Some Notes on the Composition of *Rainstick* for Tape Alone

Gerald Bennett

Rainstick is a piece for tape alone which last a bit more than 13 minutes. It was composed between September 1992 and April 1993. Much of the material was prepared in my studio in Muttenz, but the composition took place in the studio Circé in the GMEB at Bourges. *Rainstick* was played for the first time at the 23rd Festival of Experimental Music of Bourges, fittingly enough during a downpour.

In the summer of 1992, I bought a rainstick in the United States. It is a 78 cm. long piece of bamboo with a diameter of 7 cm. and is closed at each end by a piece of hide. More than 100 fine pieces of wood, about the size of toothpicks, have been set into holes drilled across the bamboo tube and glued into place. The tube is filled with small pebbles. When the tube is quickly turned into a vertical position, the pebbles fall to the lower end, striking the traversal pieces of wood on their way down. Because the pieces of wood are fixed to the tube, the walls of the tube amplify the sound of the wood, and the result sounds very much like rain. When the pebbles hit the hide at the end, the sound is like that of drops of water falling into a puddle. If one moves the rainstick slowly into a vertical position, the pebbles run down the side of the tube, making a quite different sound, perhaps more like flowing water. —The rainstick is (or was) a magic instrument in Central and South America, used to conjure rain. I was immediately captivated by the sound of the rainstick and decided to write a piece using it.

In particular, I was fascinated that the rainstick could make both continuous and discontinuous sounds and could modulate between them. In my first sketches, I worked with recorded sounds from the rainstick itself, exploring ways of making discontinuous sounds more continuous and vice versa. Most of this work was done with Csound. I wrote Csound programs to read through sound files forwards, backwards and in various combinations of direction and at various speeds, to cut holes in sound files and to perform gating functions on sound files to create windows the sound could penetrate, as well as programs to render discontinuous sounds more continuous using all-pass filtering. With these early Csound instruments I made a large collection of sounds derived from the rainstick.

Very early on, I felt that my rainstick should not conjure up rain, but should summon the four elements, fire, water, air and earth. I never did find good sounds symbolizing earth, but I worked with recordings of fire, water and unpitched breathing using the Csound programs mentioned above and soon had more material than I could possibly use in a piece of any reasonable length.

Essential to these straightforward (and less straightforward) processing programs was a temporal ordering. At the very beginning of my sketching I had derived a long (38-member) set of proportions from one of my recordings. It very soon became clear that it was not practical to work with such a large set, so I reduced it to eight members:

0.2137
0.2051
0.1342
0.0995
0.0655
0.0429
0.1106
0.1285,

or expressed as cumulative times between 0.0 and 1.0:

0.0
0.2137
0.4188
0.553
0.6525
0.718
0.7609
0.8715
1.0

This set of proportions has an obvious development: the intervals between the times get shorter until about three-quarters of the total time has elapsed, then they get longer to the end. Often, this structure is clearly audible in the piece.

This set of eight proportions was used (together with its retrograde) in every stage of the composition to determine temporal structure. The main sections of the piece are related to each other through these proportions, as are the entrance times of individual sound events in every section, as are most of the micro-structural events: amplitude envelopes, changes of filter frequencies and bandwidths, vibrato envelopes in the singing voices, reverberation times, etc., not to mention the temporal structures incorporated into the Csound programs briefly described above.

I also used these eight proportions to order the frequency axis of my music. All transpositions, but also all center frequencies for bandpass filtering, all choices of discrete pitches for the singing voices were determined by turning this set of proportions into the vertical plane and then using it to determine frequencies. When working with frequencies, of course, it is important to do all the calculations with logarithms, and not with the frequencies themselves. Here is an example of the calculation of eight frequencies related through the proportions between middle c (261.63 Hz) and the c two octaves higher (1046.5 Hz).

log (1046.5) = 3.0197
log (261.63) = 2.4177
difference = 0.602

This difference must be multiplied by the cumulative proportions shown above and then added to log(261.63). The antilogarithms of the resulting numbers are the frequencies in the proper proportion:

antilog(2.4177)	=	261.63 Hz
antilog (2.4177 + (.2137 * .602))	=	351.84 Hz
antilog (2.4177 + (.4188 * .602))	=	467.54 Hz
antilog (2.4177 + (.553 * .602))	=	563.13 Hz
antilog (2.4177 + (.6525 * .602))	=	646.41 Hz
antilog (2.4177 + (.718 * .602))	=	707.84 Hz
antilog (2.4177 + (.7609 * .602))	=	751.21 Hz
antilog (2.4177 + (.8715 * .602))	=	875.66 Hz
antilog (2.4177 + (1.0 * .602)) =	1046.5 Hz	

Of course, these calculations can be hidden inside a Csound instrument definition and never need be thought of again. I also wrote simple C programs to calculate frequencies for Csound scores. In addition, for use with programs which offer transposition by tempered intervals, the proportions can be used directly to obtain the intervals required. In the course of the composition of *Rainstick*, I created a large number of scales of related sounds by transposing over a range which itself had been determined by the same set of proportions.

