Faster Than A Calculator

or

Using Markov Chains for the Composition of New Wave Music

By Love, Execution Style
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Abstract
The experimental music group Love, Execution Style utilized Markov chains in order to compose a congratulatory song for Elizabeth Wilmer, upon the completion of her PhD. Using Markov chains made from the sequences of notes from two relevant songs, *Pomp and Circumstance* by Elgar and *Y.M.C.A.* by the Village People, new musical sequences were constructed with the aid of a random number generator.

Experiment Setup
On June 17, 1999, Love, Execution Style received a note from Douglas Wolk, requesting the construction of a new wave song to celebrate Elizabeth Wilmer's completion of her PhD. It was decided to use Markov chains to aid the music-writing process. Two songs were selected to capture the spirit of the occasion: *Pomp and Circumstance* (the honor of graduation) and *Y.M.C.A.* (the exhilaration of dancing). These two songs were transposed to the key of C and mapped out as follows:
Pomp and Circumstance:
CBCDAGFEFGDEFGADGCCBABCBCDAGFEFGDEFGADGFFEDEABCDGCCFEDC
(note: F sharps were made into F naturals for the sake of simplicity)

Y.M.C.A.: GEEDCDEGEGAEEDCDEGEGAFFEDEFACABAGFED
EGEGEGAGAGEGEGEDCDCDCACACCCACACCCACACAGCCA

Tables 1 (*Pomp and Circumstance*) and 2 (*Y.M.C.A.*) were constructed from these sequences. The notes representing the rows are the initial notes, while the notes representing the columns are the subsequent notes. For example, take the first two notes of *Pomp and Circumstance*, CB. For this two-note sequence, we would mark a 1 in the cell at the intersection of the C row and the B column. The next two-note sequence is BC, for which we would mark a 1 in the B row, C column cell. This was repeated for the entire sequence of notes.

Table 1

	C	D	E	F	G	A	B	total
c	2	3		1			3	9
d	1		3		3	2		9
e		2		4		1		7
f			4	1	4			9
g	2	2		3		2		9
a		2			2		2	6
b	4					1		5

Table 2

	C	D	E	F	G	A	B	total
c	5	4				9		18
d	5		4					9
e		5	2	1	9			17
f			2	1		1		4
g	1		8	1		4		14
a	7		1	1	4		1	14
b						1		1

Then, tallies were calculated per row for the frequency of the second note; these were turned into percentages. Tables 3 (*Pomp and Circumstance*) and 4 (*Y.M.C.A.*) were constructed using these percentages. With these tables, given any note, we know the probability of a particular note directly following it in the songs examined.

