AUDIO-BASED APPROACHES IN TUNING RETRIEVAL OF GAMELAN ENSEMBLE

By

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Preliminary studies on gamelan instruments namely bonang, peking and kenong discussed in this work focus on their physical structure, tunings, and sound production. Since sound descriptions can only be measured by listening and are at the discretion of the creator, this work discusses about how to distinguish gamelan frequencies in a signal and the time-localized frequency content for each tone at a given time. This study focuses on the audio-based approach to tuning retrieval where the fundamental and overtone pitch is shown at all frequencies at a given time using Fourier transform, spectra, spectromorphology, and spectrograms. Three approaches used in retrieving tunings of gamelan are as follows: chladni patterns experiment using fine particle (sand), acoustic excitation from speaker for non-contact sinusoidal acoustic excitation and non-contact laser detector at specific eigen frequency, electronic speckle pattern interferometry (espi) for coherent addition of speckle fields diffracted by object and reference fields and laser doppler vibrometer (LDV) captured the vibration of the eigen frequency from the gong. Picoscope Melda analyser and Adobe using voltage-based triggers generate fast fourier transform (FFT) producing a spectrum, the decay signal is used for Q (loss factor) calculation. This study compares the harmonic, pitch, and size of bonang. The tone of peking was investigated using time-frequency analysis (TFA). Melda analyzer proved that all peking sustained the initial fundamental frequency and overtone at t=0 until 2s. This work also looks into timbral visualization of bonang. The bonang's sound profile has distinct characteristics, indicating a high recognition rate. The spectrogram revealed a simple fundamental frequency indicated by the brightest colours. The Q factor indicates the long-term viability or rapid decay.

This research shows some of the preliminary findings and challenges associated with the analysis of the acoustic properties of selected gamelan instruments. When listening to its tones in a musical environment, individual harmonics of a complex tone and partial identification may be nearly impossible to discern by the human ear. The method of temporal localization on the dominant frequency at its unique time for each tone allows

for the detection of frequencies present in the signal. According to this research, one gamelan's intonation, tone, and sentiments will always differ from another gamelan's. As a result, it proved that these primitive methods may provide tuning to the gamelan set. Field trips to the Jogjakarta gamelan builders reveal that the gamelan tuner solely tuned the gamelan based on hearing, which is passed down from generation to generation. The maker's intuition permits him to create a specific 'signature' through sound that is unique to a given gamelan set.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENDEKATAN BERASASKAN AUDIO DALAM MEMPEROLEHI TALAAN ENSEMBEL GAMELAN

Oleh

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Kajian awal mengenai instrumen gamelan iaitu bonang, peking and kenong dibahas dengan fokus pada struktur fizikal, penyesuaian, dan produksi bunyi mereka. Disebabkan bunyi hanya dapat diukur dengan mendengar dan mengikut budi bicara pencipta, kerja ini membincangkan bagaimana membezakan frekuensi gamelan dalam suatu isyarat dan perincian mengenai kandungan frekuensi pada suatu masa untuk setiap nada pada waktu tertentu. Kajian ini memfokuskan pada penalaan berasaskan audio. Frekuensi dan pic nada dipamirkan pada semua frekuensi pada masa tertentu menggunakan spektrum Fourier, spektromorfologi, dan spectrogram. Tiga pendekatan diguna untuk mengambil semula penalaan gamelan seperti berikut: ujian corak Chladni mengguna serbuk halus (pasir), pengujaan akustik dari pembesar suara menghasilkan pengujaan akustik sinusoidal tanpa sentuh dan pengesan laser tanpa sentuh pada frekuensi eigen yang khusus, interferometer corak elektronik spekel untuk penambahan koheren dari medan spekel yang dibelau oleh objek dan medan rujukan. Meter getaran laser Doppler menangkap getaran dari frekuensi eigen pada gong. PicoScope, analisa Melda dan Adobe menggunakan pencetus berdasarkan voltan menjanakan transfomasi Fourier menghasilkan spectrum. Isyarat yang menyepai diguna untuk pengiraan Q (faktor kehilangan). Kajian ini membezakan harmonik, pic dan saiz bonang. Nada peking dikaji menggunakan analisis frekuensi masa (Time Frequency Analysis). Analisa Melda membuktikan bahawa semua peking mengekalkan permulaan frekuensi asas dan nada pada t=0 hingga 2s. Penyelidikan ini juga melihat visualisasi bonang. Profil bunyi bonang mempunyai ciri yang berbeza, menunjukkan kadar pengecaman yang tinggi. Spektrogram mempamirkan frekuensi asas mudah yang ditunjukkan oleh warna terang. Faktor Q juga menunjukkan daya maju jangka panjang atau kerosakan cepat bagi sesuatu bunyi. Penemuan awal dan cabaran yang berkaitan dengan analisa kualiti akustik alat gamelan yang dipilih dibentangkan dalam kajian ini. Harmonik individu dengan nada yang kompleks serta identiti pecahannya, hampir sukar untuk dikesan dengan telinga manusia semasa nadanya didengari dalam persekitaran muzik. Pengesanan frekuensi yang terdapat dalam isyarat adalah melalui kaedah penyetempatan masa atau *time localization*, pada frekuensi dominan untuk setiap nada pada masa tertentu. Mengikut

