MALAWIAN PANGO MUSIC FROM THE VIEWPOINT OF INFORMATION THEORY

by

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Music played on a Malawian *pango*, a board zither, will be analysed by using concepts of probability theory and information theory. I have tried to make my analysis comprehensible to non-mathematicians. It is, however, impossible to translate all mathematical concepts into a few words which convey the same accuracy. So I had to compromise. The Conclusion of this article* gives the main results of my analysis without using mathematical formulae.

The music is played at a constant speed of about 6 pulses per second. The data for my analysis consists of the chords and sung melody notes which sound at each pulse.

I am interested in predicting the chord to be played at any arbitrary pulse 't'. Knowledge of the frequency distribution of the chords being played in this music decreases the uncertainty in this prediction: the chords are not equally probable. I will show that knowledge of the chord at the previous pulse (t–1) (read: t minus one) greatly decreases the uncertainty in the prediction of the chord at (the next) pulse t, and, therefore, that knowledge of the matrix of transition probabilities increases our insight into the character of this music considerably.

One may think that knowledge of the chord at pulse (t–2) (read: t minus two) in addition to knowledge of the chord at pulse (t–1), i.e. knowledge of the *two* preceding chords, will again considerably reduce the uncertainty in the prediction of the chord at pulse t. This appears not to be so, however, for the uncertainty is only slightly reduced. The chain of chords can, therefore, in good approximation, be described as a Markov chain. The entropy is used as a measure of the uncertainty in the prediction. (These concepts will be explained in the section "The chain of chords".)

This analysis is also applied to the sung melody notes, and the relation between chord and sung melody is discussed. A comparison is made between this approach and the more usual approach of analysing chord sequences. At the end of the paper the 10 analysed *pango* songs are written down.

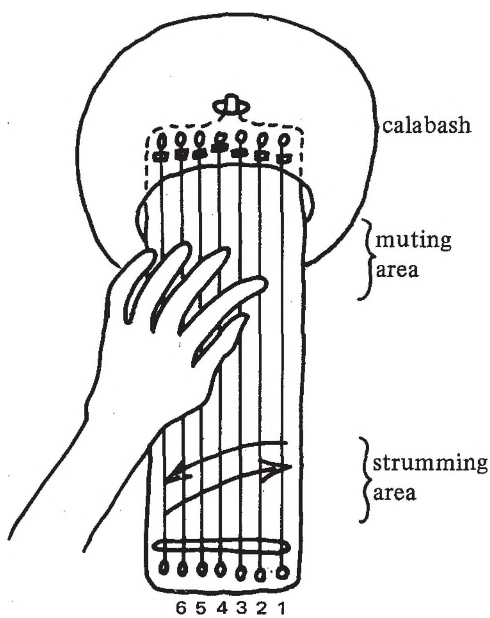
THE INSTRUMENT, THE PLAYING AND THE MUSIC

The music that will be analysed originates in the Rumpi District in the Northern Region of Malawi, and belongs to the musical culture of the Tumbuka people. It was played to me in 1971 by Emmanuel C.R. Gondwe, who was at that time a student at the University of Malawi. The instrument, the *pango*, accompanies the singing. Both singing and playing are done by the same person. The *pango* is a board zither that is called *bangwe* in the Central and Southern Regions of Malawi (see for nomenclature

**Ed*: Originally received in 1977.

also Nurse: 1970). The size and the number of strings of the *pango* or *bangwe* may vary.

The *pango* of Emmanuel Gondwe consisted of a 1 cm thick board that measured about 15 cm by 45 cm. Through the 7 holes in the top end and the 7 holes in the bottom end of the board one piece of strong steel wire (in the Southern Region of Malawi this wire was called "telephone wire"!) is wound so that 7 different strings are formed. The strings are lifted 3 to 4 mm from the board by one small bar of bamboo on the bottom end and 7 small pieces of bamboo on the top end. The tuning of the instrument is accomplished by putting these pieces of bamboo in the right position. The top end of the board is put into a calabash or a large tin for resonance. Some bottle tops are usually fixed on top of the calabash or tin in order to get a buzzing sound to accompany the playing. Emmanuel Gondwe's *pango*, however, did not have these bottle tops.



Pango of Emmanuel Gondwe*

The string at the far left was not used by Emmanuel Gondwe. I have numbered the other strings from 1 to 6 going from right (the highest tone) to left (the lowest tone).

The player sits on the ground or on a stool and holds the calabash between his knees. One way of playing the instrument is to pluck the strings with the thumb and forefinger of both hands. The other way is to mute some of the strings by putting the forefinger, the middle-finger and the ring-finger of the left hand on them and to strum with the forefinger of the right hand (see the picture). The left hand, which is used for muting the strings, has two positions only. In the first position the 2nd, 4th and 6th string are muted and in the second position the 1st, 3rd and 5th string are muted. The thumb is kept up, in order not to touch the strings. The little finger is resting on the board. In the first position two chords may be played by either strumming string 1 and string 3 (chord *1*) or by strumming string 3 and 5 (chord *3*). In the second position also two chords may be played by either strumming string 2 and string 4 (chord *2*) or by strumming string 4 and string 6 (chord *4*). The strumming is done consecutively from right to left to right, etc. The strumming is continuous: a chord is struck at every pulse.

