A Model of Computation-based Naming System for Musical Elements of Java Traditional Song

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Abstract. In a research which involves mathematics and music, information of pitch, such as note, bars, melody line, beat, tempo, and others, was used as dataset to be processed by computer in generating or predicting musical objects. Helmholtz notation and scientific pitch notation used in western music are formal notation writing systems that have been applied in the computer science research as in the topics of algorithmic composition or music information retrieval. A Model of computation-based naming system for musical elements of Java traditional song called *gendhing scientific pitch notation* or GSPN was proposed to provide a method of information data recording of pitch in a term that can be read and write by human and computer. The method was conducted in two phases, which were Identification of musical elements and formulation of computation-based naming system. The model was successfully implemented in a simple computer program that has a task to read a data in GSPN format and to write by generating a music sheet based on the input data.

1. Introduction

Pitch is related to wavelengths and frequencies, and different pitches in western music are named with letters A, B, C, D, E, F, and G as natural notes [1]. An octave is a set of eight musical notes, for examples from A to next A, or from C to next C. The note names are repeated across the octaves, from the lowest to the highest note. There are two formal systems used for naming notes in a particular octave, which are Helmholtz notation and scientific pitch notation. Helmholtz notation uses CC-C-c-c^{i}-c^{ii}-c^{iii} for lowest to the highest C, and lower octave is named with CCC, while higher octaves are named with higher numbers. Scientific pitch notation names octaves with numbers, for instance, starting from C_1 for the lowest C, so the higher C are C_2, C_3, and so on.

Helmholtz notation and scientific pitch notation have been applied in the topics of algorithmic composition or music information retrieval which are parts of a computer science research. The development of these research topics in various types of music genre, both in western music or traditional music, became a motivation to develop a model of computation-based naming system to be applied in *karawitan*, a traditional music from Java, Indonesia. *Karawitan* uses *gamelan* for the music instrument and *gendhing* as the song.

Both Helmholtz notation and scientific pitch notation are used in western music, and through the globalization, the notation technology of western music has been adopted in *karawitan*, including the use of song formulation for *gendhing* [2]. The notation naming system in *karawitan* is still needed to

be improved in using as computation-based. For instance, the note names in notes in *gendhing* uses number 1, 2, 3, 5, 6 for musical scale of *slendro*, and 1, 2, 3, 4, 5, 6, 7 for musical scale of *pelog*. The higher note is marked with a dot mark above the note number, and for the lower note, the mark is below the note number. This naming system cannot be read by computer as different with scientific pitch notation which uses number after letter to mark higher or lower notes.

A computation-based notation naming system for musical elements of *gendhing* called *ghending scientific pitch notation* (GSPN) was proposed in order to support a computer music research with *karawitan* as the research object. The purpose of GSPN is to provide a method of information data recording of pitch in a term that can be read and write by human and computer.

2. Related Works

In a research which involves mathematics and music, information of pitch, such as note, bars, melody line, beat, tempo, and others, was used as dataset to be processed by computer in generating or predicting musical objects. Twelve attributes of harmonic function, such as tonic, dominant, supertonic, submedian, and others, were used by [3] as dataset to automatically harmonize chorales in style of J.S. Bach, while information of chord and bars was used by [4] as dataset to automatically generate a melody.

The use of machine learning approach to generate musical objects involving information of musical elements from a collection of songs used as dataset. The information is then represented to achieve knowledge to generate a musical objects or to make a prediction of musical objects. Note pattern and tempo from classic music was used by [5] to generate an original music using Long-Short Term Memory method, while Eigenfeldt dan Pasquier [6] using corpus from different composer as dataset.

Research which involves mathematics and *karawitan* has been conducted in several decades by [7-10]. Statistic approach by [7], grammar method by [8-9], rule-based method by [10] were used to formulate rules of composition generation, while used rule-based method. An automatic composition generation was developed by [11] using rule-bases method to define constraints which was then used by Genetic Algorithm to generate a note sequence of *gendhing*. All these researchers used note sequences of *gendhing* as dataset, and only note numbers used as the information. On the other hand, other musical elements which are also important to support automatic music generation or to make a prediction of musical objects are still not formulated in the research with *karawitan* as an object.

3. Proposed Method

A computation-based notation naming system for musical elements of *gendhing* was developed and named with *gendhing scientific pitch notation* (GSPN). The proposed method was divided into two phases, which were identification of musical elements and formulation of GSPN. The first phase was conducted by examining a *gendhing* music sheet to identify the musical elements. The second phase was conducted by analyzing the existing note formulation of *gendhing* and scientific pitch notation formulation to define GSPN.

