Can You Shake It? The Angklung of Southeast Asia

By Professor Kuo-Huang Han

School of Music

Northern Illinois University

Angklung is a popular bamboo musical instrument in Southeast Asia. It is the easiest instrument to play: you just shake it. It is now widely used in music education. In this article, you will be informed about the background, usage, and playing methods of this instrument.

A. Bamboo in Asia

Bamboo is a type of plant of the grass family. There are about 75 genera and approximately 1000 species in the world. Asia, especially Southeast Asia and the Far East, has the major concentration of bamboo production. In fact, the word "bamboo" came from a Malay term, "bambu", which originally described the crackling sound of burning bamboo: "bam"! "bu"!

Bamboo seems to grow everywhere in these regions. It is one of the most important materials in many Asian peoples’ daily lives. It is also a symbol of good luck and an essential part in their spiritual lives.

1. Material Culture

Bamboo is strong but light and elastic. Throughout the ages, it has been used for a great variety of purposes. It is used as building material for houses, fences, bridges, irrigation pipes, bulletin boards, tables, chairs, and beds. It is also used as a carrying pole, a walking stick, chopsticks, water containers, cups, pencil holders, bow and arrows, etc. Split bamboo is used for weaving nets, hats, baskets, and umbrellas. Finally, bamboo shoots and bamboo seeds can be eaten.

Bamboo pulp fibers were used to make paper. In ancient times, bamboo slips were used for carving characters. In art, bamboo is used for handicrafts. In the realm of music, many musical instruments were and still are made of bamboo.

In fact, in Chinese writing, many musical instruments’ names are crowned with the character, "bamboo" (zhu), an indication of the material from which they were made.

2. Spiritual Culture

Bamboo grows rapidly. It is seen as embodying the force of growth and fertility in many Asian societies. The Dusun people of north Borneo Island (Kalimantan, Indonesia) pay homage to a sacred bamboo to assure fertility and also believe that yellow bamboo can ward off evil spirits. In Taiwan, myth tells how bamboo was brought to earth by a man
from heaven. In India, myth tells how King Rama’s wife, Sita, had an extra finger on one hand, which she cut off and planted. From it grew a bamboo plant, which in its sections contained all kinds of grain, which became available to human kind through a hole in the bamboo, chewed there by a pig. (Wessing 1998: 51).

3. Aesthetics, Philosophy, and the Arts

Bamboo is regarded as a symbol of virtue and good character in most Far Eastern cultures. The Chinese scholar Su Shi (Su Dongpo, 11th century) of the Song Dynasty wrote:

"Meals can be without meat, but living cannot be without bamboo.

The lack of meat makes one thin; the lack of bamboo makes one vulgar.

A thin person can become fat, but a vulgar person cannot be cured."

(translated by K. H. Han)

Bamboo occupies an important role in the literati life in China, Korea, Japan, and Vietnam. Composing poems on bamboo or painting bamboo became a fashion among scholars. Because bamboo is strong and upright, it is used as a metaphor for a virtuous person. Some Chinese boys are given the name, "Zhujun" which is translated as "bamboo gentleman".

The anthropologist Robbins Burling characterized Southeast Asia as the bamboo culture (1965: 29). It seems that most parts of Asia can be labeled as the area of bamboo culture.

B. Bamboo in Southeast Asian Music

Since bamboo is such an important material in Asian people’s lives, it is not surprising to find numerous bamboo musical instruments. As far as Southeast Asia is concerned, bamboo is used for three out of four categories of musical instruments, namely, aerophones (winds), chordophones (strings), and idiophones (percussion without membrane).

Aerophones (winds)

Numerous bamboo flutes exist in Southeast Asia. The most famous are probably the Indonesian ring flute, suling, and the Thai recorder, khlui, both end-blown. Among the tribal people in the Philippines and Malaysia, the nose flute, a magical instrument, is common. Bamboo panpipes are found among the tribal people in the Philippines while bamboo mouth organs (with wooden or gourd chambers) are common among the hill tribes in mainland Southeast Asia. Lowland people in Thailand and Laos are famous for their long bamboo mouth organ, the khaen. Indonesians even invented a bamboo "gong": blowing a smaller bamboo tube which is placed inside a bigger one.

