound of which depends on the waveforms traced and the rotation speed of the discs.

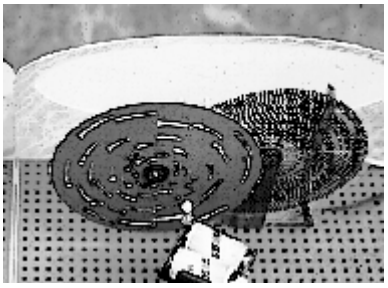


Figure 1: Photosonic reader and sequencer

Lines, sectors and rings are clearly visible to the naked eye. Depending on the disc, the lines can vary from one to five millimeters in width and the number of rings from a few to more than a hundred.

The shapes drawn on the discs are not necessarily crowns but can be unfoldings of various forms. The instrument is played using a manually moved light source. This beam, intercepted by the disc, is projected onto a crescent-shaped photoelectric cell. This specific shape, along with the filtering and non-linearity of the cell, gives this instrument its distinctive color.

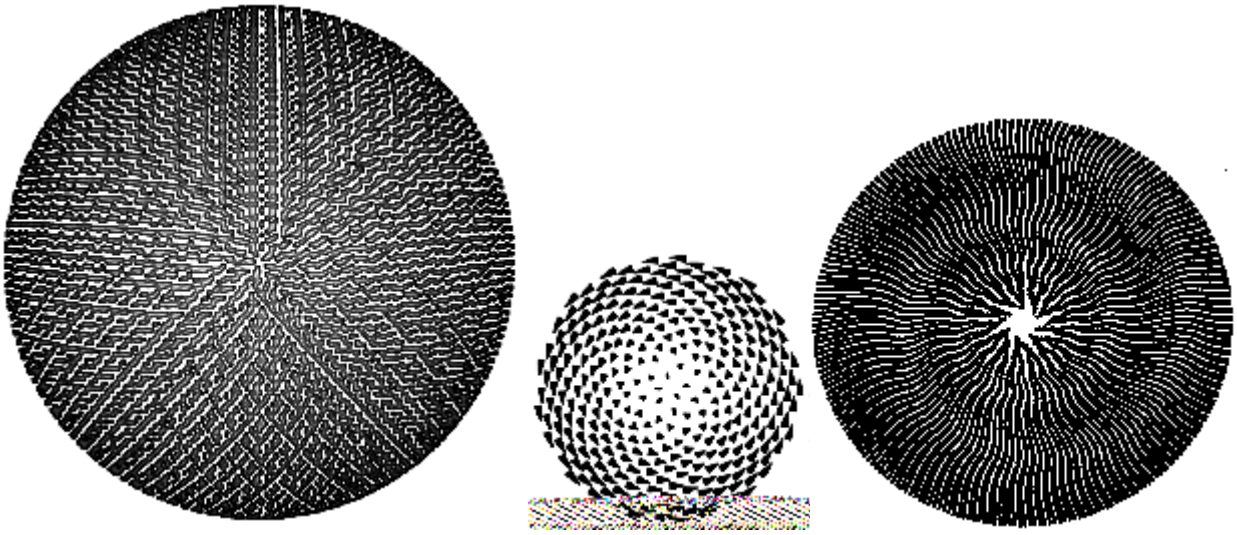


Figure 2: Some photosonic disks

Among the degrees of freedom afforded by these disks is the interception of the beam by a comb filter. Depending on its position (manual and variable), this filter induces a frequency selection, analogous to digital comb filters. In fact, the filter's impulse response is inscribed on a vertical line in this image. It is also possible to intercept ambient light, rather than point light, using sequencer disks (see Fig. 1) that themselves rotate at a slower speed.

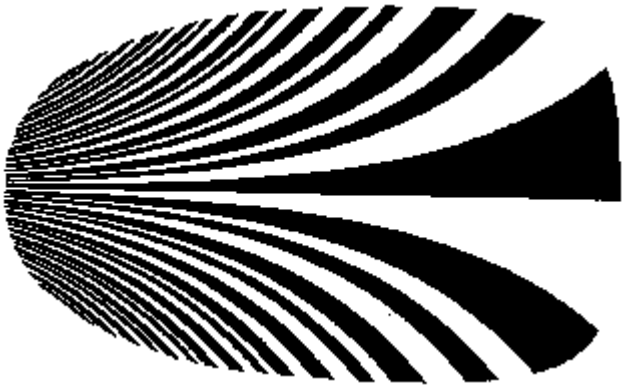


Figure 3: An interceptor comb

Nevertheless, it is the original waveform inscribed on the disc that provides the exploratory field of timbres. Two generations of software have made it possible to create these discs.

