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Basic Relationship Formulation of the Sundatang Physical Characteristics

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Abstract
Sundatang is one of the traditional musical instruments which were made based from natural resources in the land of Sabah. The instrument which belongs to the Kadazan, Dusun and Rungus communities ought to be conserved and upgraded to make it popular and well-accepted among the new generation in this state and generally throughout the world. The purpose of this study was to formulate the basic relationship of the physical characteristics of sundatang. To achieve this, several important dimensions were measured from four units of sundatangs. The measured physical characteristics were scrutinized, analyzed and compared to obtain general physical characteristics of sundatang. Four basic relationship equations of the physical characteristics were formulated which are related to the length of sundatang, distance of frets, height of frets and width of sundatang. The formulated equations can be used to calculate the intended physical dimensions in the making process of sundatang. It is also very important to the advancement of construction technique study of sundatang in future.

Introduction

Sabah is the second largest state in Malaysia which richly blessed with natural diversity and unique heritages. One of the heritage products which based on flora and fauna resources in this state is sundatang. The sundatang is a traditional musical instrument among the Kadazan, Dusun and Rungus communities in Sabah (Alman, 1961; Liew, 1962; Frame, 1975; 1976; Pugh-Kitingan, 1987; 1992; 2003; 2004). This instrument has the basic shape of guitars with two metal strings as shown in Figure 1 (anatomy of sundatang) and Figure 2 (photo of sundatangs). The body of sundatang was made of vitex or acacia wood, and its frets were made of metal and fixed on the top plate and neck of sundatang using bee wax. The vitex and acacia woods and bee wax are widely available in Sabah secondary forest. Nowadays, sundatang is likely to disappear among the people in Sabah, overridden by popularity of the modern musical instruments such as guitar, violin, piano and etc. This instrument ought to be conserved and upgraded to make it popular and well-accepted among the new generation in this state and generally throughout the world.

Since in the new millennium, researches on traditional musical instruments in Sabah, Malaysia were started to focus on the scientific studies as reported by Ong and Dayou (2009), Wong *et al*. (2013a) and Wong *et al*. (2013b) for sompoton, Ismail *et al*. (2006) for kompang, Batahong and Dayou (2003a; 2003b), Batahong *et al*. (2003) and Batahong and Dayou (2002) for kulintangan, and

Batahong, *et al*. (2014a; 2014b) and Batahong and Dayou (2016) for sundatang musical instrument. Study of the vibrational properties of sundatang soundboard in clamped edge and free edge was reported by Batahong *et al.* (2014a), making technique by Batahong *et al.* (2014b), and effect of frets to the instrument sound frequency by Batahong and Dayou (2016). Thus, as an additional research on sundatang, the goal of this study was to formulate the basic relationship of the physical characteristics of sundatang. To achieve this goal, physical dimensions of sundatang were investigated.