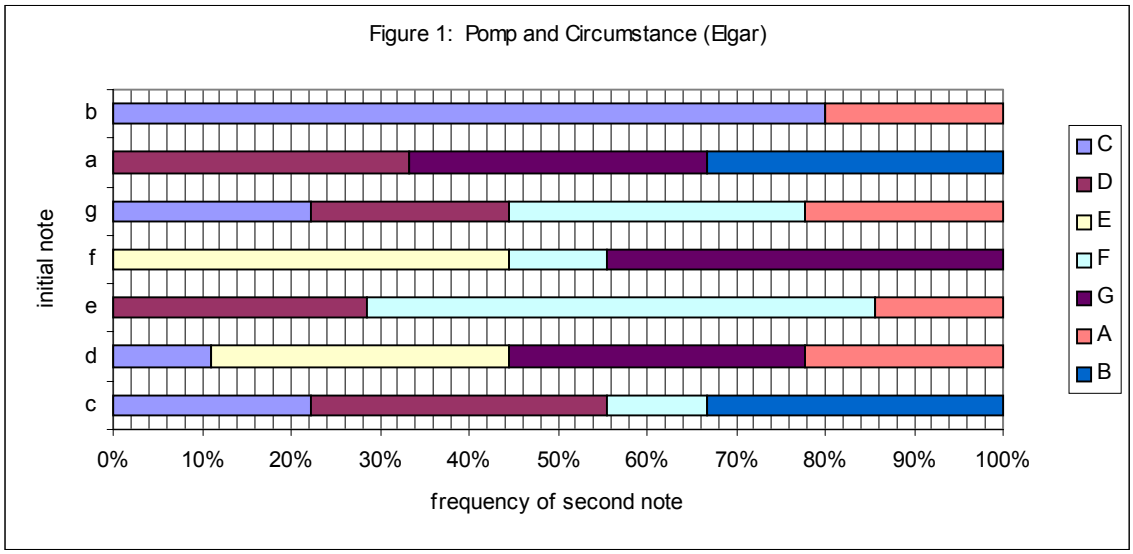
Table 3

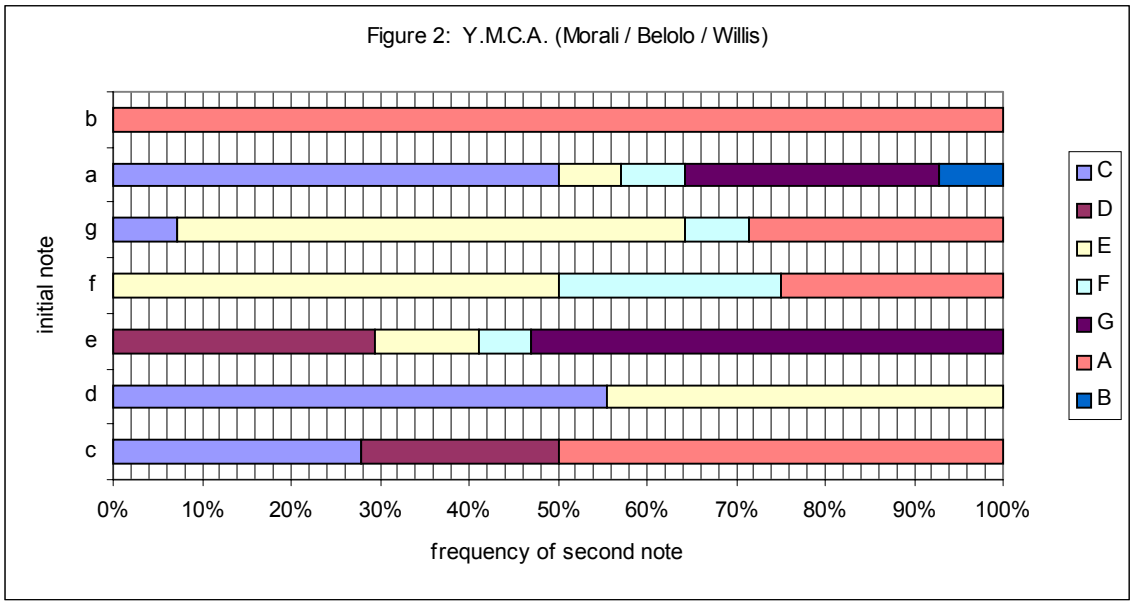
	C	D	E	F	G	A	B
c	0.222	0.333	0.000	0.111	0.000	0.000	0.333
d	0.111	0.000	0.333	0.000	0.333	0.222	0.000
e	0.000	0.286	0.000	0.571	0.000	0.143	0.000
f	0.000	0.000	0.444	0.111	0.444	0.000	0.000
g	0.222	0.222	0.000	0.333	0.000	0.222	0.000
a	0.000	0.333	0.000	0.000	0.333	0.000	0.333
b	0.800	0.000	0.000	0.000	0.000	0.200	0.000

Table 4

	C	D	E	F	G	A	B
c	0.278	0.222	0.000	0.000	0.000	0.500	0.000
d	0.556	0.000	0.444	0.000	0.000	0.000	0.000
e	0.000	0.294	0.118	0.059	0.529	0.000	0.000
f	0.000	0.000	0.500	0.250	0.000	0.250	0.000
g	0.071	0.000	0.571	0.071	0.000	0.286	0.000
a	0.500	0.000	0.071	0.071	0.286	0.000	0.071
b	0.000	0.000	0.000	0.000	0.000	1.000	0.000

Figures 1 and 2 are graphical representations of the data in Tables 3 and 4.





New musical sequences were formed by starting with an arbitrary note (C was chosen in both cases), using a random number generator to obtain a number from 1 to 100, then consulting a graph to see which note was selected to follow. This new note would then become the "initial" note when obtaining the note that follows it, and so on. The random number generator used was a pair of 10-sided dice (colloquially referred to as "dungeon dice").

Outcome of Experiment 1
The following sequence of notes was constructed using Figure 1:
CBCDGDADAGDGDGCCFEDE

This sequence may be heard in the keyboard part played during the verses.

Outcome of Experiment 2
The following sequence of notes was constructed using Figure 2:
CACCAEGEGEGEGA

This sequence may be heard in the keyboard part played during the choruses.

For both sequences, the lengths of the notes were chosen by Love, Execution Style to be aesthetically pleasing and to conform to a 4/4 time signature.

Conclusion
Markov chains and random number generators may be used effectively to create melodies from existing songs. Simply selecting random notes typically does not yield lovely tunes. By using Markov chains and pre-made note sequences, we are more likely to produce agreeable results because each new two-note progression is one that already exists in a tried and true "good" melody. It is advised to select existing songs that have varied notes and do not repeat the same note frequently (*e.g.* "Sam" by Meat Puppets or "One Note Samba").

Supplemental Data
Lyrics to "Faster than a Calculator"

Elizabeth is now done with school
She knows every math-related axiom and rule
She's reached a goal to which she's aspired
Now she's gonna set the dance floor on fire

After years and years with her nose in books
She'll shake her thing and flaunt her looks
The logarithm sets her free
And she can dance infinitely

Do you know the probability of any guy falling for her?
You really don't need a math degree; it's a hundred percent for sure

She's faster than a calculator
She's so fine the other girls hate her
She'll heat you up like a percolator
She'll use the force just like Darth Vader

When she defended her dissertation, she just blew away the jury
With her expertise in computation and her all-out dancing fury

She's faster than a calculator
She's so fine the other girls hate her
She'll heat you up like a percolator
She'll use the force just like Darth Vader