2. Old method (Daniel ARFIB [1988])

Jacques Dudon virtually designs the shape and distribution of the strokes on a computer, using specialized software whose specifications he defined with Daniel Arfib. The strokes, thus parameterized by the software, are drawn using a plotter, and the final design is imprinted onto a flexible, transparent plastic disc by photographic printing. It is the strokes and their grouping into repetitive patterns that correspond to the range of sounds available on this disc.

This process was used to create four hundred discs that allowed for the experimentation of multiple parameters linking wave geometry and sound, as well as the development of players that have now reached a fully operational stage. Around one hundred concerts were given on these instruments, culminating in a first compact disc (" *Audible Lights* ") produced by the Harmonic Exploration Workshop.

This software, written in Turbo Pascal 3.0, generated a set of HPGL instructions from an ASCII text file, designed to control a plotter. The accuracy of the disk drawings was entirely dependent on the machine's operating condition and the pens. A disk of average complexity required approximately eight hours to plot.

Furthermore, the process only allowed for the plotting of flat areas, the minimum width of which was limited to the thickness of the pen stroke (0.5 mm).

3. New version: "WaveLoom" (Patrick SANCHEZ [1996])

The advent of PostScript and new computer technologies has improved the process by increasing the speed and precision of the drawing, and by integrating new graphic possibilities such as grayscale. The resulting disc description files are directly usable by current professional photogravure equipment.

The software was developed using Visual Basic 4.0 on a PC-compatible computer and integrates with Windows 3.x or Windows 95. On-screen disk visualization was made possible by the implementation of the freeware software Ghostview. This visualization allows for continuous monitoring of the disk creation progress.

The language used to describe photosonic disks is at the level of a machine language: each sentence consists of an operation code followed by a variable number of fields. The basic operation code is that used to create a "daylight." A "daylight" is the space left free on a corona for the passage of light between two opaque arcs. On a corona, these lines are determined by two angles (start and end) which are expressed as inverses of a turn. The last field indicates the transparency of the line: this value is between 0 and 1 (0 for black, 1 for white). For example, to draw a circular arc between 0 and 180 degrees on a corona, the data to be entered are:

```
J1 1 (0.0 0.5) 0.5
```

Another basic operation involves deploying the defined arc into a ring with a width specified by its minimum and maximum radii: `DA 1 20 30`

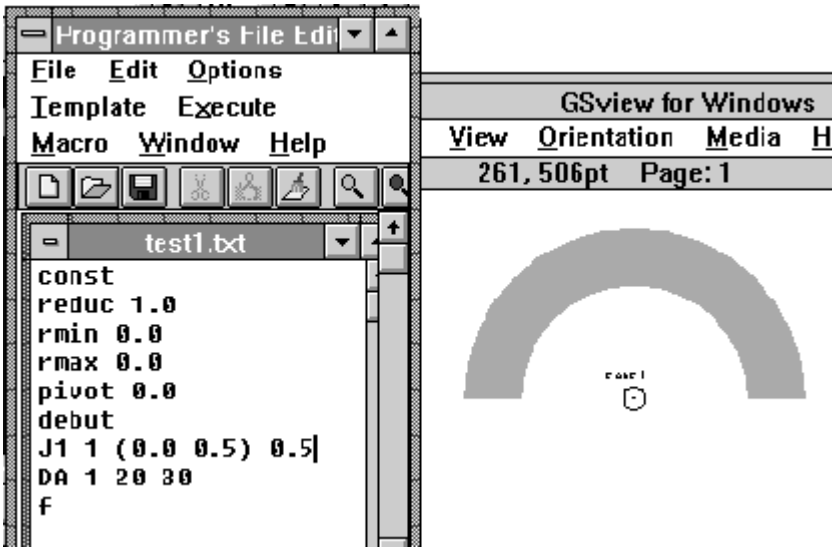


Figure 4: A simple example of arc creation

The operating codes represent an alphabet of 22 basic operations such as:

* Wave repetition

* Symmetry

* Pivoting

* Composition, omission

* Frequency modulation

* Erasure, elongation, compression, etc.

* Addition, subtraction

These operations allow for a wide range of creative possibilities. Furthermore, the list is not exhaustive. The language has been enriched with functions allowing transformations across the entire disk (reduction, radius adjustment, etc.).