Chordophones (strings)
Bamboo strips are detached out of the body but remain attached at both ends. Small bridges are then inserted between the strips and the body. The player plucks the strips (strings) like playing a zither. This type of instrument is called idiochord and is found among the tribal people in the Philippines, Indonesia, Malaysia, Vietnam, and along the Burma-Thailand border. The more famous sassandu of Timor, now using metal strings, probably began with bamboo strips.

Idiophones (percussion)

There are more bamboo idiophones in Southeast Asia than anywhere else in the world. Bamboo tubes can be struck against each other, struck by sticks or mallets, stamped against hard objects, or shaken. Half-cut bamboo tongues in jew’s harps (mouth harps) are plucked.

Stamping bamboo tubes are common among the Akha people in Thailand and the Kalinga people in the Philippines, and to a lesser extent, in some part of Sabah, Malaysia.

Bamboo tubes of various sizes are arranged in gradual order to form a musical scale. The Sundanese calung ensemble is a good example.

But more common is the single-unit xylophone type. It is found everywhere in Southeast Asia, for instance, Vietnamese t’rung, Sundanese Calung (single-unit), Javanese gambang, and Balinese grantang. In fact, the entire ensemble can be made of bamboo xylophones in Bali (Gamelan Jogog) and Banyumas, Central Java. The bars of some Thai renad xylophones are also made of bamboo.

The mouth harp (or jew’s harp; jaw’s harp) is a common courting instrument among tribal peoples all over Southeast Asia. The tongue of the instrument is half cut from a piece of bamboo. Some people consider this an aerophone, but most still consider it an idiophone.

Finally, bamboo is essential in some folk dances in the Philippines. Instead of wood, the castanets in the Philippines are made of bamboo. The dancers of the famous Tinikling dance hop in and out of two long bamboo poles -- which serve as dance tools as well as give rhythm.

C. Angklung, the Bamboo Shaker

The most indigenous Southeast Asian bamboo idiophone is the angklung, the bamboo shaker. An angklung is a pair (or more) of bamboo tubes mounted on a bamboo frame. The tubes are in different lengths and are cut halves at the upper two-thirds. The lower end of each tube is closed by a node. Two prongs extend out and fit loosely into a corresponding slot of the horizontal bass tube.
The structure of an angklung

The two tubes are tuned an octave apart (three tubes can be two octaves or can form a chord). When shaken, the concussion of the tubes against the base produces a pitch. Since each instrument makes only one pitch, it takes many single angklungs to make a complete melody.

Even though angklung can be found in many parts of Southeast Asia, it is generally believed that it originated on the island of Java. There are many reports about the 'funny' manner of angklung performance in Sunda, West Java by European travelers in the nineteenth and early twentieth centuries. Traditional angklung music is also used in East Java, Central Java and other islands, but Sunda is the most representative area.

1. Traditional Angklung Music in Sunda

The villagers in Java believe in a rice field goddess, Sri Dewi, who oversees the benefit of the fields and the people. When she is properly served with rituals there will be a bumper harvest and peace in the region.

On the other hand, there may be drought, epidemics, and even wars. Javanese villagers used to make rituals to her by performing angklung music. This traditional style, which is usually performed outdoors, uses angklung tuned to an untempered pentatonic scale (5-pitches) and plays ostinato melody (cyclic). This is still practiced in villages in Sunda. Traditional angklung music is accompanied by drums, gongs, metal plates, and an optional double-reed oboe (tarompet). A lion mask dancer is added in some forms. Shouts and action are part of the performance. In some forms, performers fall into trance.
However, traditional angklung music like what is described can also be used for entertainment. Other traditional angklung music is performed indoors. Dance improvisation is common in all forms. Some of the names for traditional angklung music in Sunda are Reak, Buncis, Ogel, etc. (Baier 1985-6).

