

Computer Science Department

Qualifying Examination, Spring 2007

Computer Music

Closed book. Answer all the questions. The percentage scores are given for each question.

1. Consider a mono, periodic, linear PCM encoded signal with sampling rate 48,000 samples/second, sample size 32 bits, and frequency 1,000 Hz. (10%)
 - a. What is the signal's Nyquist frequency?
 - b. How many samples are in one cycle ?
 - c. If 32 bits represents 0 dBA, how many bits is -12 dBA?
 - d. How many bytes are needed to store 20 secs. of the signal?
 - e. What is the quantization noise ratio of the signal?
 - f. If a Fourier transform is taken using 1,000 samples, what is the frequency resolution (bin width) of the transformed signal?

2. Consider the linear digital filter whose difference equation follows. (40%)
$$y[n] = x[n] + x[n-1] - y[n-2]$$
 - a. Rewrite the filter taking the z-transform of the equation.
 - b. Write the filter's transfer function, H , as a function of z .
 - c. Write the filter's frequency response as a function of $e^{i\omega T}$, where ω is the frequency and T is the sampling rate.
 - d. How many zeros and poles does the filter have?
 - e. Draw a graph showing the first twenty samples of the filter's impulse response.
 - f. Is the filter stable or unstable? Why?

3. Explain, in your own words, the psycho-acoustic phenomenon of masking, both tonal and temporal, and the principles of its use in audio compression algorithms. (25%)

4. Explain, your own words, the differences between the following forms of synthesis (25%):
 - a. granular
 - b. FM
 - c. subtractive
 - d. additive
 - e. wavetable
 - f. physical modeling

What form of synthesis does the following Csound orchestra file exhibit? Explain you answer.

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;*****
; Tone Wheel Organ with Rotating Speaker
;*****

sr      = 44100
kr      = 2205
ksmps  = 20
nchnls = 2

instr 1 ; Rotor Organ #2

    gaorgan  init 0
    gaorgan2 init 0

    iphase = p2
; ikey = p6
    ikey = 12*int(p5-6) + 100*(p5-6)
    ifqc = cpspch(p5)

; The lower tone wheels have increased odd harmonic content.
    iwheel1 = ((ikey-12) > 12 ? 1:2)
    iwheel2 = ((ikey+7) > 12 ? 1:2)
    iwheel3 = (ikey > 12 ? 1:2)
    iwheel4 = 1

    kenv linseg 0, .01, p4, p3-.02, p4, .01, 0

    asubfund oscil p6, .5*ifqc, iwheel1, iphase/(ikey-12)
    asub3rd  oscil p7, 1.4983*ifqc, iwheel2, iphase/(ikey+7)
    afund    oscil p8, ifqc, iwheel3, iphase/ikey
    a2nd     oscil p9, 2*ifqc, iwheel4, iphase/(ikey+12)
    a3rd     oscil p10, 2.9966*ifqc, iwheel4, iphase/(ikey+19)
    a4th     oscil p11, 4*ifqc, iwheel4, iphase/(ikey+24)
    a5th     oscil p12, 5.0397*ifqc, iwheel4, iphase/(ikey+28)
    a6th     oscil p13, 5.9932*ifqc, iwheel4, iphase/(ikey+31)
    a8th     oscil p14, 8*ifqc, iwheel4, iphase/(ikey+36)

    gaorgan = gaorgan + kenv*(asubfund + asub3rd + afund + a2nd + a3rd + a4th +
a5th + a6th + a8th)
    gaorgan2 = gaorgan