kajian ini, intonasi, nada dan keeksklusifan bunyi sesebuah gamelan akan sentiasa berbeza dengan gamelan yang lain. Hasilnya, telah ditunjukkan bahawa pendekatan asas ini boleh digunakan untuk menala set gamelan. Kajian lapangan ke gedung pembuat gamelan di Jogjakarta mendedahkan bahawa penala gamelan hanya menggunakan pendengaran untuk menala gamelan, yang diturunkan dari generasi ke generasi. Intuisi pembuat membolehkan dia mencipta 'tanda tangan' yang unik melalui bunyi bagi sesuatu set gamelan.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Gamelan is a melodic instrument typically made from bronze and placed on a resonator. Initial observation proved that there are no two-gamelan tuned exactly alike as mentioned earlier by Rossing (Rossing, 1982). The tuning methods during the crafting process were made in the fieldwork. In our initial observation, it is concluded that there is no specific reference to any specific tune devices as had been practiced on crafting western musical instruments. Gamelan are known and recognized to have a specific scaled that is either in the five tones *Slendro* or seven tones *Pelog* scales. Pelog is one of the essential tuning systems used in gamelan instruments that has heptatonic scale. The other, older, scale commonly used is called slendro (number as 1, 2, 3, 5, 6). Pelog has seven notes, (numbered as 1, 2, 3, 4, 5, 6, 7) but many gamelan ensembles only have keys for five of the pitches. Even in ensembles that have all seven notes, many pieces only use a subset of five notes. Tone (hertz)-units consist of at least one tonic syllable (a tonic syllable being a syllable with tone and prominence).

Interestingly, in Malaysian practice the ensemble is typically tune diatonically to pentatonic scale, which provoked interesting discussion by Dufford **(**Dufford, 2014). Preliminary findings on the gamelan instruments have highlighted some issues, particularly on its physical composition, tunings, as well as the sound it produces. This study will discuss some of the preliminary findings and issues related to the investigation on acoustic properties of selected gamelan instruments.

Music has always been recognized as a form of entertainment since the existence of civilization. Early style of music, according to the western music civilization are divided according to their musical periods such as medieval, renaissance, baroque, romantic, classical as well as 20th century music. The form of a musical genre was largely classified according to their period as it was performed, as well as its musical principles. So much study has been conducted by various researchers on the notion of musicology as well as anthropological perspectives of Malaysian traditional musical instruments such as the Malaysian Gamelan. However, not much have been investigated on its technical aspects such as its materials, acoustic properties, sound perception, tunings, as well as scientific analyses on sound it produces. The question of "what constitutes a good sound" or "how do you define good sounds" from the context of traditional musical instruments has always been a subjective discussion. Most of the learning processes on the mastering of the traditional musical instruments are always delivered between a teacher and a student without any specific reference to any documentation. The practices are similar as in musical instruments craftsmanship processes. The process on crafting gamelan instruments is through years of experiential learning between the master crafter and his devoted worker. The process involves a hands-on experience of the crafting processes. The practices have always been where a devoted worker will undergo the learning processes 'casually' with the master and acquire the skills and knowledge through time. The process will start from a basic knowledge from identifying and preparing the materials, molding till the finished product.