2. Modern Angklung Music in Southeast Asia

By the beginning of the twentieth century, traditional angklung music gradually disappeared in the cities due to its vulgar nature. In the 1930s, Daeng Sutigna, a Western
educated teacher in the Dutch school in Sunda, cooperated with an instrument maker and introduced the newly tuned angklung instruments to a boy scout troop. This gave birth to modern angkung music (Perris 1971: 404). Before long, many schools established angklung clubs as part of their extra-curriculum activities. By now, one can find this new style of angklung band almost everywhere in Southeast Asia. The new angklungs are tuned to the Western tempered diatonic scale. They play familiar Western folksongs or contemporary local popular songs. The new angklung music is characterized by the use of all seven pitches of the tempered diatonic scale (some even use accidentals). (Photo 4) Western triadic harmony is easily utilized. Instead of gongs and drums, a string bass and a drum-set can be found in some ensembles. In some cases, a bamboo xylophone called Gambang arumba is added. More often than not a conductor is used in performance. In short, it is like a Western bell-choir. It is this style that can be easily introduced in schools, church, and social clubs.

*How to Play the Angklung?

Hold the instrument loosely with one hand and grab one edge of the bottom tube of the frame. Shake it rapidly sideways. You make a pitch! That is all.

In some cases, one person can play more than one instrument by holding one in each hand or by hanging one on one’s forearm while holding another.

Each angklung plays only one pitch of the scale. When there are five, you can play a pentatonic scale; when there are seven or more, you can play most simple folksongs. For instance, to play "Mary Had a Little Lamb", you need only four angklungs (four pitches). Nowadays, angklung sets can be purchased in the U.S. and colleges and schools are using them in classes and social activities.
*How to Use the Cipher Notation?*

There are several notational systems. One easy one is the cipher system. Each pitch of the scale is represented by a number. In the key of C, which is most common in angklung instruments, C (do) = 1, D (re) = 2, E (mi) = 3, F (fa) = 4, G (sol) = 5, A (la) = 6, B (ti) = 7. When a pitch is an octave higher than the middle range, a dot is placed above the number; when a pitch is an octave lower, a dot is placed beneath it. Two dots denote two octaves higher or lower. But in general, very few folksongs have too high or too low pitches.
Rhythm is represented by a combination of pitch numbers, lines, and dots (using a quarter note as a unit in 2/4, ¾, and 4/4 times):

1. Single number = quarter note.
2. Single number with a line after it = a half note.
3. Two numbers with a line above = 2 eighths notes.
4. Four numbers with 2 lines above = 4 sixteenth notes.
5. A number with a dot after followed by a number with a line above = dotted quarter + an eighth.
6. A number with a line above and a dot after followed by a number with 2 lines above = dotted eighth + a sixteenth.
7. A number followed by a line and a dot = a half and a quarter (3 beats).
8. 0 = rest.
9. Vertical lines = bar lines.
10. Slur above numbers = tied-over notes (syncopation).
11. When there are two or more lines, players perform both lines simultaneously. The result is harmony.
12. Fermata, da capo, repeat, and other signs are the same as staff notation.

References:


Musical Examples

The following are simple modern and traditional musical examples to be used in angklung performance. For additional resources, demonstrations, and workshops, contact the Center for Southeast Asian Studies, Northern Illinois University, DeKalb, IL. 60115. Or e-mail us at cseas@niu.edu.