The tuning of the strings was measured by a set of 54 tuning forks from 212 Hz, going up by 4 Hz to 424 Hz. The tuning of the strings on an arbitrary day was:

**Ed:* For a photograph of a somewhat similar instrument, see Wim van Zanten's article in Vol. 6, No. 1, 1980, p. 108.

string no.	1		2		3		4		5		6		(7)
Hz (vibr./sec):	364		328		304		276		244		210		(not used)
interval in cents:		181		131		168		213		260			

In the bottom row the interval between the strings is given in cents. The tuning of the instrument did vary from one day to the next. It seems that generally tuning may vary considerably. One day I myself tuned the bangwe. The tuning, which was quite acceptable to Emmanuel Gondwe, was the following:

string no.	1		2		3		4		5		6		(7)
Hz (vibr./sec):	392		356		324		292		264		218		(not used)
interval in cents:		167		163		180		175		331			

Emmanuel Gondwe played his music at a speed of about 360 pulses per minute. At each pulse (time point) a chord may be struck or not. In the rare instances when no chord is being struck at a certain pulse (this only happens when the plucking technique is applied) I have indicated this in the transcriptions by a point. The same holds true for the melody tones.

There are 4 different chords:

chord *1*: notes of strings 1 and 3, interval 312 cents
chord *2*: notes of strings 2 and 4, interval 299 cents
chord *3*: notes of strings 3 and 5, interval 381 cents
chord *4*: notes of strings 4 and 6, interval 473 cents.

For comparison: a minor third is 300 cents, a major third 400 cents and a fourth 500 cents. For the second tuning the intervals between the strings are: chord *1*: 330 cents, chord *2*: 343 cents, chord *3*: 355 cents and chord *4*: 506 cents.

The chords are named after the *higher* note of the chord, because in this way the relation between the chord and the melody note comes out most clearly. In table 6 you can see that the melody note is usually the top note of the accompanying chord.

The tones used in the melody are the tones of the strings of the *pango*, indicated by 1, 2, 3, 4, 5 and 6. In one song the higher octave of the notes 5 and 6 is also used; these notes will be indicated by 5^1 and 6^1. It should be noted, however, that some melodies are sung falsetto and some are not. I do not differentiate between these two kinds of performance. In my analysis I am not interested in the pitch of the tones, but rather in the melodic movement within one song.

You will find the transcriptions of the 10 songs that I have used for the analysis at the end of this paper. The music presented there gives the pattern for each song. This pattern is repeated many times, sometimes with singing, sometimes with whistling, and sometimes just *pango* playing. I have given some indications about the playing at the time of recording.

THE CHAIN OF CHORDS

The pattern of the song "Chijungu" consists of 24 pulses; at each pulse (time point) a chord is struck. The chain of chords from the 1st pulse to the 24th pulse is for this song

3 1 1 1 1 1 1 1 1 2 3 3 4 4 4 4 2 2 3 4 3 3 4 4

Note that we are not just looking for *changes* in the chords as done for instance by Tracey, 1970 and 1971. If I would just write down the consecutive chord changes in the song "Chijungu" this would yield the array

3 1 2 3 4 2 3 4 3 4

In this array of chords *we cannot see how long a particular chord sounds.* Such arrays I shall call *sequences*. I distinguish in this paper therefore a *chain* of chords from a *sequence* of chords. A chain of chords gives the chord being played at each pulse and it contains therefore information on how many pulses a particular chord is continuously sounding. My analysis is based on chains and not on sequences. In the section "Structural analysis", however, I shall neglect the information on the duration of chords and consequently use the information on the sequences only.

Zero order approximation.

In what is called zero order approximation the number of time units a particular chord sounds is counted, i.e. the frequencies of the chords are determined. If a chord is not being struck at a particular pulse, we can assume that the chord of the previous pulse is being heard. For the song "Chijungu" the frequency distribution is:

chord:	*1*	*2*	*3*	*4*	*total*
frequency:	8	3	6	7	24
relative freq.:	.33	.13	.25	.29	1.00

For the 10 *pango* songs together the relative frequency will become an estimate of the probability that a particular chord will be produced at any arbitrary pulse in this kind of music. The frequencies and the estimated probabilities for these 10 songs together are:

chord:	*1*	*2*	*3*	*4*	*total*
frequency:	107	98	209	98	512
estimated probability:	.21	.19	.41	.19	1.00

This set of probabilities gives us some information about the *pango* music. We can see, for instance, that the probability that chord *3* will sound at any arbitrary pulse is the greatest.

We have seen that in one of the tunings the intervals occurring in resp. the 1st, 2nd, 3rd and 4th chord are 312 cents, 299 cents, 381 cents and 473 cents. Therefore the harmonies consist for 80% of intervals between 300 and 400 cents ("thirds"; chords *1*, *2* and *3*), and for 20% of intervals around 500 cents ("fourths"; chord *4*). This differs from what Davidson (1970) found for Zambia, and Tracey (1970) for Zimbabwe. In these cultural areas the fourth (fifth) seems to be predominant.

