Engin.100: Music Signal Processing Project #1: Specifications

- Musical notes: frequencies and relations
- Basic musical staff and MIDI notation

- Musical tone synthesizer and transcriber:
- Specifications for the two deliverables;
- Two new Matlab commands for graphics

What you (hopefully) learned in Lab#2

- Frequencies of musical tones in ”Victors”:
- 392, 440, 494, 523, 587, 659, 698 Hertz.

- Semi-log plot revealed missing frequencies:
- 415, 466, 554, 622, 740 Hertz (accidentals).

- 12 frequencies with common ratio 1.06 (actually $2^{1/12}$ since 12 notes doubles freq)

MIDI (frequency) Musical Notation

- MIDI=Musical Instrument Digital Interface
- Musical frequencies represented by integers
- MIDI=69+12log$_2$(frequency in Hertz/440)
- “The Victors”: {71,67,69,71,67,69,71,72…}
- Also includes amplitude and duration info
- MIDI transcription is much easier than using:

Musical Staff Notation

- 7 “whole” notes labelled A,B,C,D,E,F,G.
- The 7 notes that appeared in “The Victors” (and make up most musical compositions)
- 5 “accidentals” labelled A#,C#,D#,F#,G#
- 5 equivalently labelled Bb,Db,Eb,Gb,Ab
- A# (“A-sharp”) same as Bb (“B-flat”); between notes A and B (above A, below B)

Frequencies of musical tones

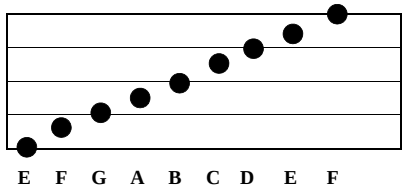
NOTE	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
Hertz	523	554	587	622	659	698	740	784	830	880	932	988
Ratio	$2^{0/12}$	$2^{1/12}$	$2^{2/12}$	$2^{3/12}$	$2^{4/12}$	$2^{5/12}$	$2^{6/12}$	$2^{7/12}$	$2^{8/12}$	$2^{9/12}$	$2^{10/12}$	$2^{11/12}$
approx	1:1		9:8		5:4	4:3		3:2		5:3		15:8

“The Sound of Music” (solfage) notation

G	A	B	C	D	E	F#	G
1:1 392	9:8 440	5:4 494	4:3 523	3:2 587	5:3 659	?:? 740	2:1 784
DO	RE	MI	FA	SO	LA	TI	DO

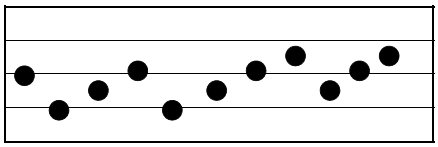
Don’t know any music? Humming these notes might help.

Musical Staff Notation



Not shown: The treble clef (script “G”) at the start. The tail of the script “G” circles the 2nd line from the Bottom, which is the line representing the note “G.”

Musical Staff Notation: "The Victors"



B	G	A	B	G	A	B	C	A	B	C
Hail	to	the	vic-	tors	val-	iant	Hail	to	the	con-

NOT SHOWN: Staffs ♫ attached to each note indicate its duration.

Comments on Musical Notes

- Octave: 2:1 frequency ratio (e.g., A to A).
- Fifth: 3:2 frequency ratio (e.g., A to E).

- Previously: small integer ratios between notes.
- But then: Key change → ratios had to change.
- J.S. Bach, "The Well-Tempered Clavichord."
- Used $2^{1/12}$ ratio between "semi-tones" so that key changes preserve the ratios between notes.

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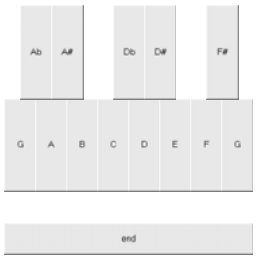
Project #1: Specifications

- Pure tonal music **synthesizer**:
- Matlab-generated keyboard (shown later).
- Click on key with mouse generates that note.
- Writes sequence of played notes into .wav file.
- Pure tonal music **transcriber**:
- Input: .wav file of music played on synthesizer.
- Output: pseudo-musical-staff notation of music.
- Details of these specs are shown on other slides.
- Suggestion: output MIDI notation 1st, then staff.

Project #1: Tone Synthesizer GUI

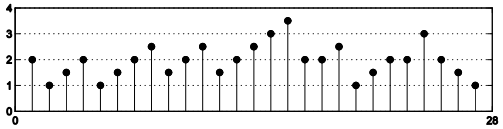


Mimics single octave of a piano keyboard: black keys above (for accidental notes); white keys below (for whole notes).

You can jazz this up (add colors & labels) if you desire to do so.

Clicking on key with mouse plays that note

Project #1: Tone Transcriber Output



Crude musical staff notation of "The Victors."
Musical notes: uses stems instead of ♫ or ♪.
No interval info.-all notes have same duration.

But *heights* against 5-line background correct.
Computing these heights from sampled signal from your synthesizer is the point of project.

Matlab Commands for Project #1

- >> uicontrol('Style','Pushbutton','Position', [100 250 40 80],'String','B','Callback','*')
- Creates button 40 pixels wide and 80 tall, located 100 from left and 250 above bottom of screen, and puts a "B" in the middle of it.
- When "pushed" by left-clicking with mouse, executes Matlab command "*"
- Use sequence of these commands to create:

Matlab Command for Project #1

>>subplot(311),stem(X),axis([0 length(X) 0 4])
creates stem plot of the numbers in vector X that mimics musical staff notation w/o staffs

>>set(gca,'Ygrid','on','Ytick',[0 1 2 3 4])
creates the five musical staff lines behind

Use stem(X,'filled') for filled-in circles

Add 'GridLineStyle','-' for solid staff lines

Musical Tone Transcriber

- If using MIDI notation, this would be easy: Just stem-plot $12\log_2$(frequency/(440 Hertz))
- But musical staff notation treats whole notes differently from accidentals (sharps & flats)
- Need to plot whole notes at integer heights and accidentals at half-integer heights
- Let I=$12\log_2$(F/440) & plot S(I) for vector S

Musical Tone Transcriber

- Durations of N tones identical at M, so use >>M=length(X)/N; Y=reshape(X',M,N); Z=(Y(3:M-1,:)+Y(1:M-3,:))./Y(2:M-2,:)/2; F=(8192/2/pi)*acos(mean(Z)); F=estimates
- Then generate MIDI number, then map to staff notation using [0 .5 .75 1 1.25 1.5...]. Example of how to do this on next slide.

Musical Tone Transcriber

- **Example**: Start with note A instead of E

Musical Note	A	A#	B	C	C#	D
Frequency (Hz)	440	466	494	523	554	578
$12\log_2$(F/440)	0	1	2	3	4	5
vertical height	0	.5	1	2	2.5	3

- S=[0 .5 1 2 2.5 3…];stem(S(12*log2(F/440)))
- Use 12*log2(F/440) as an index (define log2)

Conclusion

- Tone Synthesizer and Transcriber (two .m files). Your lab IA should confirm both of these work.
- Your team will present your project results orally. You will learn how to do this in tech comm half. This will be your grade for this project!
- Save your presentation as a .pdf, not .pptx, file. (Select "print"; print to "Adobe" at top of menu.) The file name should be just your team name. Email to aey@eecs.umich.edu the night before.