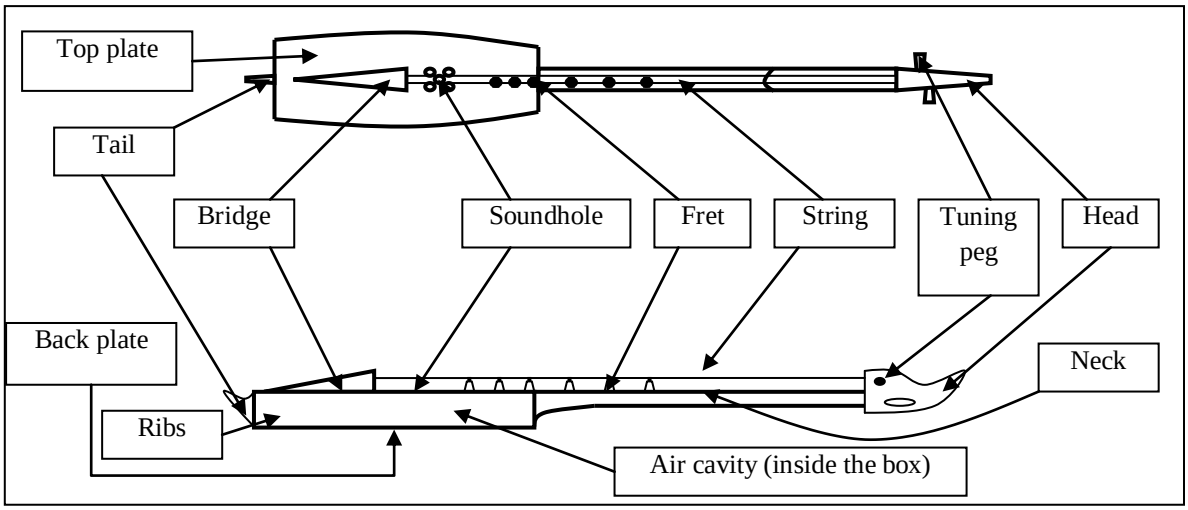


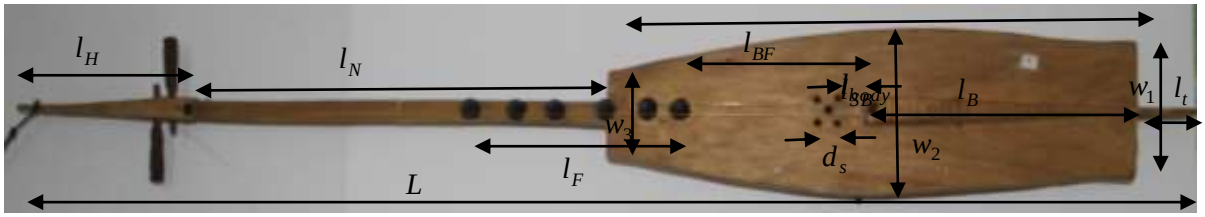
Figure 1. Anatomy of sundatang

Figure 2. Photo of sundatang A, B, C and D.

As explained by Batahong *et al.* (2014b), the traditional sundatang was made without using modern equipments and written reference of dimensions standard. The formation of sundatang is affected by the maker's instinct, past experience and imitation at ready-made sundatang. Hence, different sets of sundatangs show variety of features. However, there are some patterns observed in its physical characteristics. This study was conducted to discover these patterns and reveal that the traditional making technique also able to produce musical instruments with its own standard. The formulated equations are very important as a tool to the advancement making technique study of sundatang in future. The equations can be used to calculate the important dimensions of sundatang.

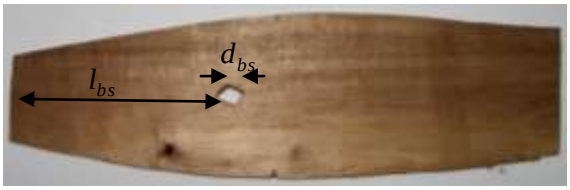
Materials and methods

Study of physical properties was conducted on four units of sundatangs which were made by Mr. Boginda Mokilin, a well-known sundatang maker and player from Kampong Tinangol, Kudat, Sabah as shown in Figure 2. The sundatangs were labeled as sundatang A (acacia wood) and B (acacia wood) and C (vitex wood) and D (vitex wood). In this study, thirty four important physical dimensions of the sundatang body were measured (Figure 3) and analyzed.

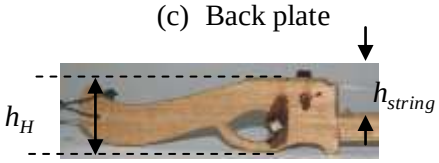


(a) Front view

(b) Back view



(c) Back plate



(d) Head

Figure 3: Measured dimensions of different part of the sundatang.

Results and discussion

The results show that twenty four of the physical dimensions are very close to each other with SD is in the range of 0 cm to 1 cm, and another ten physical dimensions is in the range of 1 cm to 4.65 cm. The ten physical dimensions consists of the total length, L, length of body, l_{body}, length of tail, l_t, distance of sound holes and bridge, l_{SB}, length of neck, l_N, length of head, l_H, distance of bridge and fret, l_{BF}, width 1, w_1, width 2, w_2 and width 3, w_3 as shown in Table 1. The total length, L and width 2, w_2 of the sundatang are having a greater SD, this is may be because of these dimensions are depend to the original length and width of the wooden block as a main material of construction.

Table 1. Measured physical dimensions of the sundatang A, B, C and D.