A measure for the *uncertainty in the prediction* of the chord that will be played at any arbitrary pulse t is given by the entropy H(T).[1] The entropy H(T), as I have defined it, is a real number between 0 and 1. If all the chords were equally probable, i.e. .25 in our case with 4 chords, then H(T) = 1 or the uncertainty in the prediction is maximal (see table 1, scheme 1).

If the probability of a particular chord is 1, and therefore the probability of the other chords 0, it is certain that this particular chord will be played at any arbitrary pulse. In this case the entropy equals 0 or the uncertainty in the prediction is minimal (table 1, scheme 4).

Below I have given the entropy for each of 4 probability schemes. Schemes 1, 3 and 4 are imaginary and scheme 2 is the one found for the 10 *pango* songs.

	scheme 1				scheme 2			
chord:	1	2 2	3	4	1	2	3	4
probability:	.25	.25	.25	.25	.21	.19	.41	.19
entropy:	H(T) = 1				H(T) .96			
	scheme 3				scheme 4			
chord:	1	2	3	4	1	2	3	4
probability:	.1	.5	.1	.3	0	0	1	0
entropy:	H(T) = .84				H(T) = 0			

Table 1: 4 different probability schemes and their respective entropies

Scheme 1 represents a random prediction of chords with equal probabilities: .25. Scheme 2 is the actual situation of the 10 *pango* songs; the entropy (.96) is very close to 1. Knowing the probabilities of the chords, therefore, does not remove much of the uncertainty in predicting a chord at an arbitrary pulse. In other words: knowledge of the probability distribution of the chords does not give us much idea about the character, the nature, or the structure of these 10 *pango* songs. Thus the zero order approximation is too crude.

First order approximation. The next step is to find out how much uncertainty will be removed in the prediction of a chord at any arbitrary pulse, when the chord played at the preceding pulse is known. This is called the first order approximation. All pairs of consecutive chords are investigated. For the song "Chijungu", e.g., we get

31, 11, 11, 11, 11, 11, 11, 11, 12, 23, 33, 34,
44, 44, 44, 42, 22, 23, 34, 43, 33, 34, 44, 43

The last pair consists of the last chord of the pattern followed by the first chord, as the pattern of the song is repeated several times. The results for the song "Chijungu", are summarized in the following frequency table.

		chord at pulse t			
		1	*2*	*3*	*4*
chord at	*1*	7	1	0	0
previous	*2*	0	1	2	0
pulse: t-1	*3*	1	0	2	3
	4	0	1	2	4

Table 2: number of transitions between chords for the song "Chijungu"

The matrix clearly shows that, e.g., chord *1* is never followed by chord *3* or *4*. When chord *1* has been played, 7 out of 8 times it is followed by chord *1* again, and 1 out of 8 times it is followed by chord *2*.

For the 10 *pango* songs together one gets the frequency matrix given in table 3.

		chord at pulse t				total row frequency
		1	*2*	*3*	*4*	
chord at	*1*	81	23	2	1	107
previous	*2*	4	60	31	3	98
pulse: t-1	*3*	21	4	146	38	209
	4	1	11	30	56	98
						512

Table 3: number of transitions from chord at pulse (t-1) to chord at the next pulse t for the 10 *pango* songs

The estimation of the *matrix of transition probabilities* (table 4) for this type of music can be constructed from table 3. This is done by dividing each frequency in a certain row by the total row frequency.

		chord at pulse t				row entropy
		1	*2*	*3*	*4*	
chord at	*1*	.76	.21	.02	.01	.48
previous	*2*	.04	.61	.32	.03	.65
pulse: t-1	*3*	.10	.02	.70	.18	.63
	4	.01	.11	.31	.57	.70

Table 4: matrix of transition probabilities (estimated)

Table 4 yields the transition probabilities from one chord to the next. The probability that, e.g., chord *3* will be played at pulse t, given that chord *2* has been played at the previous pulse, (t-1), is estimated by the number of times chord *2* is followed by chord *3* divided by the number of times chord *2* has been played, i.e. $\frac{31}{98} =$ .32. In any row the sum of these probabilities equals 1. The matrix of transition probabilities expresses how likely it is that a particular chord is followed, in the next pulse, by each of the four chords.

The probability that, e.g., chord *2* will be played depends on the preceding chord because the probabilities of the second column differ very much. The chord production, therefore, cannot be described as a random process: the production of a chord at pulse t does depend on the production of a chord at pulse (t-1)[2].

How much uncertainty is there in the prediction of a chord at pulse t, when the chord being played at pulse t-1 is known? As a measure for this uncertainty I use the conditional entropy H(T/T-1). This quantity is the weighted sum of the row entropies, calculated from the matrix of transition probabilities given in table 4[3]. In this case it is found that H(T/T-1) = .61; this is much closer to 0 (complete predictability) than the entropy of the zero order approximation H(T) = .96. The first order approximation, therefore, does indeed reduce the uncertainty: knowledge of the chord being played at pulse (t-1) reduces the uncertainty in the prediction of a chord at pulse t.

Second order approximation.