Simple Western and Southeast Asian Music for the Angklung

Twinkle, Twinkle Little Star

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| 1 | 3 | 5 5 | 5 6 5 | 4 4 3 3 | 2 2 1 |
| 5 5 | 4 4 | 3 3 2 | 5 5 | 4 4 | 3 3 2 |

The Flower Carol

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| 1 | 1 | 2 | 1 | 5 | 6 5 6 7 | 1 | 1 |
| 1 | 1 | 2 | 1 | 5 | 6 5 6 7 | 1 | 1 |
| 5 4 3 2 | 3 2 1 | 6 5 6 7 | 1 | 1 |

Mary Had a Little Lamb

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| 3 2 | 1 2 | 3 3 3 | 2 2 2 3 2 |

The Saints Go Marching On

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| 6 1 3 4 | 5 | 5 1 3 4 | 5 | 5 1 3 4 |
| 5 3 | 1 3 2 | 2 | 3 2 1 |
| 3 4 5 | 5 4 4 5 4 | 5 3 | 1 2 |
| 1 |

Traditional Indonesian Music (perform in cycle).

Masopoe

Surda

\[
\begin{array}{c|c}
6 & 5 & 0 & 6 & 6 & 5 & 0 & 6 \\
3 & 1 & 2 & 1 & 3 & 1 & 2 & 1 \\
x & x & x & x & x & x & x & x \\
\end{array}
\quad
\begin{array}{c|c}
6 & 5 & 0 & 6 & 6 & 5 & 0 & 6 \\
3 & 1 & 2 & 1 & 3 & 1 & 2 & 1 \\
x & x & x & x & x & x & x & x \\
\end{array}
\]

\(x = \text{small drum}; X = \text{large drums}\)

Kemang Kecahing

Surda

\[
\begin{array}{c|c}
5 & 3 & 2 & 1 & 5 & 1 & 1 & 1 \\
X & x & x & x & x & x & x & o \\
\end{array}
\quad
\begin{array}{c|c}
5 & 3 & 2 & 1 & 5 & 1 & 1 & 1 \\
X & x & x & x & x & x & x & o \\
\end{array}
\]

\(x = \text{small drum}; X = \text{large drums}; 0 = \text{gong}\)

The first half line is an introduction and is played only once.
Pitch and Timbre Determination of the Angklung

Mohd Ridzuwary Mohd Zainal, Salina Abdul Samad, Aini Hussain and Che Husna Azhari
Faculty of Engineering,
University Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia

Abstract: This research describes the pitch and timbre determination of the angklung, a musical instrument made entirely out of bamboo. An angklung has two main parts: the frame and the rattle tubes. The pitch of the rattle tubes can be determined using a formula that takes into consideration the length and diameter of the air resonator. This is compared with the results obtained using sound analysis with the fast Fourier transform as well as with measured results. The coupling effects of having two rattles on the pitch and timbre are investigated. It is found that the pitch of the angklung is closely related to the fundamental frequency of air resonance in the bamboo tubes of the angklung rattles. Therefore, the pitch of an angklung can be estimated by calculating that fundamental frequency using information from the length and diameter of the closed cylinder air column of each rattle. The timbre of the angklung is also determined to be a mix of the sound output from each of its individual rattles. The timbre has an identifying characteristic of having two prominent peaks with each one corresponding to the pitch of each rattle.

Key words: Digital signal processing, music synthesis

INTRODUCTION

An angklung is a rattle like musical instrument that is made entirely from bamboo. The angklung sound is produced from an impact mechanism within its body structure without the use of any tensed strings or stretched membranes. Therefore, the angklung is classified as a percussion musical instrument of the group idiophone along with the xylophone and the gong. Figure 1 shows the front view of the angklung.

The angklung is generally supposed to originate from West Java. According to folklore, angklung was a musical instrument of agricultural festivals and was also used during the festivities to arouse the fighting spirits of soldiers. It was also associated in Java with hobby-horse dancing\(^1\)^\(^2\). In the 1920s, it was used as children’s toy and then in the 1930s, it was used by beggars to attract passers by. Daeng Sutigna of Bandung, a musician, then started to resurrect and popularise the angklung. He introduced tunes similar to Western music, composed modern arrangements and recruited more angklung enthusiasts. Angklungs normally found nowadays are tuned to the Western diatonic scale which differs from the traditional pentatonic scale\(^3\).