A second stage of treatment of the sounds took place in the studio at Bourges. I used harmonizer techniques and reverberation to complete my scales and to render the sound itself denser and more complex. In these operations too the proportions played an important role.

The temporal structure of *Rainstick* is in some sense more straightforward than the pitch structure, because the proportions can be applied directly to time. I had originally planned for the piece to be about 11 minutes long, but at some point it became clear that the material would require more time to evolve, so I decided on a duration of 13 minutes (in fact the piece turned out to be 13 minutes and 15 seconds long). The piece has eight sections whose lengths (and starting times) were derived directly from the set of proportions.

Starting times of each section:

I	0.0
II	2'46.9"
III	5'27.1"
IV	7'11.9"
V	8'29.6"
VI	9'20.8"
VII	9'54.3"
VIII	11'20.6"

Next, I divided each section into eight subsections. For this and all the succeeding calculations, I rarely used the set of proportions directly, but treated it rather as a collection of lengths whose order I chose at random. Then I typically used the proportions again to calculate 16 points in time, 8 using the direct proportions, 8 using the retrograde form (first and last point were of course the same). I frequently made prolation canons. So for instance I might use the second point in time calculated for one section as the starting time for another sequence of eight times, taking either the end time of the section as end time, or another time within the section, or a time calculated for another section altogether. All these points in time might provide starting times for a sound event whose length was derived by an independent process. In fact, in the final stages of the piece, I eliminated some of the events to thin out the texture.

Until very late in the composition process, I worked monophonically. Only after all the work of transformation, transposition, etc. was finished did I place each sound individually in stereo space. I only rarely did so by simulating a panorama control. Many sounds in the piece simulate movement in a two-dimensional space. The position of those which do not move is simulated by calculating arrival time differences with reference to two loudspeakers typically five meters apart, as well as adjusting the amplitude of each channel as a function of the sound's distance. The very small differences in arrival time (less than 10 milliseconds) create a de-phasing of the sounds which I consider essential for giving a sense of depth to the sound canvas.

For a long time into the composing, I was not at all clear about the piece's dramatic structure. I was quite happy with the sound material, and I was sure I would be able to devise satisfactory ways to organize the material locally, but I had no clear idea of what the piece was to be about. From the first sketches, it seemed that the piece as a whole should move from rather more continuous to discontinuous. I also had experimented for a long time, and only moderately successfully, with Csound instruments which would transform a rainstick-like sound into the sound of fire, water or air. I imagined the piece should have a dramatic structure, building to a climax somewhere in the shortest two sections (V and VI). It seemed reasonable to put a dissolution of some motivic sound into the discontinuity of the rainstick at the climax, but none of the transformations I had sketched seemed to me powerful enough to mark the dramatic high point of the piece.

It was not until fairly late in the composition that I decided to use singing voices in the piece. Because singing synthesis is something I know about, the idea of using voices had occurred to me early on, but I had rejected it because I saw no relation between singing voices and the rainstick. Once I had a clearer idea of the sound material I would use however, it seemed that singing voices might raise the dramatic level of the piece a bit by adding to the music an aspect the listener could identify more strongly with than with the sounds of the rainstick. As I had with the other elemental sounds (fire, water, air), I worked on a Csound instrument to make the transition from a voice to a rainstick-like sound.

Since the fragmentation of the singing voice is both one of the most dramatic gestures of the piece and at the same time one of the few synthesized passages of technical interest, I will take a moment to explain it in detail. The Csound instrument and score to make a similar sound are appended to this text. The passage as it appears in the piece can be heard in the sound example.