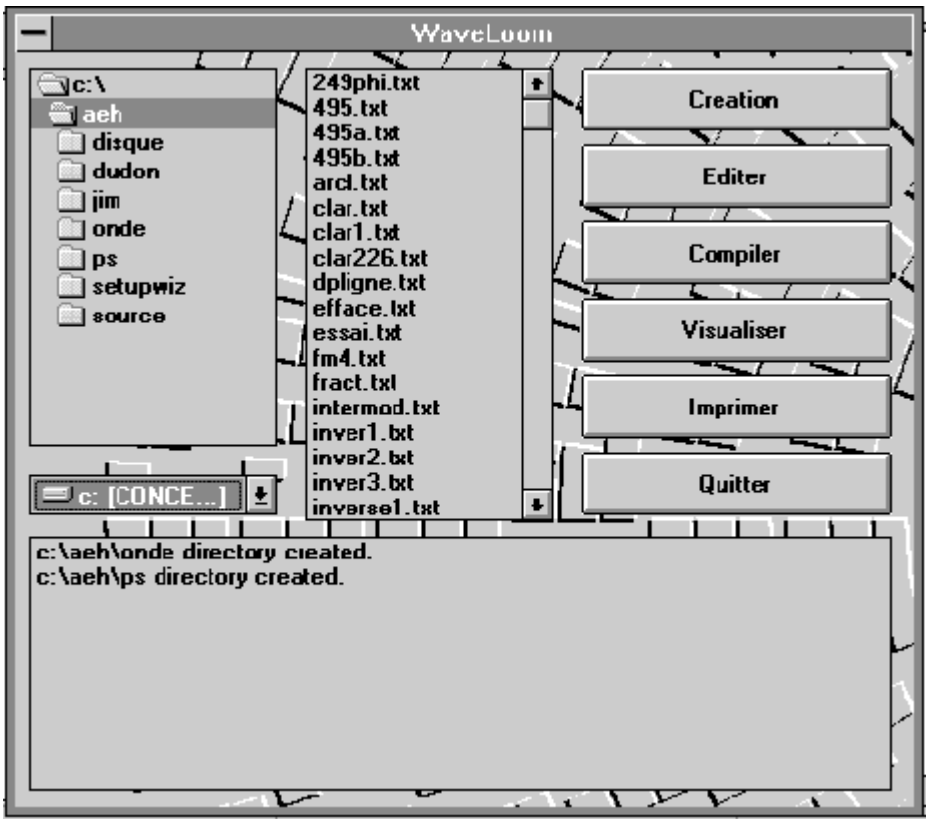


Figure 5: An example of the user interface

The user interface is designed for ease of use. A drag-and-drop interface allows for editing, compiling, viewing, and printing. The editor is also freeware; in this case, it's called Programmer's File Editor (PFE). Errors are displayed in a control window during compilation.