One could ask whether knowledge of the chord being played at pulse (t-2), in addition to knowledge of the chord being played at pulse (t-1), i.e. knowledge of the *two* previous chords, will reduce the uncertainty in the prediction of the chord at pulse t even more. In this case all the triplets of consecutive chords must be considered. In the song "Chijungu," e.g., they are:

311, 111, 111, 111, 111, 111, 111, 112, 123, 233,
334, 344, 444, 444, 442, 422, 223, 234, 343, 433,
334, 344, 443, 431

From the triplets for the 10 *pango* songs together a frequency table is constructed, and the 64 estimated conditional probabilities are calculated from there[4]. These probabilities are given in table 5. In the last row but one in table 5, for instance: suppose that chord *3* has been played at pulse (t-2) and suppose that chord *4* has been played at pulse (t-1) (these are the two conditions). The probability that these will be followed at pulse t by:

chord *1* is equal to .00
chord *2* is equal to .03
chord *3* is equal to .37
chord *4* is equal to .60

So the consecutive chord triplet *3 4 1* does not occur in this music. If chords *3* and *4* have been played they most likely are followed by chord *4* (60%), less likely by chord *3* (37%) and rarely by chord *2* (3%).

In table 5 the last column gives the relative frequency P_{ij} of chord i at pulse (t-2) and chord j at pulse (t-1). These factors can be found from table 3 by dividing each frequency by 512. The probability of chord *2* at pulse (t-2) and chord *3* at pulse (t-1) is for instance $\frac{31}{512} = .061$.

chord at pulse (t-2)	chord at pulse (t-1)	chord at pulse t *1*	*2*	*3*	*4*	weight factor P_{ij}
1	*1*	.70	.26	.03	.01	.158
2	*1*	1.00	.00	.00	.00	.008
3	*1*	.90	.10	.00	.00	.041
4	*1*	1.00	.00	.00	.00	.002
1	*2*	.00	.78	.22	.00	.045
2	*2*	.05	.50	.42	.03	.117
3	*2*	.25	.75	.00	.00	.008
4	*2*	.00	.82	.09	.09	.021
1	*3*	1.00	.00	.00	.00	.004
2	*3*	.00	.03	.87	.10	.061
3	*3*	.12	.01	.65	.22	.285
4	*3*	.03	.03	.84	.10	.059
1	*4*	.00	1.00	.00	.00	.002
2	*4*	.00	.33	.33	.33	.006
3	*4*	.00	.03	.37	.60	.074
4	*4*	.02	.14	.27	.57	.109

Table 5: conditional probabilities of chord at pulse t when the chords at pulse (t-2) and pulse (t-1) are known

The measure for the uncertainty in the prediction of a chord at pulse t, given the chords that were played at pulse (t-1) and pulse (t-2), is the conditional entropy H(T/T-2, T-1). This conditional entropy is a weighted sum of the row entropies in the matrix of table 5. The weights are P_{ij}, given in the last column of this matrix. Calculations yield:

$$H(T/T\text{-}2,\ T\text{-}1) = .58$$

Comparison approximations.

It has been shown that

zero order:	H(T)	=	.96
first order:	H(T/T-1)	=	.61
second order:	H(T/T-2, T-1)	=	.58

The first order approximation is an improvement on the zero order approximation, but the second order approximation is hardly an improvement on the first order approximation. The uncertainty in the prediction of a chord at pulse t is not substantially reduced, going from the first order approximation to the second order approximation. *We may conclude, therefore, that the matrix of transition pro-*

babilities, given in table 4, describes the character of the chord chains with almost the highest accuracy we can obtain by this method.

This matrix of transition probabilities enables one to compose — in a crude way — chord chains in the style of the 10 *pango* songs[5]. Composition of chord chains with the table of transition probabilities (and a table of random numbers) is in fact the construction of a Markov chain. In this production of the chain of chords the "memory" of the "composer" of the chords is restricted; he remembers only the chord that has been composed on the last pulse[6]. Of course I am here talking about a model of the music production and not about the actual production.

SUNG MELODY

The notes being used for the sung melody are 5^{I}, 6^{I}, 1, 2, 3, 4, 5, and 6. At each pulse a melody note is produced, with a very few exceptions in which only a chord is played on the *pango*. I shall analyse the melody as a chain of notes at the consecutive pulses in the same way as the chord chains have been analysed.

First I shall demonstrate how strong the association between melody note and chord is on the *pango*. The number of times that a particular chord and melody note sound at the same pulse t are given in table 6.

	melody note									
	5^{I}	6^{I}	1	2	3	4	5	6	no note	frequency, chords
chord *1*	8	—	83	—	16	—	—	—	—	107
chord *2*	—	3	—	88	2	5	—	—	—	98
chord *3*	—	—	5	—	129	—	61	—	14	209
chord *4*	—	—	1	1	—	81	—	7	8	98
frequency, notes	8	3	89	89	147	86	61	7	22	512

Table 6: frequency table for simultaneously sounding chord and melody note

Using table 6 one can calculate the uncertainty in predicting the melody note at pulse t when the chord at that same pulse t is known. This is expressed by the conditional entropy H(melody / chord) = .35. Similarly one can calculate the uncertainty in predicting the chord at pulse t when the melody note at that same pulse t is known. This is expressed by the conditional entropy H(chord / melody) = .17. These two entropies are small, i.e. the association between chord and melody is strong.