Gamelan instruments are struck with different kinds of mallets. Gamelan instruments are divided into two structural groups namely *wilah* (consists of bars, plates) and *pencon* (mainly gongs) (Sorrell, 1990). The *wilah* instruments include the *saron* and *gender* family (gambang from wooden bars). *Wilah polos* is a thick slightly curved bar and are mounted over a single trough resonator. The mallets used are hard wood or horn and the struck may be loud or soft. The *gender* type *wilah blimbingan* is a thin, ribbed plate and suspended over a tube resonator or *bumbung*, which is tuned to the pitch of that wilah. The mallets have a head in the shape of a disc which is covered by a detachable ring of padding and the strokes are usually gentle.

Pencon are circular gong with a central protruding boss called *pencu* which is struck *by a mallet.* The pencon instruments are divided into two types. The large pencon gendhul instruments are the gong *ageng*, gong *suwukan* and *kempul*. Their shape is characterized by a flat surface around the *pencu*, becoming slightly concave near the edge. The smaller version called the *ketuk* and the lower pitched gongs the *bonang barung* and *bonang penerus* are called *pencon pangkon*. The other *pencon pangkon* gongs are the higher pitched gongs on the other bonangs, the *kempyangs* and *kenongs*. Their shape is distinguished by a surface which slopes up to the *pencu*. Gongs with this shape are always supported from below, several gongs of the flatter shape associated with the large *pencon gendhul* are also supported in this way. These broad distinctions are shown in Figure 1.1 The following descriptions of the individual instruments which comprise the metal idiophone section of the gamelan are according to these four divisions.

The kenong are supported from below with the central boss (*pencu*) pointing upward and are struck with mallets consisting of a stick with padding made of coiled string. The height from the rim to the top of the boss is approximately 32 cm and the maximum diameter approximately 34 cm in the case of the smallest kenong (kenong *pelog*). The largest kenong (kenong *slendro*) has a similar height, though the diameter is approximately 37 cm. It should be noted that although all gongs in the gamelan require support, none require a resonator. Nowadays it is common to find a kenong for each note of *pelog* and *slendro*. As with the kempul, the notes I *(slendro* and *pelog*) are pitched above the note 6 and *slendro 5* maybe borrowed to do service as *pelog* 4 if required. This assumes that the two tuning systems coincide on note 6.

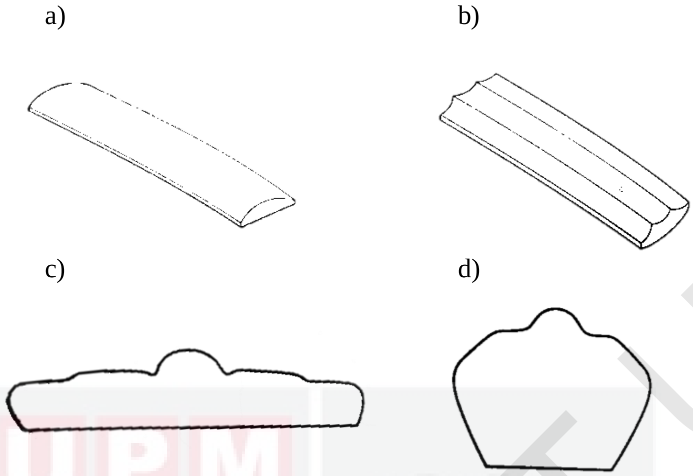

Figure 1.1 : The broad distinctions of the metal idiophone section of the gamelan, a) Wilah Polos, b) Wilah Blimbingan, c) Pencon Gendhul, d) Pencon Pangkon

A hard mallet gives a brighter tone with more high partials of overtones. A soft mallet yield more damped sound. The instrument is hand forged in a charcoal furnace which is a slow gruelling process. Final shaping is done by hammer once it has cooled. The instrument is tuned and adjusted using a hand file. Final tuning is done once all instruments are assembled.