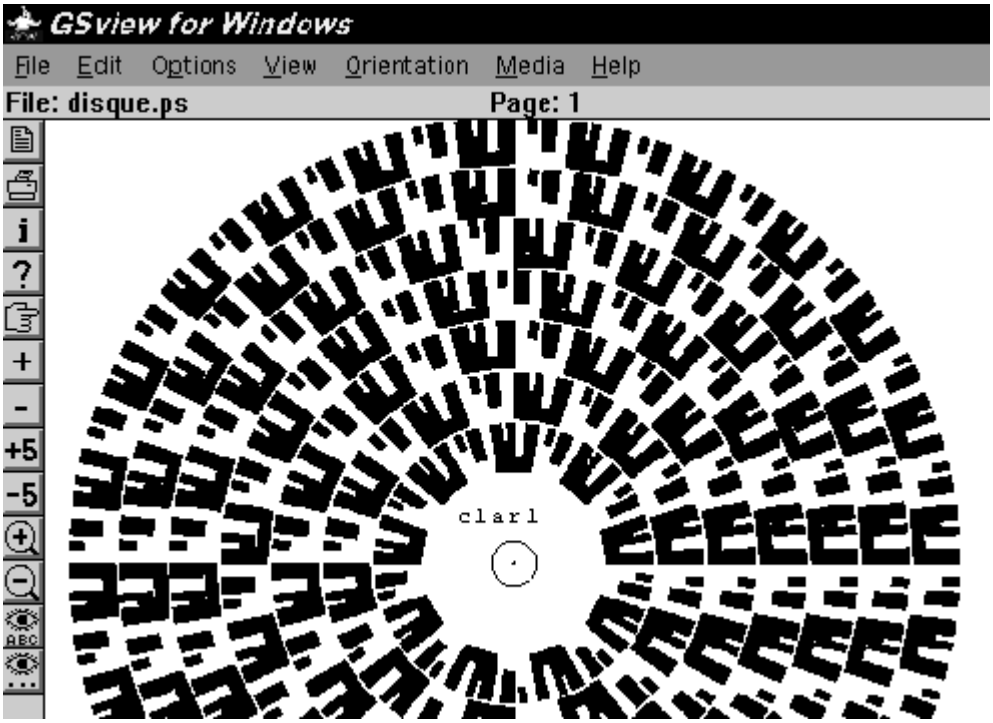


Figure 6: "clar" fractal wave, pentatonic scale

This new version includes new features compared to the previous one but is still being developed; for example, a synthesis developed on several rings from real sounds, as well as other extractions from natural

sounds, are planned. The main advantage of this software is that it integrates the design and creation of photosonic discs into a single workstation with significant precision and ease of development, particularly in terms of interactivity (immediate visualization of the discs).

4. Analysis of some crowns:

In parallel with the creation of discs on transparent media, Daniel Arfib is studying the digital modeling of the device, in order to have a listening approach before any material realization.

It is interesting to be able to understand the relationship between the waveforms drawn on the disks and the resulting spectra. However, the photosonic synthesis instrument itself does not read only one ring at a time; nevertheless, it is very useful to know in advance the result produced by each ring. Therefore, the figures below show some waves and their Fourier transforms generated using Matlab software.

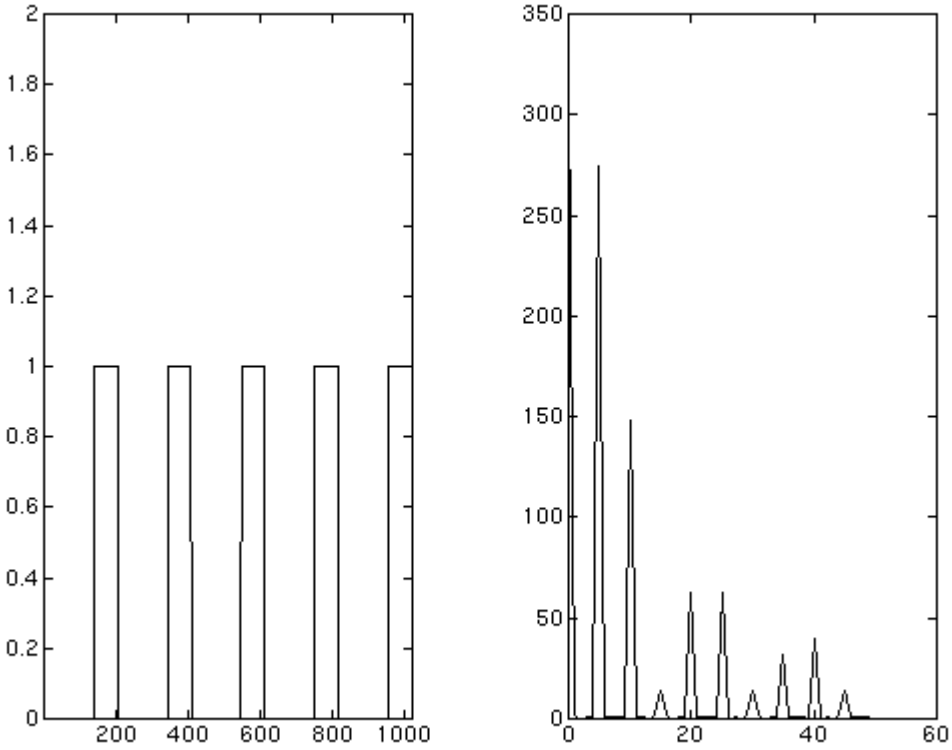
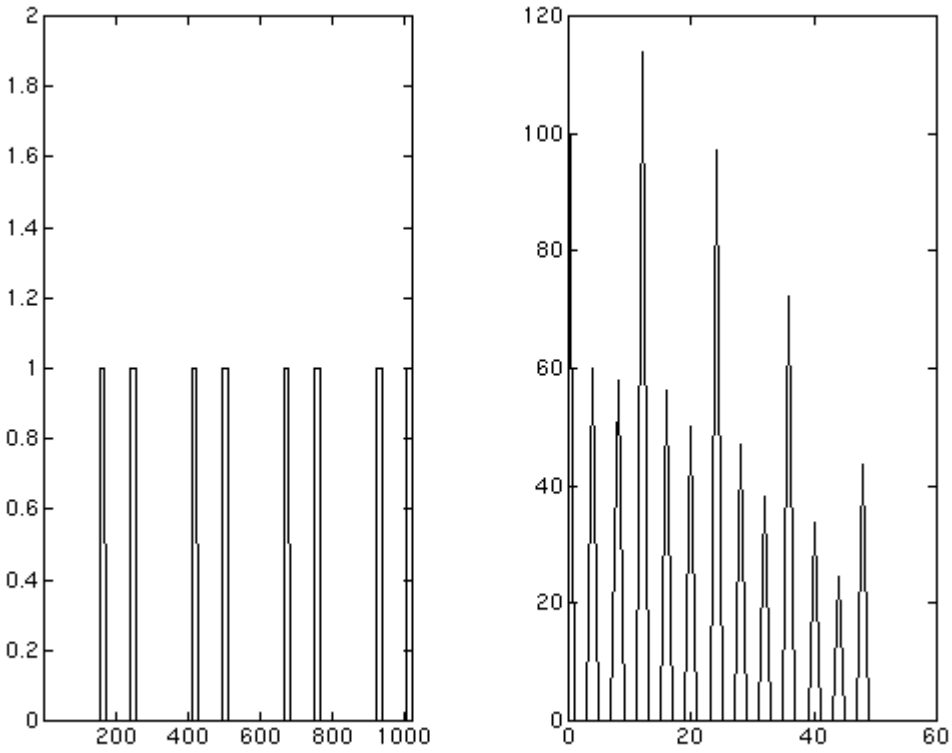