endin

;Rotating Speaker
instr 3

; Speaker phase offset
    ioff = p4

; Phase separation between right and left
    isep = p5

; Global input from organ
    asig = gaorgan

```

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; Distortion effect A lazy "S" curve. Use table 6 for more distortion.
asig = asig/40000
aclip tablei asig, 5, 1, .5
aclip = aclip*16000

; Delay buffer for rotating speaker
aleslie delayr .02, 1
delayw aclip

; Acceleration
kenv linseg .8, 1, 8, 2, 8, 1, .8, 2, .8, 1, 8, 1, 8
kenvlow linseg .7, 2, 7, 1, 7, 2, .7, 1, .7, 2, 7, 1, 7

; Upper Doppler Effect
koscl oscil 1, kenv, 1, ioff
koscr oscil 1, kenv, 1, ioff + isep
kdopl = .01-koscl*.0002
kdopr = .012-koscr*.0002
aleft deltapi kdopl
aright deltapi kdopr

; Lower Effect
koscllow oscil 1, kenvlow, 1, ioff
koscllow oscil 1, kenvlow, 1, ioff + isep
kdopllow = .01-koscllow*.0003
kdoprlow = .012-koscllow*.0003
aleftlow deltapi kdopllow
arightlow deltapi kdoprlow

; Filter Effect
; Divide into three frequency ranges for directional sound.

; High Pass
alfhi butterbp aleft, 7000, 6000
arfhi butterbp aright, 7000, 6000

; Band Pass
alfmid butterbp aleft, 3000, 2000
arfmid butterbp aright, 3000, 2000

; Low Pass
alflow butterlp aleftlow, 1000
arflow butterlp arightlow, 1000

kflohi oscil 1, kenv, 3, ioff
kfrohi oscil 1, kenv, 3, ioff + isep
kflomid oscil 1, kenv, 4, ioff
kfromid oscil 1, kenv, 4, ioff + isep

; Amplitude Effect on Lower Speaker
kalosc = koscllow * .4 + 1
karosc = koscllow * .4 + 1

; Add all frequency ranges and output the result.

```

```

outs alfhi*kflohi+alfmid*kflomid+alflow*kalosc,
arfhi*kfrohi+arfmid*kfromid+arflow*karosc

gaorgan = 0

endin

;Rotating Speaker
instr 4

; Speaker phase offset
ioff = p4

; Phase separation between right and left
isep = .2

; Global input from organ
asig = gaorgan2

; Distortion effect A lazy "S" curve. Use table 6 for more distortion.
asig = asig/40000
aclip tablei asig, 5, 1, .5
aclip = aclip*16000

; Delay buffer for rotating speaker
aleslie delayr .02, 1
delayw aclip

; Acceleration
kenv linseg .8, 1, 8, 2, 8, 1, .8, 2, .8, 1, 8, 1, 8
kenvlow linseg .7, 2, 7, 1, 7, 2, .7, 1, .7, 2, 7, 1, 7

; Upper Doppler Effect
koscl oscil 1, kenv, 1, ioff
koscr oscil 1, kenv, 1, ioff + isep
kdopl = .01-koscl*.0002
kdopr = .012-koscr*.0002
aleft deltapi kdopl
aright deltapi kdopr

; Lower Effect
koscllow oscil 1, kenvlow, 1, ioff
koscllow oscil 1, kenvlow, 1, ioff + isep
kdopllow = .01-koscllow*.0003
kdoprlow = .012-koscllow*.0003
aleftlow deltapi kdopllow
arightlow deltapi kdoprlow

; Filter Effect
; Divide into three frequency ranges for directional sound.

; High Pass
alfhi butterbp aleft, 7000, 6000
arfhi butterbp aright, 7000, 6000

```

```
; Band Pass
alfmid butterbp aleft, 3000, 2000
arfmid butterbp aright, 3000, 2000

; Low Pass
alflow butterlp aleftlow, 1000
arflow butterlp arightlow, 1000

kflohi oscil 1, kenv, 3, ioff
kfrohi oscil 1, kenv, 3, ioff + isep
kflomid oscil 1, kenv, 4, ioff
kfromid oscil 1, kenv, 4, ioff + isep

; Amplitude Effect on Lower Speaker
kalosc = koscllow * .4 + 1
karosc = koscrlow * .4 + 1

outs alfhi*kflohi+alfmid*kflomid+alflow*kalosc,
arfhi*kfrohi+arfmid*kfromid+arflow*karosc

gaorgan2 = 0

endin
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