3.1. Musical Elements Identification

The identification of musical elements of *gendhing* was conducted using theory of *karawitan* and analysing *gendhing* music sheets collected from www.gamelanbvg.com. In *karawitan,* musical scale is called *laras*, and there are two types of musical scales in *karawitan*, which are *laras slendro* and *laras pelog*. *Laras slendro* contains five notes of 1, 2, 3, 5, and 6, while *laras pelog* contains seven notes of 1, 2, 3, 4, 5, 6, and 7 with different wavelengths and frequencies. Both of *laras slendro* and *laras pelog* have three types of musical modes or called as *pathet*. Musical mode is defined based on the dominant notes in a composition. *Laras slendro* contains of musical modes of *pathet nem, pathet sanga,* and *pathet manyura*; *laras pelog* contains of musical modes of *pathet lima, pathet nem,* and *pathet barang*. Figure 1 shows an illustration of musical scale and mode in *karawitan*.

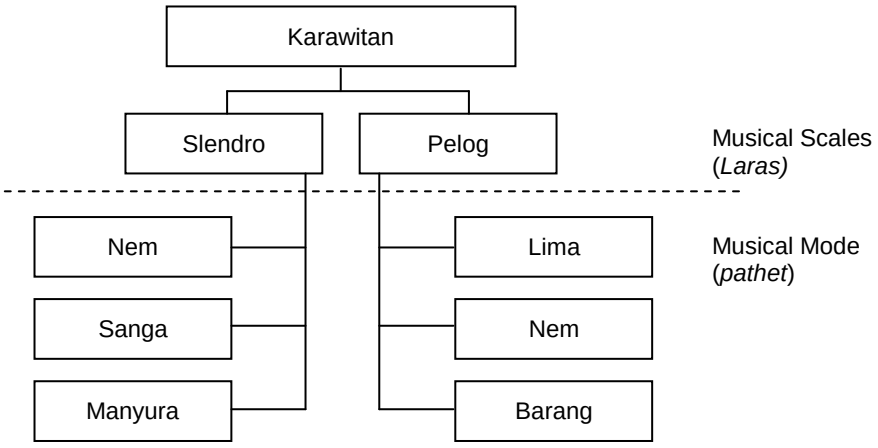


Figure 1. Musical scale and mode in *karawitan*

A *gendhing* has a song skeleton that has a role as a chord in western music, in which notes of song skeleton were played to accompany the main melody. Figure 1 shows an example of a music sheet of *gendhing* entitled *Ladrang Gayung* played in *laras slendro* and *pathet nem*, with symbol *a* indicates the song skeleton parts, and symbol *b* indicates the main melody parts.