Figure 7: Regular harmonics

The first wave (on/off) is a succession of regular "holes." In this case, the frequencies are multiples of the harmonics of this repetition frequency. But the distribution of these harmonics depends on the width of the hole. Thus, a "hole" with a duty cycle of 1/n will see the kn harmonics disappear. In this example, a repetition cycle of 5, a duty cycle of 0.32, will cause a dip around the 15th, 30th, and so on harmonics.



the

Figure 8: Regular omission

The second wave is a "regular omission." This means there are two cycles: the pulse cycle itself, which is 12 in the example above, and the omission cycle, which consists of omitting one hole every three cycles, resulting in four omissions per cycle. In this case, we observe that the fundamental frequency is that of the omission, but the predominant harmonic is that of the pulses. The sound effect is therefore that of a double note, one higher and the other lower. The lower note can be considered, in a way, a subharmonic of the higher note. Generally, records using this technique generate an ascending scale chosen on high harmonics for the pulse frequency and for the other sequence of divisions of these frequencies that form an independent melody.

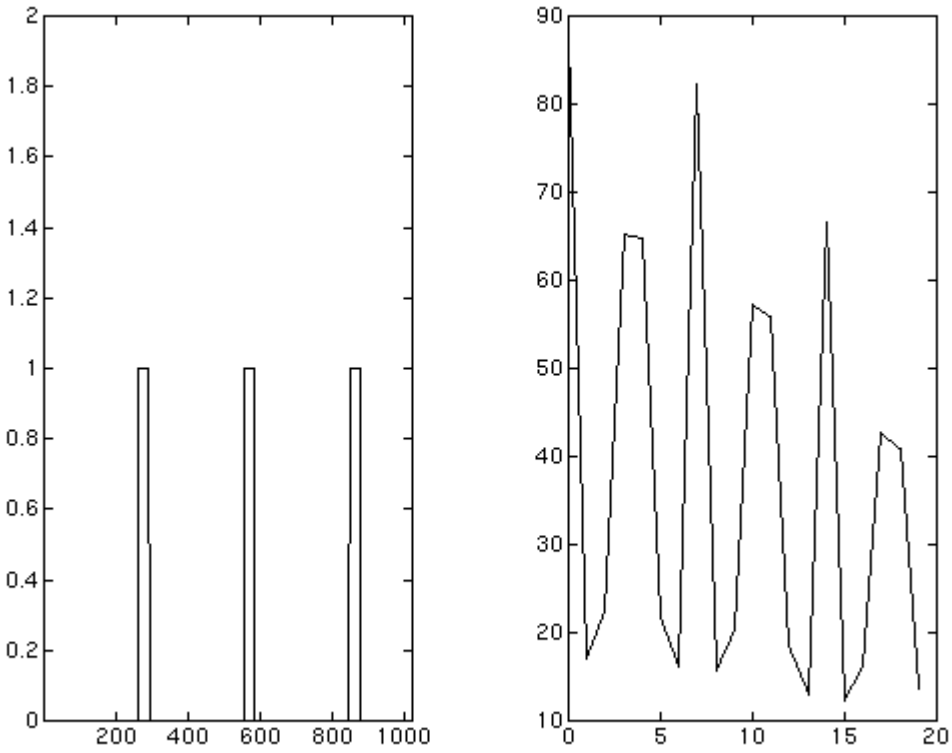


Figure 9: Irregular omission

When the omission is irregular, the phenomenon is more peculiar since the generated harmonics would be multiples of an irrational number. In fact, this is impossible, and there is an accentuation of the harmonics around these multiples, which, for example, for a ratio of 3.5, gives an accentuation of the 3rd and 4th harmonics, then 7th, then 10th and 11th, etc., but the perceptual effect is very ambiguous.

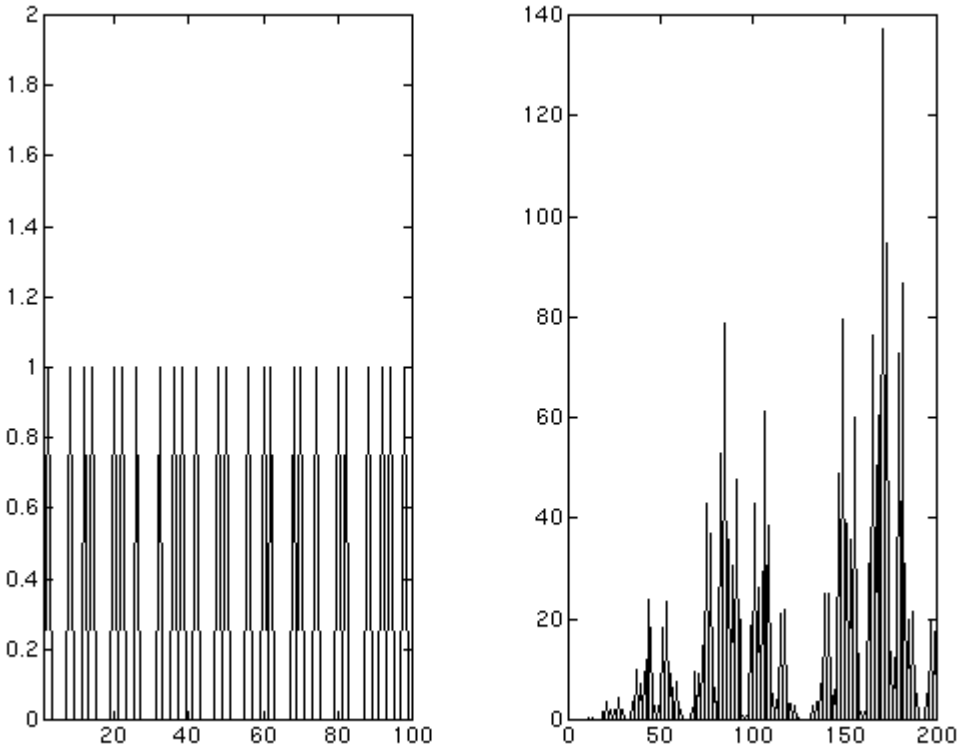


Figure 10: Fractal wave

Waves can differ from classical repetitions. In particular, fractal waves can be represented. The example above is generated by the following recurrence law: *Vn=(0 1)*

Vn+1=(Vn 1−Vn)

In other words, we concatenate the vector with its inversion, which allows us to obtain waves of lengths 4.8, 16, 32, etc. The spectrum is very turbulent but contains only odd harmonics.

5. conclusion

Research and creation tools in photosonic synthesis have been revitalized, both by improving disc composition software and by developing new analytical and simulation capabilities that will enhance our understanding of photosonic synthesis. However, the photosonic instrument is ultimately dependent on the performer's skill, and ultimately, the ear is the sole judge of its sonic and musical quality.

6. References

[Dudon, Arfib 1990] *Photosonic synthesis* , 1st Congress of Acoustics, Colloquium C2, pp. 845-848

[Dudon, 1996] *Audible Lights* , CD, Harmonic Exploration Workshop, Les Camails 83340 Le Thoronet