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Corresponding Author: Mohd Ridzuwary Mohd Zainal, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia
Tel: +603-89216317 Fax: +603-89216146
apus or Gigantochloa apus Bl. ex Schultes f., which is less favorable because its tubes are not straight and the nodes have little swellings that cause some disturbance in the sound it produces[3].

The angklung’s physical parameters and sound is analyzed in this research. Analyzing the angklung is important to recognize the main characteristics that make up the unique sound of the angklung. This will help to make the instrument more accessible and easily utilized in the modern digital music scene. This research will describe how the pitch of an angklung can be determined using physical measurements of the angklung. The length and diameter of the angklung rattle air column are used to calculate the angklung’s pitch. This research will also examine the timbre of an angklung and determine the main characteristics that distinguish sound of the angklung from other instruments.

MATERIALS AND METHODS

Every component of an angklung may have its traditional name, but in this research, these components will be given a descriptive name. An angklung has two main parts, the frame and the rattle tubes as shown in Fig. 1. The frame’s functions are to hold the rattle tubes and as a place for an angklung player to hold the angklung.

The rattle tubes are the main sound generators for an angklung. The tubes are made from a segment of a bamboo with one of its ends still closed by its node. Part of the segment near the open end of the tube is removed forming the tongue of the rattle tube. A pair of small protuberances is left at the closed end of the tube which we will call tines. These rattle tubes are suspended vertically in the angklung frame. The tubes are suspended in such a way that the tines can slide easily and loosely inside slits made in the bottom frame tube. The bottom frame tube is also made from a bamboo segment but both its ends are open. Figure 2 shows the rattle tube of an angklung[4].

The angklung is played by holding the frame with one hand and shaking the bottom frame tube sideways with the other hand. This sideways motion will cause the rattle tubes to swing and the tines will strike the end of their respective slits. The angklung can also be played with the frame tilted sideways to shake it just once. Note that each angklung is made to produce just one musical note. Therefore, a whole ensemble of angklung players is needed to play any particular melody. Nevertheless, it is possible to play a melody with just a single player by using a device that holds multiple angklung and allows the player to play all of them by himself.

Tuning of an angklung mainly depends on two measurements, the length of the air resonator and the length of the tongue of the rattle tubes. The air resonator acts like an amplifier in that it amplifies the frequency of sound that matches the natural frequency of the air vibrating inside the resonator. The length of the tongue determines the natural frequency of the whole rattle tube vibration. Generally, the longer the whole rattle tube, the lower the pitch of the generated sound. The rattle tube can be fine tuned by carving parts of the tongue. Sharpening or raising the pitch can be achieved by shortening the tongue at its end. Flattening or lowering the pitch can be done by carving away the part where the tongue and the air resonator meet, thus making the effective tongue length slightly longer.

To determine the reference frequency values corresponding to an angklung pitch, a set is used consisting of eight angklungs with eight different pitches that make up a full octave without accidental notes ranging from C5 to C6. This research uses the tempered scale for comparison purposes, with the A above the middle C being equal to 440.00 Hz and with C4 being the middle C. Table 1 gives the frequency for each corresponding angklung pitch in the set.

This research uses the cents notation for subdividing the basic interval of the tempered scale. Cents is calculated using the relationship:
Table 1: Corresponding frequency values for C5-C6 using tempered scale

<table>
<thead>
<tr>
<th>Pitch</th>
<th>Standard frequency (Hertz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>523.25</td>
</tr>
<tr>
<td>D5</td>
<td>587.33</td>
</tr>
<tr>
<td>E5</td>
<td>659.26</td>
</tr>
<tr>
<td>F5</td>
<td>698.46</td>
</tr>
<tr>
<td>G5</td>
<td>783.99</td>
</tr>
<tr>
<td>A5</td>
<td>880.00</td>
</tr>
<tr>
<td>B5</td>
<td>987.77</td>
</tr>
<tr>
<td>C6</td>
<td>1046.50</td>
</tr>
</tbody>
</table>