Csound contains an fof-unit generator for formant synthesis so I could use essentially the same synthesis stratagems as in the program CHANT, which Xavier Rodet and I designed and realized at IRCAM in the late seventies. In formant synthesis, one synthesizes damped sinusoidal waveforms corresponding to resonances. In the case of singing synthesis, these resonances correspond to the resonances in the vocal tract which produce formants. Each formant wave form has its own center frequency and bandwidth; its spectral shape can also be easily controlled. The illusion of a fundamental frequency is made by synchronizing the attacks of however many formants one is synthesizing. In a sense, formant synthesis can be thought of as granular synthesis, with each of the formant attacks being one grain of sound. It was fairly straightforward to uncouple the attacks of the five formants I used for the male singing voice and to give each formant frequency its own trajectory, thus exploding the voice into individual grains. The appended Csound example shows the details of the process.

Once I decided to use voices in *Rainstick*, my own idea of the form became much clearer. I, too, began to identify with the singing voices as dramatis personae, as I hoped the listener would do. I decided to write a duet for a male and a female voice towards the middle of the piece in section IV and then to let the male voice dissolve into the rainstick at the climax of the piece, that is sometime during the sections V or VI. Once this vocal part of the piece was clear in my mind, the dramaturgy of the rest of the music became much clearer. I decided to choose the sound material for the sections before the middle so as to prepare for the cataclysm of the dissolving voice. After the dissolution, I would use much of the same material as beforehand, but would choose treatments that led to strong fragmentation and great discontinuity. Once this plan became clear in my mind, I set about composing the great wealth of material I had collected.

The rapid review of the composition of *Rainstick* would not be complete without an anecdote which I am somewhat ashamed to tell, since it casts my compositional judgment in a bad light. On the other hand, however, I think my experience contributes to understand the relationship between construction and expression. I worked on the Csound instrument to transform a singing voice into the rainstick for structural reasons: the passage from continuous to discontinuous was one of the points of departure for the piece, and its realization with the voice was essentially a technical exercise. Once I got the Csound instrument working, I was shocked at the result. The effect of the (virtual) singer seeming to open his mouth obscenely wide and then seeming to self-destruct was not the kind of gesture I felt I made in my music—it was too obvious, too theatrical and hence too strong in comparison with the other gesture of the music. On the last day of my stay in Bourges to work on the piece, I played the final mix to Françoise Barrière and Christian Clozier, including the dissolving voice, but telling them that the final version would be free of this blemish. Christian was his usual enigmatic self, but Françoise categorically said I would destroy the piece if I took the dissolving voice out. At first I didn't understand what she meant, and the first time I played the piece, I was somewhat ashamed of and worried about the passage. Now, of course, I know she was absolutely right, and I am infinitely grateful for her advice. The reason why I find the anecdote interesting, apart from its illustrating an important weakness of mine, is because of the light it casts on the interdependence of structure and expression. What began as the technical realization of a structural idea turned out to have unexpected, and at first disturbing, expressive import. By accepting this import into my musical world, I extended my compositional vision greatly. It seems obvious that expressive vision and imagination color strongly the techniques we use to make our music. It is perhaps less obvious that technical vision and imagination can change profoundly the expressive world within which a piece is located.

Sound Example

The sound example is taken from *Rainstick* for tape alone by Gerald Bennett, beginning a little about 9 minutes into the piece. The example illustrates the end of a duet between a synthesized female and a synthesized male singing voice. At the end of the example, the male voice seems to "explode", thus transforming itself into the sound of the rainstick. The example has a duration of about 1 minute.