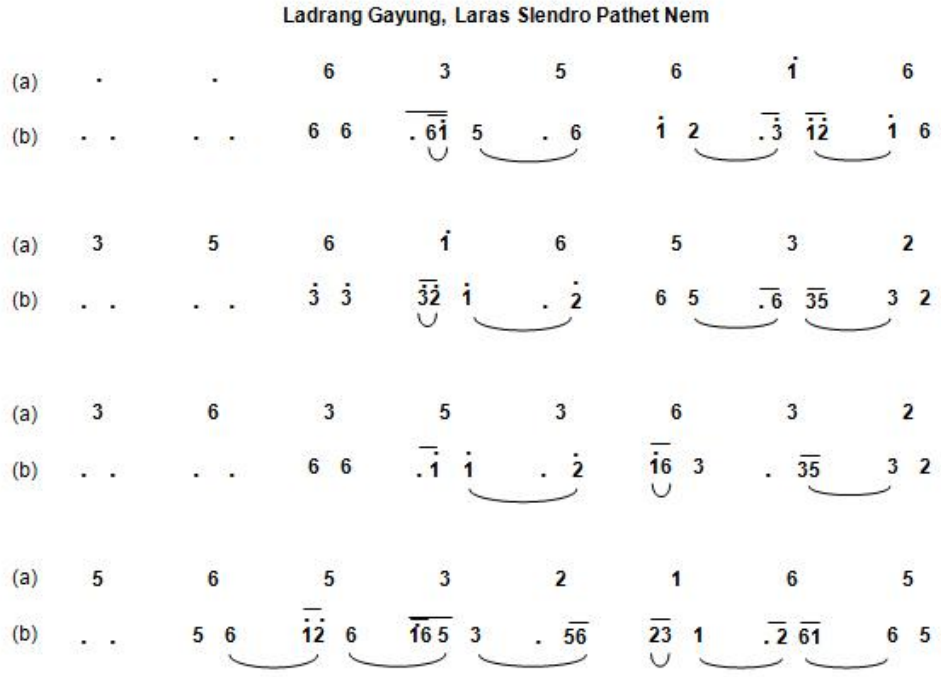


Figure 2. An example of a music sheet of *gendhing*

Theory of *karawitan* was used to analyze the structure of musical elements of *gendhing*. A *gendhing* consists of a note sequence arranged in bars called *gatra*, where bars are arranged in melody lines. In the song skeleton, a bar contains four beats, and a beat can filled with a note or more which define the rhythm. A beat filled with a note defines rhythm at 1/1, a beat filled with two notes defines rhythm at 1/2, a beat filled with four notes defines rhythm at 1/4, and so on. In parts of main melody, a

horizontal line above a note indicates the value of 1/2 for the note, and double horizontal lines above a note indicate the value of 1/4 for the note, while a note without a horizontal line mark has a value of 1. Legato mark is put below the note.

3.2. Formulation of Gendhing Scientific Pitch Notation

The formulation of *gendhing scientific pitch notation* was started from the musical scale and musical mode. For the musical scales, *laras slendro* is abbreviated with S, and *laras pelog* is abbreviated with *P*, while musical modes in each musical scale is labelled with number. Alphabet sorting was applied to define the number for each musical mode. In the *laras slendro,* the number to label *pathet manyura* is 1, *pathet nem* is 2, and *pathet sanga* is 3, while in the *laras pelog*, the number to label *pathet barang* is 1, *pathet lima* is 2, and *pathet nem* is 3. The label of musical scales and musical notes is shown below:

S1: laras slendro-pathet manyura.
S2:laras slendro-pathet nem
S3: laras slendro-pathet sanga
P1: laras pelog-pathet barang.
P2: laras pelog-pathet lima.
P3: laras pelog-pathet nem.

Rhytm which has values of 1/1, 1/2, 1/4, 1/8, and 1/16 is labelled with number 1, 2, 3, 4, 5. Hence, given a name of *Ladrang Gonjang: S1-2*, it means a *gendhing* entitled *Ladrang Gonjang* played in musical scale of *laras slendro,* and in musical mode of *pathet manyura*, and in the rhythm of 1/2.

Laras slendro consists of five notes of 1, 2, 3, 5, 6, while *laras pelog* consists of seven notes of 1, 2, 3, 4, 5, 6, 7. There is a dot notation called *pin* in both of musical scales. The dot notation was converted into number of 0 for it can be treated as other notes do. Union operation was implemented to label the notes, with *T* stands for notes, *S* stands for *laras slendro*, and *P* stands for *laras pelog*, the label for notes is as follow:

$P = \{0, 1, 2, 3, 4, 5, 6, 7\}$
$S = \{0, 1, 2, 3, 5, 6\}$
$T = P \cup S = \{0, 1, 2, 3, 4, 5, 6, 7\}$

There is pitch region that has a role as octave in western music. The pitch region consists of low pitch marked with a dot below a note, middle pitch, and high pitch marked with dot above a note. The low pitch was labelled with *a*, and high pitch was labelled with *b*. The middle pitch and note of 0 was set without label addition.

Low pitch (marked with a dot below the note): 1a, 2a, 3a, 4a, 5a, 6a, 7a
Middle pitch: 1, 2, 3, 4, 5, 6, 7
High pitch (marked with a dot above the note): 1b, 2b, 3b, 4b, 5b, 6b, 7b
Dot notation: 0

A note marked with single horizontal line or double horizontal lines indicate the value of the rhythm. Label *A* and *B* was used to indicate a value of a note, as follows:

Value of 1/1: 1, 2, 3, 4, 5, 6, 7
Value of 1/2: 1A, 2A, 3A, 4A, 5A, 6A, 7A
Value of 1/4: 1B, 2B, 3B, 4B, 5B, 6B, 7B
...