No.	Dimensions	Set of sundatang				Average	Standard Deviation
		A (± 0.1cm)	B (± 0.1cm)	C (± 0.1cm)	D (± 0.1cm)		
1	Total length, L	109.0	104.0	103.0	113.0	107.25	4.65
2	length of body, l_{body}	50.0	45.3	43.6	47.0	46.48	2.73
3	length of bridge, l_B	22.1	23.3	21.5	23.5	22.60	0.96
4	length of tail, l_t	4.0	5.6	3.2	4.7	4.38	1.02
5	distance of sound hole and bridge, l_{SB}	3.2	2.4	3.9	5.2	3.68	1.19
6	distance between two sound holes, d_s	2.3	1.8	1.9	1.7	1.93	0.26
7	length of neck, l_N	39.6	36.4	38.0	39.5	38.38	1.51
8	length of head, l_H	20.0	17.1	17.9	22.4	19.35	2.37
9	distance from 1st to 2nd fret, $l_{F_{1-2}}$	4.1	4.0	3.9	3.5	4.05	0.45
10	distance from 2nd to 3rd fret, $l_{F_{2-3}}$	3.8	3.5	3.1	3.6	3.50	0.29
11	distance from 3rd to 4th fret, $l_{F_{3-4}}$	4.2	4.3	4.1	4.3	4.20	0.12
12	distance from 4th to 5th fret, $l_{F_{4-5}}$	3.0	3.6	3.3	2.9	3.18	0.28
13	distance from 5th to 6th fret, $l_{F_{5-6}}$	2.7	2.9	2.9	2.7	2.80	0.12
14	distance from 1st to 6th fret, l_F	17.7	18.2	18.0	17.0	17.73	0.53
15	distance of bridge and fret, l_{BF}	17.6	15.8	15.7	17.5	16.65	1.04
16	height of ribs, h_R	3.8	4.7	4.0	4.5	4.25	0.42
17	length of tuning peg, l_{TPeg}	7.2	7.4	7.4	8.8	7.70	0.74
18	width of neck, w_n	2.0	1.9	1.9	1.9	1.93	0.05
19	height of neck, h_n	1.9	1.6	1.9	2.0	1.85	0.17
20	height of bridge, h_B	1.9	1.8	1.8	1.8	1.83	0.05
21	height of 1st fret, h_{F1}	1.9	1.9	2.6	2.2	2.15	0.40
22	height of 2nd fret, h_{F2}	1.8	1.8	2.5	2.0	2.03	0.40
23	height of 3rd fret, h_{F3}	1.7	1.7	2.3	1.9	1.90	0.35
24	height of 4th fret, h_{F4}	1.6	1.6	2.1	1.8	1.78	0.29
25	height of 5th fret, h_{F5}	1.5	1.5	1.9	1,7	1.63	0.23
26	height of 6th fret, h_{F6}	1.4	1.4	1.8	1.6	1.55	0.23
27	height of head, h_H	5.5	6.0	5.6	6.5	5.90	0.45
28	height of string, h_{string}	2.0	1.9	2.4	2.5	2.20	0.29
29	width 1, w_1	15.4	11.9	14.0	16.0	14.33	1.82
30	width 2, w_2	18.0	13.9	18.0	19.0	17.23	2.27
31	width 3, w_3	9.9	7.8	9.0	10.4	9.28	1.14
32	diameter of back plate sound hole, d_{bs}	2.0	2.0	2.0	2.0	2.00	0.00
33	thickness of ribs, r_{ribs}	0.4	0.5	0.4	0.4	0.43	0.05
34	thickness of back plate, t_{bp}	0.4	0.4	0.4	0.4	0.40	0.00

Length of sundatang

By referring to the measurement values of the length of tail, l_t, length of body, l_{body}, length of neck, l_N and length of head, l_H of the four units of sundatangs in Table 1. Obtained that the total length of the sundatang, L can be written in a mathematical expressions as

$$L = l_t + l_{body} + l_N + l_H . \quad (1)$$

Ratio of the length of tail, length of body, length of neck and length of head to the total length of each unit of sundatang were calculated as shown in Table 2. It shows that the ratio values for each of the sundatang are closer to each other. In the other word, the sundatangs have an approximately ratio of the length of tail, length of body, length of neck and length of head to the total length. If average of the ratio values is calculated as written in sixth column in Table 2, average relationship of the length of tail, length of body, length of neck and length of head to the total length of the sundatangs, separately, can be expressed mathematically as

$$l_t = 0.04L , \quad (2)$$

$$l_{body} = 0.43L , \quad (3)$$

$$l_N = 0.35L \quad (4)$$

and

$$l_H = 0.18L , \quad (5)$$

respectively. These equations can be used to determine length of tail, body, neck and head of sundatang from the available total length, L in the early stage of sundatang construction which is forming the basic shape of sundatang.