Appendix

Here I include as an appendix to this text the Csound instrument and score used to produce the transformation from a singing voice to a rainstick-like sound. It will be of most interest to those readers who have a working knowledge of Csound. It can be without modification to produce a phrase much like that illustrated in the sound example.

```
: voice-stick.orc
; Csound instrument used in Rainstick by G. Bennett to transform
singing voice into rainstic
; This is only one of five similar instruments, one for each of five
formants in the bass voice.

            sr    =     44100
            kr    =     441
            ksmps =     100
            nchnls =    1


            instr 1

; Vowel [a] - Bass  — formant 1

; p4        perceived loudness in dB, 0dB Maximum, affects timbre
; p5        f0 (fundamental)
; p6        formant frequency
; p7        formant frequency at beginning
; p8        formant frequency at end
; p9        actual amplitude at loudspeaker
; p10       first sung pitch
; p11       second sung pitch
; p12       rise time of "glottal" impulse
; p13       steady state of "glottal" impulse
; p14       decay of "glottal" impulse
; p15       vibrato frequency
; p16       vibrato amplitude
; p17       formant bandwidth
; p18       factor for randomness of f1 (1 = large, 8 = small)
; p19       nominal formant amplitude in dB (according to tables,
;           Mathews & Pierce: Current Directions in Computer Music
;            Research pp. 34-43)
; p20       jitter factor

; ________________________________________
; initialize

if0         =           p5
iolaps      =           200
iamp        =           p4
if    iamp  !=    0     igoto w1
iamp        =           -.1

w1:
kfundamp    init        iamp
ivibfr      =           p15
ivibamp     =           p16
kvibfr      init        ivibfr
kvibamp     init        ivibamp
```

```
iloudness    =           p9
iformamp     =           p19
if iformamp !=     0     igoto w2
iformamp     =     -.1

w2:
iformamp     =     ampdb(90+iformamp)
ijitter      =     p20

; Formant-Frequenzen
ifr          =           p6
ifrbeg       =           p7
ifrend       =           p8

; ______________________________________________
; corrections to the fundamental

; Vibrato
k3           randi .15, 1/1.015, .5432
k4           randi .15, 1/0.93, .5533
kvibfr             =     ivibfr * (k3 + k4) + ivibfr   ; vibrato
frequency

k1           randi 1, 1/.93, .9917
k2           randi 1, 1/1.015, .6573                   ; vibrato
amplitude
kvibamp      =     ivibamp + k1 + k2

; make the vibrato
kvib         oscili      kvibamp, kvibfr, 1

; Jitter
k10          randi ijitter, 1/.05, .8135
k11          randi ijitter, 1/.111, .3111
k12          randi ijitter, 1/1.2186, .6711
kjitter            =     (k10 + k11 + k12) * if0

; a general-purpose envelope using the basic proportions
; first, the values to be calculated along the way as needed
iv1    =     p10          ; a   starting value ** sung
iv2    =     (p10+p11)/2 ; b   .2136 ** sung
iv3    =     p11          ; a   .4187  ** sung
iv4    =     (p10+p11*2)/3; b  .5529   ** sung
iv5    =     if0/1.5      ; a   .6521
iv6    =     if0*2        ; b   .7173
iv7    =     if0/2        ; a   .7593
iv8    =     if0*1.5      ; b   .8693
iv9    =     if0          ; a   ending value

; then the envelope itself (note the use of the basic proportion):
kfundfrq    expseg
      iv1,.2137*p3,iv2,.2051*p3,iv3,.1342*p3,iv4,.0995*p3,iv5,.0655*p
3,iv6,.1285*p3,iv7,.1106*p3,iv8,.0429*p3,iv9

; add vibrato and jitter to fundamental
kf0          =           kfundfrq + kvib + kjitter

; _______________________________________
; corrections to the formant frequencies to ensure that the first two
formant
; frequencies do not fall on f0
; f1
if           if0 * 2 < (ifr - 0.05*ifr) igoto skip1
```

```
if          if0 * 2     < (ifr + 0.05*ifr) igoto cor1
if          if0   < (ifr - 0.05*ifr) igoto skip1
if          if0   < (ifr + 0.05*ifr) igoto cor1
cor1:
ifr         =     ifr + 0.05 * ifr

skip1:
; make a glissando for formant 1 using the general-purpose envelope

; a general-purpose frequency envelope using the basic proportions
; first, the frequency breakpoints
i1w1  =     ifr         ; a   starting value ** sung
i1w2  =     ifr- 5      ; b   .2136 ** sung
i1w3  =     ifr         ; a   .4187 ** sung
i1w4  =     ifr+ 3      ; b   .5529 ** sung
i1w5  =     ifrbeg+10   ; a   .6521