with $\epsilon$ is cents, $f_1$ is the reference frequency and $f_2$ is the interested frequency value\textsuperscript{[5-7]}. \textbf{Rattle modeling:} The air resonator directly affects the sound of an angklung. When the tine of an angklung rattle hits the bottom frame tube, sound is introduced at the bottom of the air resonator. The sound wave will travel back and forth between the mouth and the bottom of the air resonator resonating at the air resonator fundamental frequency and odd harmonics. A closed cylindrical air resonator will produce resonant standing waves at the fundamental frequency and at odd harmonics. In the case of an angklung, the fundamental frequency is the pitch the angklung is tuned to. The fundamental frequency can be calculated as follows:

$$f_2 = \frac{2 \cdot \epsilon}{1200}$$ \hspace{1cm} (1)

where, $f$ is the frequency in Hertz, $n$ is the harmonic number, $v$ is the speed of sound in air, $L$ is the length of the air resonator and $d$ is the diameter of the air resonator. Figure 3 shows the parameters associated with air resonance in a closed cylinder\textsuperscript{[7,8]}. 

An important method of processing and analyzing a sound signal is to look at the signal’s frequency content. The Fast Fourier Transform (FFT) method can be used for this purpose. FFT is based on the complex Discrete Fourier Transform (DFT) equation

$$\text{Re} X[k] = \sum_{i=0}^{N} x[i] \cos(2\pi ki / N)$$

$$\text{Im} X[k] = \sum_{i=0}^{N} x[i] \sin(2\pi ki / N)$$

with index $k$ running from 0-N/2 where $N$ is the number of sample\textsuperscript{[9,12]}.

The fundamental frequency for the primary rattles of each angklung is calculated based on the calculation of air resonance in a closed cylinder. The results are given in the Table 2 with $v = 340.29 \text{ m sec}^{-1}$. 

Sound from the primary rattles of the angklungs are sampled and collected. The rattle is only allowed to strike once to capture the full length of the rattle sound. A rattle sound played this way would have a length of between 80ms to 140 ms. The rattle sound cannot reach its full length in a real angklung performance since the speed that the angklung is shaken will cause the rattle to strike again before its previous sound completely dies off. The samples are analyzed using FFT to determine the prominent frequency that can be chosen as the rattles’ pitch. FFT is computed with a resolution of 65536 points using zero padding. The high resolution is possible because the samples are very short and data handling is manageable.

Figure 4 shows the waveform of an gklung C5 primary rattle sample, to illustrate a typical result. The frequency spectrum shows that each primary rattle sample has a single prominent frequency, which we name $f_{\text{primary}}$. Harmonics of that frequency are either very weak or non existent. Some inharmonic peaks are observed to be present in the spectrum. The most
Table 2: Calculated fundamental frequency for the primary rattles

<table>
<thead>
<tr>
<th>Angklung pitch</th>
<th>L (mm)</th>
<th>d (mm)</th>
<th>f₁ (Hertz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>158</td>
<td>31</td>
<td>508.03</td>
</tr>
<tr>
<td>D5</td>
<td>136</td>
<td>32</td>
<td>583.65</td>
</tr>
<tr>
<td>E5</td>
<td>120</td>
<td>26</td>
<td>664.99</td>
</tr>
<tr>
<td>F5</td>
<td>112</td>
<td>25</td>
<td>711.16</td>
</tr>
<tr>
<td>G5</td>
<td>95</td>
<td>25</td>
<td>828.96</td>
</tr>
<tr>
<td>A5</td>
<td>86</td>
<td>24</td>
<td>911.62</td>
</tr>
<tr>
<td>B5</td>
<td>80</td>
<td>23</td>
<td>977.68</td>
</tr>
<tr>
<td>C6</td>
<td>72</td>
<td>23</td>
<td>1076.66</td>
</tr>
</tbody>
</table>