Table 2. Ratio of length of tail, body and neck to the total length of sundatang.

Ratio	Sundatang				average
	A	B	C	D	
Length of tail to total length, l_t/L	0.04	0.05	0.04	0.04	0.04
Length of body to total length, l_{body}/L	0.46	0.44	0.42	0.42	0.43
Length of neck to total length, l_N/L	0.32	0.35	0.37	0.35	0.35
Length of head to total length, l_H/L	0.18	0.16	0.17	0.20	0.18

Distance of frets

From the row 9th to 13th in Table 1 is written the values of the distance between every two nearest frets, whereas, in row 14th in the table is written the distance of the 1st fret to the 6th fret of the four units of sundatangs. Sum of the distance from the 1st fret to 2nd fret, $l_{F_{1-2}}$, 2nd fret to 3rd fret, $l_{F_{2-3}}$, 3rd fret to 4th fret, $l_{F_{3-4}}$, 4th fret to 5th fret, $l_{F_{4-5}}$ and 5th fret to 6th fret, $l_{F_{5-6}}$ is equal to the distance from the 1st fret to the 6th fret, l_F. Mathematically, this summation can be expressed as

$$l_F = l_{F_{1-2}} + l_{F_{2-3}} + l_{F_{3-4}} + l_{F_{4-5}} + l_{F_{5-6}} . \quad (6)$$

In order to obtain the ratio relationship between the distance of every two nearest frets with the distance of the 1st fret and 6th fret, first, their ratio values and average ratio values were calculated as written in Table 3, and using the average ratio values, the relationship can be expressed as

$$l_{F_{1-2}} = 0.23 l_F , \quad (7)$$

$$l_{F_{2-3}} = 0.20 l_F , \quad (8)$$

$$l_{F_{3-4}} = 0.24 l_F , \quad (9)$$

$$l_{F_{4-5}} = 0.18 l_F , \quad (10)$$

and

$$l_{F_{5-6}} = 0.16 l_F . \quad (11)$$

These equations can be used to determine the distance between frets in the frets installation process of sundatang. It also allows a linearly modification to the distance of frets if needed.

Table 3. Ratio of the distance between two nearest frets and distance from the first fret to the sixth fret.

Ratio	Sundatang				average
	A	B	C	D	
$l_{F_{1-2}}/l_F$	0.23	0.22	0.26	0.21	0.23
$l_{F_{2-3}}/l_F$	0.21	0.19	0.17	0.21	0.20
$l_{F_{3-4}}/l_F$	0.23	0.24	0.23	0.25	0.24
$l_{F_{4-5}}/l_F$	0.17	0.19	0.18	0.17	0.18
$l_{F_{5-6}}/l_F$	0.15	0.16	0.16	0.16	0.16
				Total	1.00

Height of frets

Measurement values of the height of frets for the four units of sundatangs are shown in the row 21st to 26th in the Table 1. From the table, if the height of fret versus fret number is plotted for every sundatangs as shown in Figure 4, equations below are obtained.

Sundatang A: $h = -0.1n + 2$ (12)

Sundatang B: $h = -0.045n + 1.86$ (13)

Sundatang C: $h = -0.17n + 2.8$ (14)

Sundatang D: $h = -0.114n + 2.266$ (15)

The equations explain that the height of fret decreased when the number of fret increased. On the other hand, height difference between two nearest frets was analyzed and shown in Table 4. From the table, the average difference between two nearest frets is ≈ 0.1 cm. It means that, the height of fret decreased $\approx$ 0.1 cm when the fret number is increased of 1. This finding is very important as a reference in the making of the frets of sundatang.