i1w6  =     ifrbeg      ; b   .7180
i1w7  =     ifrbeg-10   ; a   .7593
i1w8  =     ifrbeg+3    ; b   .8693
i1w9  =     ifrbeg      ; a   ending value

; then the envelope itself:
kformfrq    expseg
      i1w1,.1342*p3,i1w2,.2137*p3,i1w3,.2051*p3,i1w4,.0995*p3,i1w5,.0
655*p3,i1w6,.1285*p3,i1w7,.1106*p3,i1w8,.0429*p3,i1w9

; this switch is coupled to the gen-purpose envelope to control
randomness
konoff      linseg      0,.553*p3, 0, .0995*p3, 1, .3515*p3, 1

; now make some randomness
krand randi kformfrq/p18, 1/.1342*p3, .6178
; normalize it
krand       =           krand+kformfrq/2
; and turn it on and off
kformfrq    =           kformfrq + krand * konoff

;
; amplitude corrections

iloudness   =           ampdb(90+iloudness) / 32767   ; ifact < 1.0

; amplitude envelope for the note in dB

iv1   =     0.001
iv2   =     ampdb(90+iamp-6) / 32767
iv3   =     ampdb(90+iamp-4) / 32767
iv4   =     ampdb(90+iamp-2) / 32767
iv5   =     ampdb(90+iamp-1) / 32767
iv6   =     ampdb(90+iamp-2) / 32767
iv7   =     ampdb(90+iamp-3) / 32767
iv8   =     ampdb(90+iamp) / 32767
iv9   =     0.001

; the amplitude envelopes:
; first for the fundamental
kfundamp    expseg
      iv1,.2051*p3,iv2,.1342*p3,iv3,.2137*p3,iv4,.0995*p3,iv5,.0655*p
3,iv6,.1285*p3,iv7,.1106*p3,iv8,.0429*p3,iv9

; then for the formant
i1x1  =     1     ; a   starting value ** sung
i1x2  =     .98   ; b   .2136 ** sung
```

```
i1x3  =     .99   ; a   .4187  ** sung
i1x4  =     .9    ; b   .5529
i1x5  =     1.0   ; a   .6521
i1x6  =     .618  ; b   .7173
i1x7  =     .5    ; a   .7593
i1x8  =     .99   ; b   .8693
i1x9  =     1.0   ; a   ending value

; then the envelope itself:
kformamp    expseg
      i1x1,.2137*p3,i1x2,.1342*p3,i1x3,.2051*p3,i1x4,.0995*p3,i1x5,.0
655*p3,i1x6,.0429*p3,i1x7,.1285*p3,i1x8,.1106*p3,i1x9

kformamp    =     kformamp * iformamp

; __________________________________________________
; the synthesis

;                  amp        f0          f1a   oct   bb      rise
debat atten iolaps  fna  fnb   idur phs cor

a1          fof    kformamp, kf0,   kformfrq,   0,  p17,    p12,
p13,  p14,   iolaps,  1,    2,    p3,  0,  0

asum        =      a1 * kfundamp * iloudness
aout        reson  asum, 100, 450, 1 ; filter to correct symmetry
                                     ; see Mathews & Pierce article
aout        balance   aout, asum

            out         aout

endin
```

```
; stick-voice.sco

f1 0 32768 10 1
f2 0 1024 19 .5 .5 270 .5          ; the shape used for rise time and decay

; Vowel [a] - Bass  — formant 1

; p4        perceived loudness in dB, 0dB Maximum, affects timbre
; p5        f0 (fundamental)
; p6        formant frequency
; p7        formant frequency at beginning
; p8        formant frequency at end
; p9        actual amplitude at loudspeaker
; p10       first sung pitch
; p11       second sung pitch
; p12       rise time of "glottal" impulse
; p13       steady state of "glottal" impulse
; p14       decay of "glottal" impulse
; p15       vibrato frequency
; p16       vibrato amplitude
; p17       formant bandwidth
; p18       factor for size of randomness of f1 (1 = large, 8 =
small)
; p19       nominal formant amplitude in dB (according to tables,
;              Mathews & Pierce: Current Directions in Computer Music
Research pp. 34-43)
; p20       jitter factor

; In the actual Csound orchestra, each formant is contolled by its own instrument
allows different envelope shapes, etc.
; for each formant. The resulting sound of this score would be much too strongly
between the individual formants.
; Here the notes for the other four formants are given to show the formant freque

;                 p4    p5    p6    p7    p8    p9    p10   p11   p12   p13   p14
      p17   p18   p19   p20

i1    0     30    -6    5     600   1500  2100  0     314.29      267.34      .00
      .007  5.3   1.5   60    4     0     .01
i1    0     30    -6    5     1040  1900  2360  0     314.29      267.34      .00
      .007  5.3   1.5   70    3     7     .01
i1    0     30    -6    5     2250  2400  2490  0     314.29      267.34      .00
      .007  5.3   1.5   110   6     9     .01
i1    0     30    -6    5     2450  3100  3000  0     314.29      267.34      .00
      .007  5.3   1.5   120   2     9     .01
i1    0     30    -6    5     2650  3300  3160  0     314.29      267.34      .00
      .007  5.3   1.5   130   2     20    .01
e
```