For the chains of melody notes, the zero order, first order, and second order approximations are similar to the ones carried out for the chords. Below I give the uncertainty in predicting a melody note at pulse t, when no previous note is known (zero order approximation), when the melody note at pulse (t-1) is known (first order approximation), and when both the melody notes at pulse (t-1) and (t-2) are known (second order approximation):

zero order approximation:	H(T) = .82
first order approximation:	H(T/T-1) = .43
second order approximation:	H(T/T-1, T-2) = .38

Again one can conclude that the first order approximation is sufficient (i.e. almost the highest accuracy we can obtain by this method) to describe the essence of the melodic movement. The chain of melody notes is reasonably well described by a Markov chain.

Table 7 shows the frequency matrix needed for a first order description of the melody.

		note at pulse t									
		5'	6'	1	2	3	4	5	6	row total	row entropy
	5'	7	1	—	—	—	—	—	—	8	—
	6'	—	2	1	—	—	—	—	—	3	—
	1	1	—	66	19	3	—	—	—	89	.34
note at	2	—	—	1	57	31	—	—	—	89	.34
pulse t-1	3	—	—	11	5	98	32	1	—	147	.46
	4	—	—	1	7	11	49	16	2	86	.57
	5	—	—	9	—	4	5	42	1	61	.48
	6	—	—	—	1	—	—	2	4	7	—
										490	

Table 7: frequency matrix of transitions between melody notes at pulse (t-1) and pulse t

Table 7 also demonstrates the following:

- there are 58 jumps to a higher note
- there are 326 transitions to the same note
- there are 106 jumps to a lower note.

The total number of jumps to a higher note is 0.55 times the total number of transitions to a lower note. The jumps to a lower note are relatively small and the jumps to a higher note are relatively large. This is also the case in music of some neighbouring areas: the melodic movement consists of a number of small jumps down and a smaller number of jumps, that are larger in size, up again (Davidson: 1970, p. 112; Tracey: 1971, p. 88). For European music this ratio (the number of jumps to a higher note divided by the number of jumps to a lower note) has been found to be 0.91 for a set of 7 Dutch folk songs (van Zanten: 1975) and 0.90 for the recorded music of the Beatles (Van den Bergh: 1976). Van den Bergh also cites some ratios given by Merriam (1956) for a number of Latin American peoples: 0.71 (Ketu, Brazil), 0.82 (Gège, Brazil) and 0.86 (Rada, Trinidad).

In the last column of table 7 the row entropies have been written down for the cases in which the row totals are "sufficiently" large to get a fair estimation of the entropies. The uncertainty in the prediction of a melody note at pulse t is largest when note 4 has been sung at pulse (t-1). This uncertainty is the lowest when the note 1 or the note 2 has been produced at the previous pulse: it is fairly certain that from note 1 or from note 2 the melody will either move to the same note again, or go down to the next lower note.

STRUCTURAL ANALYSIS

By "structural analysis" I mean the analysis that is usually carried out on chord sequences to find out which are the most common patterns in chord alternations. I will now show how to derive a "structural analysis" of the chord sequences, starting from the frequency matrix given in table 3.

Here there is no further interest in knowing how many consecutive time-units a particular chord sounds. The area of concern is the changes to a different chord. This means replacing the *chains* of chords by *sequences* of chords. Therefore it is the matrix of table 3 which should be studied disregarding the diagonal frequencies. This new frequency matrix is given in table 8, first matrix. From this matrix, that records only the frequencies of changes to a different chord, the third matrix of table 8 is constructed. I call this the "matrix of frequent chord changes". This 3rd matrix is constructed from the first one in table 8 by neglecting transitions occurring less than 15% of the time in the transitions within each row. If a transition occurs more than 15% of the time in all transitions within a row, an asterisk $*$ replaces the number.

$$\begin{array}{cc} \text{from} \backslash \text{to} & \begin{array}{cccc} \mathit{1} & \mathit{2} & \mathit{3} & \mathit{4} \end{array} \\ \begin{array}{c} \mathit{1}\\ \mathit{2}\\ \mathit{3}\\ \mathit{4} \end{array} & \left[\begin{array}{cccc} — & 23 & 2 & 1 \\ 4 & — & 31 & — \\ 21 & 4 & — & 38 \\ 1 & 11 & 30 & — \end{array}\right] \end{array} \longrightarrow \begin{array}{c} \begin{array}{cccc} \mathit{1} & \mathit{2} & \mathit{3} & \mathit{4} \end{array} \\ \left[\begin{array}{cccc} — & .88 & .08 & .04 \\ .11 & — & .81 & .08 \\ .33 & .06 & — & .61 \\ .02 & .26 & .72 & — \end{array}\right] \end{array} \longrightarrow \begin{array}{c} \begin{array}{cccc} \mathit{1} & \mathit{2} & \mathit{3} & \mathit{4} \end{array} \\ \left[\begin{array}{cccc} — & * & — & — \\ — & — & * & — \\ * & — & — & * \\ — & * & * & — \end{array}\right] \end{array}$$

1. frequency matrix of chord changes
2. matrix of relative frequencies of chord changes
3. matrix of frequent chord changes

Table 8: construction of the "matrix of frequent chord changes"

From this "matrix of frequent chord changes" a few patterns of chord sequences can be derived that are characteristic for this *pango* music. When chord *1* has been played, the next chord will almost certainly be chord *2*. After chord *2* the most probable change will be to chord *3*. After chord *3* there are two highly probable chords: *1* and *4*. Continuing this way yields the following most probable chord sequences:

1 *2* *3* ......
3 *4* *3* ......
4 *2* *3* ......