Table 3: Comparison of f<sub>primary</sub> with fundamental air resonance for each primary rattle

<table>
<thead>
<tr>
<th>Angklung pitch</th>
<th>f&lt;sub&gt;primary&lt;/sub&gt; (range)</th>
<th>Calculated fundamental resonance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>521.51-524.20</td>
<td>508.03</td>
</tr>
<tr>
<td>D5</td>
<td>583.42-595.53</td>
<td>583.65</td>
</tr>
<tr>
<td>E5</td>
<td>659.45-666.18</td>
<td>664.99</td>
</tr>
<tr>
<td>F5</td>
<td>699.83-707.90</td>
<td>711.16</td>
</tr>
<tr>
<td>G5</td>
<td>787.98-797.40</td>
<td>828.96</td>
</tr>
<tr>
<td>A5</td>
<td>894.30-904.39</td>
<td>911.62</td>
</tr>
<tr>
<td>B5</td>
<td>983.13-1000.20</td>
<td>977.68</td>
</tr>
<tr>
<td>C6</td>
<td>1061.18-1081.37</td>
<td>1076.66</td>
</tr>
</tbody>
</table>

Table 4: Calculated fundamental frequencies for secondary rattles

<table>
<thead>
<tr>
<th>Secondary rattle</th>
<th>L (mm)</th>
<th>d (mm)</th>
<th>f₁ (Hertz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>74</td>
<td>18</td>
<td>1070.23</td>
</tr>
<tr>
<td>D5</td>
<td>64</td>
<td>20</td>
<td>1213.59</td>
</tr>
<tr>
<td>E5</td>
<td>58</td>
<td>18</td>
<td>1339.94</td>
</tr>
<tr>
<td>F5</td>
<td>53</td>
<td>19</td>
<td>1446.93</td>
</tr>
<tr>
<td>G5</td>
<td>47</td>
<td>16</td>
<td>1639.79</td>
</tr>
<tr>
<td>A5</td>
<td>42</td>
<td>16</td>
<td>1814.69</td>
</tr>
<tr>
<td>B5</td>
<td>36</td>
<td>15</td>
<td>2096.67</td>
</tr>
<tr>
<td>C6</td>
<td>34</td>
<td>14</td>
<td>2222.96</td>
</tr>
</tbody>
</table>

Fig. 4: Waveform of angklung C5 primary rattle sample

Fig. 5: FFT result of angklung C5 primary rattle sample

Fig. 6: Spectrogram of angklung C5 primary rattle sample

significant inharmonic partial is at 2.45 f<sub>primary</sub>, which can sometimes have a higher magnitude than the f<sub>primary</sub>. Nevertheless, that phenomenon is not common and the strength of the partials is usually like the one shown in Fig. 5. By plotting the spectrogram of the sound using STFT, we can see that f<sub>primary</sub> is persistent along the sample length as shown in Fig. 6. Therefore, we can take f<sub>primary</sub> as the rattle’s pitch.

Table 3 shows a comparison of f<sub>primary</sub> with the calculated fundamental resonance of each rattle of Table 2. The f<sub>primary</sub> is shown as a range of maximum and minimum of the collected samples. The variation is caused by the lack of a steady-state or a sustain period in the waveform, which can be seen in Fig. 4. Thus, the sound vibration cannot settle to a stable frequency before losing all of its energy. On average, the maximum difference between the calculated fundamental frequencies of air resonance with f<sub>primary</sub> is 46.75 cents.

Similar analysis is also conducted on the secondary rattle of each angklung. Table 4 and Fig. 7-9 are the results of the analysis. f<sub>secondary</sub> is the prominent
frequency of the secondary rattles and is also classified as the pitch for each rattle.

The results for the secondary rattle analysis are also similar with the results for the primary rattle. The main difference is that for every angklung, \( f_{\text{secondary}} \) is almost equal to two times \( f_{\text{primary}} \). Note that the length of the secondary rattle samples is also shorter than the primary.