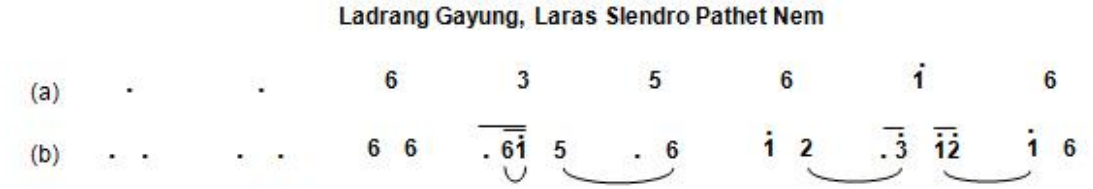
Legato mark was labelled with *x* for a note where the legato mark is started, n label *y* for a note where the legato mark is ended.

Value of 1/2: 0x, 1x, 2x, 3x, 4x, 5x, 6x, 7x
Value of 1/4: 0y, 1y, 2y, 3y, 4y, 5y, 6y, 7y

Based on the description above, the formulation of GSPN are:

Musical scale = {P, S} //{*pelog, slendro}*
Musical mode (S) = {1, 2, 3} // *{ manyura, nem, sanga}*
Musical mode (P) = {1, 2, 3} // {*barang, lima, nem}*
Rhythm = {1, 2, 3, 4, 5} // *{1, 1/2, 1/4, 1/8, 1/16}*
Notes = {0, 1, 2, 3, 4, 5, 6. 7} // *{., 1, 2, 3, 4, 5, 6, 7}*
Pitch region = {a,' ',b} // *{low pitch, middle pitch, high pitch}*
Note value = {' ', A, B, C, …} // *{1, 1/2, 1/4, 1/8, ...}*
Legato = {x, '', y} // *{start legato, no legato, end legato}*

Note was written in a formula: *note + pitch region + note value + legato*. Below is an example of the implementation of GSPN for a melody line of a *gendhing* entitled *Ladrang Gayung* played in *laras slendro* and *pathet nem*.



Ladrang Gayung: S1-2
(a) 0063561b6
(b) 0000660A6Bx1bBy5x0A6Ay1b2x0A3bAy1bAx2bA1by6

Figure 3. An example of the implementation of GSPN

4. Result and Analysis

The implementation was conducted by writing 30 note sequences of a *gendhing* in the GSPN format. A computer program to read and to display a note sequence of a *gendhing* was developed to evaluate the GSPN formulation. The task of the program was to read a note sequence written in GSPN format and to display the note sequence in original sheet music.

The procedure of read and display a note sequence of the computer program was defined by creating variables containing values of musical elements of *gendhing* to convert all labels in GSPN format into number. This to make all information of musical scale can be calculated in a computation process.

GSPN: pitch region = (0, a, "", b)
Program: pitch region = (0, 1, 2, 3)

GSPN: note value = ("", A, B, C, …)
Program: note value = (1, 0.5, 0.25, 0.13, …)

...

Below is an example of the implementation of GSPN for a *gendhing* entitled *Ketawang Barikan* played in *laras pelog* and *pathet lima*.

Ketawang Barikan: P2-1
//input note sequence of main melody in GSPN format
00000023x0053y02x0A3Ay10000555Ax1bAy6005302x0A3Ay10000555A6A4x05y61b01b
Ax2bA1bA6Ay50000762Ax5Ay4x052Ax3Ay101x2B1B6aAy5ax0A6A1y00111Ax2Ay1002
302x0A3Ay10000555Ax1bAy6005302x0A3Ay1

//extracted note sequence
0, 0, 0, 0, 0, 0, 2, 3, 0, 0, 5, 3, 0, 2, 0, 3, 1, 0, 0, 0, 0, 5, 5, 5, 1, 6, 0, 0, 5, 3, 0, 2, 0, 3, 1, 0, 0, 0, 0, 5, 5, 5, 6, 4, 0, 5, 6, 1, 0, 1, 2, 1, 6, 5, 0, 0, 0, 0, 7, 6, 2, 5, 4, 0, 5, 2, 3, 1, 0, 1, 2, 1, 6, 5, 0, 6, 1, 0, 0, 1, 1, 1, 2, 1, 0, 0, 2, 3, 0, 2, 0, 3, 1, 0, 0, 0, 0, 5, 5, 5, 1, 6, 0, 0, 5, 3, 0, 2, 0, 3, 1

//data of region pitch
0, 0, 0, 0, 0, 0, 2, 2, 0, 0, 2, 2, 0, 2, 0, 2, 2, 0, 0, 0, 0, 2, 2, 2, 3, 2, 0, 0, 2, 2, 0, 2, 0, 2, 2, 0, 0, 0, 0, 2, 2, 2, 2, 2, 0, 2, 2, 3, 0, 3, 3, 3, 2, 2, 0, 0, 0, 0, 2, 2, 2, 2, 2, 0, 2, 2, 2, 2, 0, 2, 2, 2, 1, 1, 0, 2, 2, 0, 0, 2, 2, 2, 2, 2, 0, 0, 2, 2, 0, 2, 0, 2, 2, 0, 0, 0, 0, 2, 2, 2, 3, 2, 0, 0, 2, 2, 0, 2, 0, 2, 2