For the melody one can similarly establish a few probable sequences:

1	2	3	4	5	......
3	1	2	3	......	
4	3	4	......		
4	2	3	......		

In the sequence of notes 1 2 3 4 the first note may last for 3 time units, the second note for 2 time units, the third note for 3 time units and the fourth note for 4 time units, as in the beginning of the song "Nati nikwere". This information is lost in the structural analysis: we do not know how many time units a particular note (or chord) lasts on the average. The matrices in tables 3 and 7 however, do contain this information.

CONCLUSION

I have given a quantitative analysis of Malawian *pango* songs. A quantitative approach seems worth trying, although the music analysed here is not very complicated and the Markov chain model rather crude.

My analysis has been an attempt to use certain analysing techniques and I have certainly not given a description of this *pango* music in terms of the musician's own concepts.

The pattern of each song has been described as a chain of sung melody notes with a parallel chain of chords played on the *pango*. It has been shown that the chord chains and the melody note chains can reasonably well be described as Markov chains. This means that for the prediction of the chord (melody note) to be played at pulse t it is enough to know the chord that has been played at the previous pulse, (t-1), only. The chords played before (t-1) need not be known.

If we accept the Markov chain model, all information about the structure of this music is contained in table 3 for the chords and table 7 for the melody[7]. Table 6 shows clearly that there is a strong association between chord and melody. The top note of the chord very often coincides with the melody note: 381 of the 512 pulses.

The interval between the two notes of the chord is usually between 300 and 400 cents as 80% of the chords consists of chord *1*, *2* or *3* and only 20% of the chords consists of chord *4* (about 500 cents). This predominance of parallel "thirds" contrasts with the harmonies found in neighbouring areas such as Zambia (Davidson: 1970) and Rhodesia (Tracey: 1970) in which "fourths" in the harmonies seem to be predominant.

From table 3 I have derived that the most common chord sequences are *1 2 3* ... ; *3 4 3* ... and *4 2 3* ... From table 7 it can be seen that the melody moves down in many small jumps and up again in much fewer, larger, jumps. The total number of jumps to a higher note is just over half the total number of jumps to a lower note in the melody. This means that there is a very strong downward trend of the melody compared to melodies in other musical areas (Van den Bergh: 1976; Van Zanten: 1975). The most common sequences of melody notes are 1 2 3 4 5 ... ; 3 1 2 3 ... ;4 3 4 ... and 4 2 3 ... .

NOTES

[1] see e.g. Khinchin: 1957 or Shannon and Weaver: 1949. I shall use the following definition for H(T). Suppose the possible outcome of an experiment of chance is *1, 2, 3, ..., n* with respective probabilities $P_1, P_2, P_3, ..., P_n$ then the entropy of the scheme is defined as

$$H(T) \quad = \quad - \sum_{i=1}^{n} P_i \,.\, {}^{n}\log P_i$$

As we use base n for the logarithm, the maximum value of H(T) equals 1; this maximum is reached for $P_1 = P_2 = ... = P_n = \frac{1}{n}$

[2] Mathematically this can be expressed by the formula $P \{\text{chord } i \text{ at t} / \text{chord } j \text{ at (t-1)}\} \neq P \{\text{chord } i \text{ at t}\}$ for $i, j \in \{1, 2, 3, 4\}$

[3] The conditional entropy H(T/T-1) is defined in the following manner. Suppose the possible outcome of an experiment of chance is *1, 2, 3, ..., n* with respective probabilities $P_1, P_2, P_3, ..., P_n$. Let the matrix of transition probabilities be given by the conditional probabilities $p_{ij} = P \{\text{outcome} j \text{ at t} / \text{outcome} i \text{ at t-1}\}$ for $i = 1, ..., n$ and $j = 1, ..., n$. Then the conditional entropy is defined to be

$$H(T/T\text{-}1) = \sum_{i=1}^{n} P_i \,.\, H_i = - \sum_{i=1}^{n} P_i \,.\, \sum_{j=1}^{n} p_{ij} \,.\, {}^{n}\log p_{ij}$$

where H_i is the entropy of row i in the matrix of transition probabilities.

[4] I.e. the 64 conditional probabilities

$P \{\text{chord } k \text{ at t} / \text{chord } i \text{ at (t-2) and chord } j \text{ at (t-1)}\}$ where $i, j, k \in \{1, 2, 3, 4\}$

[5] As the music made use of only 4 different chords, the analysis could easily be carried out up to the second order approximation. When there are more than 4 different chords this analysis becomes far more complicated. For example, 10 chords lead to the determination of 100 probabilities in the first order approximation and 1000 probabilities in the second order approximation.