Table 5 shows a comparison of \( f_{\text{secondary}} \) with the calculated fundamental resonance of Table 4. The average maximum difference between the calculated fundamental resonance and \( f_{\text{secondary}} \) is 26.75 cents.

Each angklung is sampled again but this time with both rattles playing. The coupling effects of the rattles gives a higher total amplitude on the sound output compared to playing the angklung with a single rattle. The coupling of the rattles also creates a sound output with a more irregular amplitude envelope such as shown in Fig. 10. This can be compared with Fig. 4 and 7.

Figure 11 and 12 show the FFT and spectrogram results for an angklung C5 played with combined rattles. Two main peaks are clearly seen with each corresponding to \( f_{\text{primary}} \) and \( f_{\text{secondary}} \) for the particular angklung. The 2.45f partial mentioned earlier are also present in the spectrum but the partial for the primary rattle cannot be seen clearly because of its close proximity with \( f_{\text{secondary}} \).
Table 6: Pitch of the angklung played with both rattles

<table>
<thead>
<tr>
<th>Intended pitch</th>
<th>Pitch of samples</th>
<th>Equivalent frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>C5-6-C5+10</td>
<td>521.44-526.28</td>
</tr>
<tr>
<td>D5</td>
<td>D5-6-D5+11</td>
<td>585.30-591.07</td>
</tr>
<tr>
<td>E5</td>
<td>E5-4-E5+36</td>
<td>660.78-673.11</td>
</tr>
<tr>
<td>F5</td>
<td>F5-4-F5+20</td>
<td>700.08-706.58</td>
</tr>
<tr>
<td>G5</td>
<td>G5+11-G5+41</td>
<td>788.99-802.78</td>
</tr>
<tr>
<td>A5</td>
<td>A5-9-A5+3</td>
<td>875.44-881.53</td>
</tr>
<tr>
<td>B5</td>
<td>B5+28-B5+41</td>
<td>1003.88-1011.44</td>
</tr>
<tr>
<td>C6</td>
<td>C6+0-C6+22</td>
<td>1046.50-1059.88</td>
</tr>
</tbody>
</table>

Table 6 shows the pitch of the angklung played with both rattles which is the normal playing mode. The pitch of the angklung played with combined rattles is equal to $f_{\text{primary}}$. Since $f_{\text{secondary}}$ is tuned to be twice $f_{\text{primary}}$, $f_{\text{secondary}}$ has taken the role of becoming the second harmonic of $f_{\text{primary}}$ in the combined rattle output sound. This has the effect of emphasizing $f_{\text{primary}}$ as the pitch of the angklung. The timbre for an angklung is identified to have two frequency peaks, one being the pitch and the second is about the second harmonic of the first. This shows that the timbre of the angklung is a mix of its individual rattles. Thus, thepartials of the respective rattle are also present in the angklung sound. There are also differences between playing the angklung with only one of its rattles than with playing the angklung with both rattles. The angklung sounds fuller and individual attacks during impact of the rattles are less noticeable when playing with both rattles.

**CONCLUSION**

The pitch and timbre of an angklung set have been determined in this research. The fundamental frequency of air resonance in each angklung rattle was calculated using the length and the diameter of the air column of the rattles. The calculated fundamental frequency of each angklung rattle was then compared with the pitch of the sound samples collected from the respective rattle. The comparison shows that the fundamental frequency of air resonance in the rattle can be used to estimate the pitch of an angklung with a tolerance of less than 60 cents with a few exceptions. The exceptions are caused by the natural shape of bamboo that differs from the effective length and diameter of the air column to that of an ideal open cylinder. The timbre of the angklung was also analysed and two main features can be observed. The first feature is that for every angklung with a rattle pair, the sound output will have two main peaks in the frequency spectrum with each peak corresponding to the pitch of each rattle. The second feature is that there are inharmonic partials for each of the peak mentioned, with the most obvious being 2.45 times respective of the peak frequency.

**REFERENCES**