The finished products are subject to various modifications either on its composition of the materials or perhaps its design. The quality of the instruments is subjectively measured on the sound it produced. Sounds generally transmit a large amount of acoustic information that later can be quantify through signal analysis such as spectral analysis or time-frequency. In traditional musical instruments such as gamelan the questions of "what constitutes good sound" are something of a concern in this research. Any sound that resulted from instruments either plucked or knocked, hit, and scratch will carry four fundamental properties. These properties are pitch, loudness, duration, and timbre (Johnston, 1989). In the case of traditional musical instruments such as the percussion the tone colour produced by experience and inexperience player would results into producing sounds that affect performance of a traditional musical ensemble. Sounds can be recorded and aurally measured, but the perceptions on quality of sounds are subjective. The phenomena of same pitch, loudness and duration but different timbre is among one of the main characteristics in gamelan performances. Timbre is something which is complicated to be represented or describe in non-scientific discussion. Among other term used in describing timbre were, 'quality' or 'tone colour' as used by Johnston in his discussion. The study investigates the acoustic property of a selected Gamelan instruments.

A fieldwork and interview in Cimahi, Bandung, Indonesia has revealed that the *Slendro* scales are varied between regions. If the *Slendro* scales are defined within the same region, it will be different between villages. These are confirmed as what was mentioned earlier by Rossing. (Rossing, 1982). During the crafting processes the crafter will initially and later refine its tune using the pianica as a reference to refine and perfect its tuning, which require a high degree of accuracy through listening. As a comparison the tuning process would be a tedious process. Upon the arrival of these instruments in Malaysia, the tuning includes a "grinding technique". During the tuning process a portable grinding machine is used to "grind" the inner part of the plate. The process can only be executed by an experience worker. During the visit it appeared that no other method was found to tune these gamelan instruments which appeared not to be as accurate as expected. So much study has been carried out by various musicologists on the anthropological approach as well as their repertoire. However, it is believed that not much have been investigated on their acoustic properties such as their sound perception, tunings, as well as the sound it produces.

In general, most of the Southeast Asian traditional instruments are unique in a way because the principles of their constructions are largely through experience from a generation to the next generation. In the case of gamelan instruments, the compositions of materials as well as construction have always been a so-called *trade secret* and passed from generations through experience learning process. Hence was not well documented and varies from one to another. What constitute a good gamelan sounds and how does a good gamelan sounds define were among questions or issues that this research attempt to deal with. Initial findings in this research, had established two types of gamelans namely *Perunggu* or bronze and *Kuningan* (mixed material composition). The *Perunggu* are known to be the finest material that may produce decent sound compared to the *Kuningan* which are generally thinner in term of their thickness. In general sound produced by the bronze material appears to be rich in term of its timbre and with pleasant and well-defined tone compared to *Kuningan* which sounds a bit distorted. Unlike the bronze's, the mixed material composition appeared to be discordant. From these facts, it is hypothesized that the materials composition and how it is mixed would be one of the important formulae for a good, sounded gamelan instruments. Unfortunately, the assessment of good sounds can only be measured qualitatively through hearing or listening to their texture or tone colour through experience. In this research the approach of investigating the multitude of vibration modes as well as their spectral content would be the approach in achieving quantitative data and results rather than qualitative.

Different layered, thickness, density, as well as how material is mixed and composed in crafting the gamelan instruments will affect not only the sound but also texture of the different harmonics in gamelan performance. In the case of gamelan instruments, from a musical point of view, it consisted of same notes with different ranges of octaves, and it makes gamelan instruments unique because of the richness of sounds produced by the variety range of harmonics in a gamelan performance. Most of the gamelan instruments, such as bonang and kenong, are designed with a tiny dome and deep rim. While other are mainly flat.

Figure 1.2 a : The early stage of the burning processes

Figure 1.2 b : The moulding processes

Figure 1.3 a : The grinding technique

Figure 1.3 b : The tuning technique with a hammer

Figure 1.3 c : Final tuning using pianica in Bandung Indonesia

During the tuning process a portable grinding machine is used to “grind” the inner part of the plate. The process can only be executed by an experience worker. During the visit it appeared that no other method was found to tune these gamelan instruments which appeared not to be as accurate as expected.