[6] I did not *prove* that the chain of chords is a Markov chain. The choice of a chord at pulse t may be influenced by the chord played at pulse (t-1) and, in addition, the chord played at, for instance, pulse (t-6). In this case the "memory" of the composer would not be restricted to the last pulse or the last two pulses. In fact the real situation is much more complicated than this model of a Markov chain: the memory of the composer is, indeed, not restricted to the last pulse or the last two pulses.

An exact definition of a (finite) Markov chain is the following (e.g. Cox and Miller: 1965, p. 76): Suppose the set of all possible states of a system is given by the set $\{1, 2, 3, ..., n\}$. At the time points 0, 1, 2, ..., k the states of the system are called $S_0, S_1, S_2, ..., S_k$ respectively. So $S_0 \in \{1, 2, 3, ..., n\}$, $S_1 \in \{1, 2, 3, ..., n\}$, ..., $S_k \in \{1, 2, ..., n\}$.

The chain of states of the system $S_0\ S_1\ S_2\ ...\ S_k$ is called a Markov chain if for each set of states *h, j, ..., m* such that

$h \in \{1, 2\ 3, , ..., n\}; j \in \{1, 2, 3, ..., n\}; ....; m \in \{1, 2, 3, ..., n\}$ the following is true

$P \{S_k = m / S_0 = h, S_1 = ..., ..., S_{k-1} = j\} = P \{S_k = m / S_{k-1} = j\}$

In my analysis the set of all possible states of the chord chain consists of the chords *1, 2, 3* and *4*. At each pulse one of these 4 chords is chosen.

[7] Whether the Markov chain model holds, and therefore tables 3, 6 and 7 contain the essence of this music, could be checked by experiment. A computer would have to compose songs using the information contained in these tables. These computer-made songs would then have to be played to people from this cultural area. They would have to judge whether the computer-made songs are of the same style as the songs played by Emmanuel Gondwe.

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PANGO SONGS USED IN THE ANALYSIS

English translation by Emmanuel C.R. Gondwe

C = chord **M** = melody note **T** = text

1. "Nanga nende"

C: *1 1 1 1 2 2 3 3 3 3 4 4 4 4 3 3 2 2 2 2 2 2 2 2*
M: 1 . 1 . 2 . 3 3 . . 4 4 4 . 3 . 2 2 2 . 2 . . .
T: na - nga ne - nde mwe mu - the - nge - le mu - li mi - nga

C: *1 1 2 2 3 3 4 4 4 4 3 3 3 3 4 4 3 3 3 3 3 3 3 3*
M: 1 . 2 . 3 . 4 . . . 5 5 5 . 4 . 3 3 3 . 3 . . .
T: na - nga ne - nde mu - the - nge - le mu - li mi - nga

(Where ever I go, there are thorns in the bush)
Strumming; falsetto voice.

2. "Mkalamu zalira"

C: *3 3 3 1 1 1 1 2 3 2 2 2 3 3 4 3 3 3 4 4 3 4 4 4*
M: 5 5 5 1 1 1 . 2 3 2 . 2 3 3 4 3 3 . 4 .
T: mka-la - mu za - li - ra ku mu che - mbo mka-la - mu za - li - ra

(The lions are roaring in the chasms)
Strumming; falsetto voice.

3. "Changa"

C: *3 3 3 3 1 1 2 3 3 4 4 4 4 2 2 3 3 4 3 3 3 3 1 1*

M: 3 3 3 3 1 1 2 3_. 4 4_. 6 2_. 3_. 3 3 3 3 1 1

T: ba - mu - ko - ra ku mu - chi - ra wa - tha - ya cha - nga ba - mu - ko - ra ku mu-
mu - ma - le - zi zi - ku - da - nga - mo ni mbe-ba na tu - yu - ni mu - ma - le - zi zi - ku-

C: *2 3 3 4 4 4 4 4 4 3 3 4*

M: 2 3_. 4 4_. 4 6 . 5 . 4

T: -chi- ra wa- tha - ya
-da- nga- mo na tu- yu- ni

(If you want to catch the tail you will miss it. Bushbaby!
In the fingermillet garden the mice and the birds start eating.)
Strumming; falsetto voice.

4. "Nithereleni maye"

C: *1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 3 3 4 4 4 4 2 2*

M: 3 1 1 1 1 1 1 . . . . . 2 2 2 2 3 3 4 . . . 2 .

T: ni - the - re - le - ni ma - ye! ni - the - re - le - ni ma - ye

C: *1 1 1 1 2 2 3 3 3 3 3 3 3 1 1 1 2 2 3 3 3 3 3 3*

M: 3 3 3 3 4 4 5 . . . . . 1_. 1 2_. 3 . . . . .

T: ni - the - re - le - ni ma - ye! ba - ke - ya - la

C: *3 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 3 3 4 4 4 4 2 2*

M: 3 1 1 1 1 1 1 . . . . . 2 2 2 2 3 3 4 . . . . .