Width of sundatang

The widths of sundatang were measured at three positions as labeled in Figure 1. Width 1, w_1 is near the tail, width 2, w_2 is at the centre of body of sundatang and width 3, w_3 is at the end of body of sundatang. As written in Table 1, it shows that every sundatang has different widths values. According to the sundatang maker, the widths of sundatang, especially the width 2 depends on the original width of the wooden block as a material of construction. Ratio of the w_1 / w_2 and w_3 / w_2 for the all sundatangs used in this study was calculated as shown in Table 5. And, ratio of the w_1 / w_3 was calculated as written in Table 6. From the Table 5, it was found that only three of the sundatangs (A, B and D) have a closer ratio value of the w_1 / w_2 and w_3 / w_2. However, it was also found that the all four units of sundatangs have a closer value of the w_1 / w_3 as shown in Table 6. Hence, it can be concluded that values of w_1 / w_3 for the all four units of sundatangs are almost equal, means the width 1, w_1 and width 3, w_3 of sundatang are fix value, whereas, the width 2, w_2 can be changed.

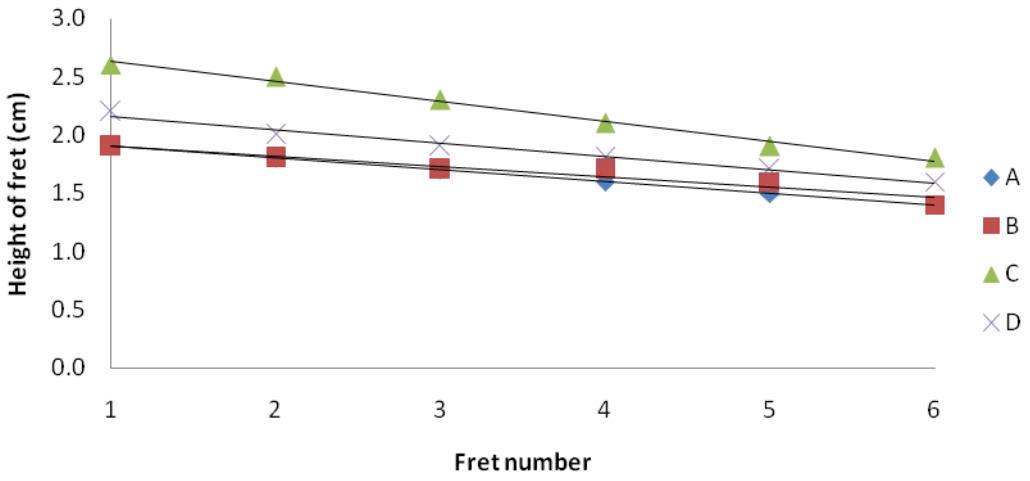


Figure 4. Graph of the height of frets of the four units of sundatang.

Table 4. Height difference of frets.

Height difference	Sundatang (cm)				Average difference
	A	B	C	D	
1st and 2nd frets	0.1	0.1	0.1	0.2	0.13
2nd and 3rd frets	0.1	0.1	0.2	0.1	0.13
3rd and 4th frets	0.1	0.1	0.2	0.1	0.13
4th and 5th frets	0.1	0.1	0.2	0.1	0.13
6th and 7th frets	0.1	0.1	0.1	0.1	0.10

Table 5. Ratio of width of sundatang

Ratio	Sundatang (cm)			
	A	B	C	D
w_1/w_2	0.86	0.86	0.78	0.84
w_3/w_2	0.55	0.56	0.50	0.55

Table 6. Ratio of $\frac{w_1}{w_3}$.

Ratio	Sundatang (cm)			
	A	B	C	D
$\frac{\frac{w_1}{w_2}}{\frac{w_3}{w_2}} = \frac{w_1}{w_3}$	1.56	1.54	1.56	1.53

Conclusion

The basics relationship between physical dimensions of sundatang has been investigated. It was found that basically the four units of sundatangs used in this investigation were different in measurement parameters, especially the total length and widths of the instruments body, except two parameters which are the diameter of sound hole at the back plate and the thickness of back plate, which were equal. Even though the sundatangs vary in most of the physical dimensions, sound from this instrument still can be tuned to their similar musical pitches. This can be achieved through the distance between frets where the ratio between the two nearest frets is quite closed in all sets of sundatangs. In addition, it was found that although all dimensions might be varied between sundatang, the ratio between the width of the bottom and the upper part of the sundatang's sound boards should be made constant. The formulated equation of the total length, distance of frets, height of frets and width ratio is seen to be very important in the construction of sundatang, especially for the new sundatang maker.

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