The gong is a round plate of hammered bronze with the edges turned up so that the shape resembles that of a shallow pan. It is excited by striking with a felt-covered hammer. The sound output resembles a heavy roar. Gong is an indefinite-pitch percussion instrument that emits a musical noise which cannot be identified as possessing a definite pitch or frequency. The instruments described in this work embrace new musical possibilities by exploring the timbral implications of a range of gong geometries, inspired by instruments from diverse musical traditions through acoustic spectra, electronic speckle pattern interferometry (ESPI) and 2D laser scanning doppler vibrometer (2D-LSDV). Acoustic spectra are used to predict the effect of a range of variations of gong geometries on modal frequencies. The mode pattern is confirmed by ESPI, and this data is compared in relation to 2D-LSDV.

1.2 Statement of the Problem

Sound analysis and re-synthesis became available for investigating tone systems and tunings of non-Western music cultures (Schneider et al., 1990, Schneider and Beurmann, 1993). The tunings in gamelan are different from the Western systems and were difficult to explain in terms of their origins regarding relevant perceptual and cognitive issues (Ellis, 1884, Stumpf, 1901, Kunst, 1934). All the work mentioned above measured the fundamental frequency but did not consider the overtone frequency. Their works are unable to determine the harmonics and sub-harmonics as well as the timbre. In this work, the fundamental and overtone frequency which is also called timbre is measured. Fourier transformation determines fundamentals, harmonics, and sub-harmonics. Different intensity and harmonics or sub-harmonics (overtones) distinguish each instrument characteristics. Most important this work showed all the range of available frequencies at a specific time.

This research is carried out to classify the sonic properties generated through the gamelan, by making scales, tuning, and other aspects of sonic. Accordingly, this study considers the configuration procedures of audio equipment, software, as well as workflows that are required for frequency extraction from the individual musical instrument of the gamelan. Through this extraction process, it will provide an indicator, not only what sound is appropriate but also, what material compositions contain in the musical instruments that contribute to what is preferred sounding of a gamelan set. The data collected, which leads to a knowledge of the transformation process factors within the object itself (physical metal compositions of the materials) such as thickness, density and whether it is layered to name a few, in the production of the gamelan set. This contributed to the facts of what is preferred sounding gamelan.

1.3 Objectives of the Study

The main objective of this study is to contribute to tuning and to all facets of sound as research data on the whole sound community of metallophone musical instruments of their high capacity for establishing an independent sound identity, namely bonang, peking and kenong and from the standpoint of retrieving the tunings of the gamelan ensemble in field recordings. This contribution helps to further clarify the role of musical acoustician and his/her relationship to the tuning of metallophones in general. Musical acoustic studies of sound preservation, including a range of responsive viewpoints, would be of growing interest in research projects. Social scientists, audio and sound forensics, technicians, and decision-makers in Malaysian communities are increasingly aware of intangible cultural attributes. Focusing on chosen metallophone instruments bonang, peking and kenong as the key objects. This study aims to prove the importance of retrieving metallophone tuning through a musical acoustic approach. Diversity in sonic studies, that is, through observation and perceptions in the context presented by these instruments' actual meaning. As the thesis applies qualitative methods of science, including instructive tests, domain, and descriptive analysis, from a musical acoustic approach, this study will model a way of retrieving metallophone tuning. Studies may concentrate on capturing the principles suggested in other metallophone instruments namely, xylophones, and gongs which was questionable Schneider (Schneider A. 1988) while checking the applicability of the techniques, instruments and theoretical views established in the research.

The specific objectives are:

1. To describe the type of gamelan ensemble set in Malaysia from the perspective of tuning, the material composition of metallaphones.
2. To describe the gamelan sounds through literature reviews, instrument makers, performers, and sound recordings.
3. To describe the tools and devices in retrieving a comprehensiveapproach to identifying sound characteristics of the gamelan ensemble set in Malaysia.
4. Retrieving sonic and material properties of four gamelan ensemble set of four public universities in Malaysia that is used in an official ceremony, which was traditionally played in a communal setting representing a local identity.

1.4 Significance of the studies

This study is conducted to identify the sound produced by a set of gamelans by making scales, and all aspects of sonic as research data. Accordingly, this study considers the configuration procedures of audio equipment, software, as well as the workflow required for frequency extraction from a gamelan set that serves as a musical instrument.