T: ni - the - re - le - ni ma - ye! ni - the - re - le - ni ma - ye

C: *1 1 1 1 2 2 3 3 3 3 3 3 3 1 1 1 2 2 3 3 3 3 3 1*

M: 3 3 3 3 4 4 5 . . . . . 1_. 1 2_. 3 . . . . .

T: ni - the - re - le - ni ma - ye! ba - ke - ya - la

C: *2 2 2 2 3 3 4 4 4 4 4 2 2 2 2 2 2 2 3 3 3 3 4 4*

M: 2 2 2 2 3_. 4 . . . . . 2 2 2 2 2 2 2 3 3 3 3 4_.

T: mwa-ni the - mwe la - ci nga - ti ni - li mwa-na wa mu du - mbu wi -

C: *3 3 3 3 3 3 3 1 1 1 2 2 3 3 3 3*

M: 5 . . . . . 1_. 1 2_. 3 . . .

T: nu ba - ke - ya - la

(Help! Oh! The K.A.R.! (=King's African Rifles) Why do you like me as if I am the child of your sister?)
Strumming; falsetto voice.

5. "Chijungu"

C: *3 1 1 1 1 1 1 1 1 2 3 3 4 4 4 4 2 2 3 4 3 3 4 4*

M: 5 3 . 3 . . 1 1 1 2 3 . 4 4 . 4 2 2 3 4 3 . 4 .

T: chi - ju - ngu chi - ri ku mi - nda m'ka-ya - be mwa-ba bo - li ba - ne

(A big pumpkin: it is in the gardens. Go and fetch it, my wife)
Strumming; falsetto voice.

6. "Dumbu wane"

C: *1 1 1 1 2 2 2 3 3 3 4 3 3 3 1 1 2 2 2 3 3 4 4 3*

M: 1 . 1 . 2 2 2 3 . . 4 5 . 1 . 2 2 2 3 3 4 4 3

T: U - yo du - mbu wa - ne yo du - mbu wa - ne ba - ko - me - la

C: *2 2 3 3 4 3 4 3 3 3 3 3*

M: 2 . 3 . 4 5 4 5 . . . . .

T: da - ra du - mbu wa - ne

(My sister, they have murdered my sister)
Strumming; falsetto voice.

7. "Wam'pata gaga"

R *3 2 4 3*

C: L *4 4 4 4*

M: 6 . 5 . 4 4 4 4 5 . 6 .

T: ah eh wa - m' - pa - ta ga - ga

(You will leave behind all luxury)
Plucking with left and right hand fingers; normal voice.

8. "Bamupara bakurya cheyo"

C: *3 2 1 1 1 1 1 1 1 1 1 3 1 1 2 2 2 3 3 3 4 3 3 4*

M: 5 3 1 . 1 1 1 1 . 1 . 3 1 . 2 . . 3 . . 4 5 .

T: ba - mu - pa - ra ba - ku - rya che - yo mwe che - yo

C: *3 3 1 1 2 2 3 3 3 4 3 4 4 4 3 3 3 4 3 3 3 3 3 3*

M: 3 . 1 . 2 2 3 3 . 4 5 4 . . 3 . . 4 5 . . .

T: ba - ku - rya tu mpa-li - ro che - yo

C: *3 3 3 3 1 1 1 1 1 1 1 1 2 2 2 3 3 3 3 3 1 1 1 1*

M: 1 . . . 5^1 . . . . 6^1 . . 1 3 5 . . 1 . 1 .

T: ah eh che - yo mwe che -

C: *3 1 1 1 1 2 3 4 4 4 3 3 3 4 3 3 3 3 3 3 3 3 3 3*

M: 3 1 1 1 . 2 3 4 . . 3 . . 4 5 . . .

T: -yo cha mu nyu - mba che - yo

(What do bachelors eat? They eat the bones. (They are like) the broom of the house)
Strumming; falsetto voice and double whistling.

9. "Nilinde"

C: R *1 1 2 2 3 . 3 . 2 2 2 3 3 . 3 .*
L *4 4 4 4 4 4 4 4*

M: 1 1 . 2 3 4 3 . 3 4 . 2 2 2 2 3 4 3 3 3 4

T: ni - li - nde ma - ma we wa - lu - ta na mwa-na, u - we - re - ko

(Don't leave me, my wife. You have gone with the child. Come back!)
Plucking with left and right hand fingers; normal voice.

10. "Nati nikwere"

C: *1 1 1 2 2 3 3 3 4 4 4 4 2 2 2 3 3 4 4 4 3 3 3 3*

M: 1 1 1 2 . 3 . . 4 . 4 . 2 2 2 3 . 4 . . 5 . 5 .

T: na - ti ni - kwe - re kwe - ra na - ti ni - kwe - re kwe - ra

C: *3 3 3 3 3 4 3 3 3 3 3 3*

M: 3 3 3 3 3 4 3 3 3 3 .

T: na - kwe - ra pa chu - ru, pa - li mi - nga

(I wanted to climb. Climb! I climbed on the hill. There were thorns)
Strumming; falsetto voice.

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