The aim of this research is to encourage and expand the approach to working with a variety of approach in obtaining harmonic contents of metallophones namely the gamelan set through audio signal retrieval via workflows, technologies, and historically as well as culturally recognized music traditions. This research is based on a deep interest in overcoming a gamelan set's traditional way of recognizing tunings and scales through a sound recording using various technological and qualitative methods. That may lead finally to a comprehensive approach to identifying sound characteristics of a gamelan set, through retrieving tunings by gamelan ensemble through tools, devices, and workflow that were traditionally played in a communal setting representing a local identity. Gamelan music is in *pelog* or *slendro*, and no matter how evocative the piece, the piano cannot reproduce these tunings. These may help discourage the confusion of general orientalism in Western music with specifically Javanese gamelan elements (Sorrell). The research on retrieving tunings by the gamelan ensemble can serve as a pioneering approach to recognition sound characteristics, perception of tunings through harmonic differences, construction of audio signal retrieval, and made visible the physical content of the material composition through workflows. This will enhance information on factors that might have an impact on the characteristics of each gamelan instrument as well as granting useful data on factors that might have contributed to the differences from one set to another. The way of the functioning (process of sound production from diverse perspectives) and as a sound culture within a community allows for enrichment of a theory based on facts.

Hence, the study will stimulate discussion and generate greater awareness among practitioners and social scientist on the importance of having a working method of identifying sound characteristics of a gamelan set, through retrieving tunings by gamelan ensemble as a framework consisting of effective tools and workflow. This study can therefore also be seen as a model that compensates for limitations in more abstract findings. This can benefit cultural supporters, in a broader sense, and from a diversity of backgrounds both internal and external musicians, anthropologists, and social scientists.

1.5 Limitations of the Study

This study is limited to 4 sets of gamelans from 4 different institute of higher learning in Malaysia. The sets from Universiti Malaysia Sarawak (UNIMAS) are studied for the sonic properties generated through the gamelan by obtaining harmonic contents. The other 3 sets from Universiti Putra Malaysia (UPM), Universiti Kebangsaan Malaysia (UKM) and Universiti Teknologi Mara (UiTM) are studied for comparing the harmonic contents only. The samples for material compositions contain in the musical instruments that contribute to "what is preferred sounding of a gamelan set" is obtained only from Bandung and Jogjakarta Indonesia only. The origin of the four sets of gamelans being tested are unknown. The other three sets of gamelans were chosen as comparisons, based on the various metal compositions contained therein. The choice of these four gamelan sets is also made in reference to the quality of it made. The sets which cost 30,000 to 40,000 Ringgit Malaysia (Haji Sulong Ismail, 2020) known for its quality, hence it's suitable for comparison of the study.

1.6 Definitions and terms used

Embat	Intervallic structure
Slendro:	an anhemitonic pentatonic tuning is made of five tones scale namely
Pelog:	heptatonic tuning is made of seven tones scale namely
Kuningan:	materials are composed mainly Copper (65.63 %) and Zinc (32.49%), and other material 1.86%.
Perunggu	bronze materials are composed of copper (68.43%), Stannum (26.14%), Silica (3.26%), Ferrum (1.08%) and other materials (1.20%)
Tone quality	shows frequencies of the fundamental spectral peaks with the overtones observed between 0 and 10 kHz.

TFA	Time Frequency Analysis spectrogram over time with the black part and the greyish part that explains its intensity at the frequency range stated on the vertical axis.
Timbre Spectrum	frequency spectrum of the fundamental and overtone frequency (in hertz)
Timbral Spectogram	the spectogram with corresponding waveforms (amplitude vs. time) and spectra (amplitude vs. frequency) respectively.
Tumbuk	Absolute pitch of the, or common tone
Baku	Tuning reference
Sekeca	Referring to what is musically comfortable, i.e., features of slendro or pelog to accommodate in an aesthetically pleasing way a wide variety of musical circumstances inherent to gamelan performance practice. *mboten sekeca* (not comfortable), *kirang sekeca* (not quite comfortable), *langkung sekeca* (more comfortable), *sekeca* (comfortable), and *sekeca sanget* (very comfortable)

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