//data of note value
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 0.25, 0.25, 0.5, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1, 1, 1, 1, 1, 1, 1, 0.5, 0.5, 1

//data of legato
1, 1, 1, 1, 1, 1, 1, 2, 1, 1, 1, 3, 1, 2, 1, 3, 1, 1, 1, 1, 1, 1, 1, 2, 3, 1, 1, 1, 1, 1, 1, 2, 1, 3, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 3, 1, 1, 1, 2, 1, 1, 3, 1, 1, 1, 1, 1, 1, 1, 2, 3, 2, 1, 1, 2, 3, 1, 1, 2, 1, 1, 3, 2, 1, 1, 3, 1, 1, 1, 1, 2, 3, 1, 1, 1, 1, 1, 1, 2, 1, 3, 1, 1, 1, 1, 1, 1, 1, 2, 3, 1, 1, 1, 1, 1, 1, 2, 1, 3, 1

Based on the input data, the computer program calculates the information of every note, and generates display as illustrated in Figure 4 using procedures below:

```
// Array extracted note sequence
For (i=0; i < extracted note sequence.length; i++)
    if (extracted note sequence[i])
    {
        data of region pitch [i]
        data of note value [i]
        data of legato [i]
        set display note sequence
    }
}
```

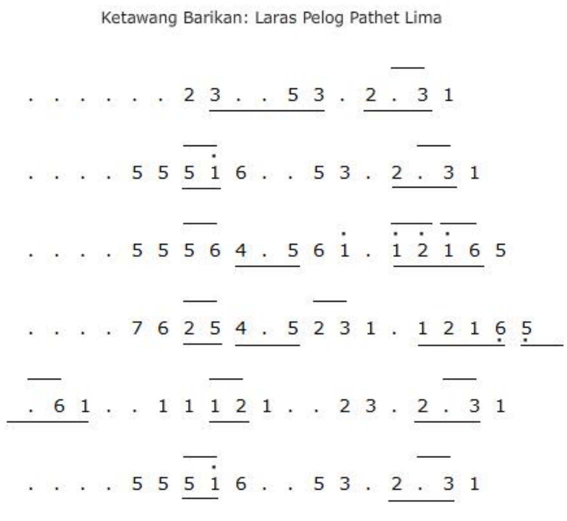


Figure 4. A music sheet generated by computer program

5. Conclusion

Knowledge representation of a song is not restricted to the notes number only, but other musical elements which construct a song are also important for research that involves mathematics and music. A Model of computation-based naming system for musical elements of Java traditional song called *gendhing scientific pitch notation* or GSPN was proposed in this study in order to provide a method of information data recording of pitch in a term that can be read and write by human and computer.

The model was successfully implemented in a simple computer program that has a task to read the data in GSPN format and display a music sheet based on the input data. It still takes an effort to manually convert an original music sheet into GSPN data format. An image processing approach can be used to overcome this problem, in which a pattern recognition method can be implemented to capture an original music sheet and then automatically convert to the GSPN data format.

For further research, the proposed model can be implemented to manage data in GSPN format to represent a mapping code for machine learning approach in generating a composition or providing a prediction of musical objects.

References

[1] Jones C S 2005, *Understanding Basic Music Theory*, The Open University of Hongkong.

[2] Hastuti K, Fanani A Z, Syarif A M, Mulyana A R 2019, *Globalization, Information and Communication Technology, and The Existence of Culture and Its Inheritors: A Case Study on Javanese Karawitan*, Proceeding of the 1st International Conference on Interdisciplinary Arts and Humanities (ICONARTIES), Yogyakarta, Indonesia.

[3] Hild H, Feulner J, Menzel W 1991, *HARMONET: A Neural Net for Harmonizing Chorales in the Style of J.S.Bach*, Proceedings of Advances in Neural Information Processing Systems 4.

[4] Pachet F and Roy-Markov P 2011, *Markov constraints: steerable generation of Markov sequences*, Constraints, **Vol. 16**.

[5] Svegliato J and Witty S 2016, *Deep Jammer: A Music Generation Model*, www.semanticscholar.org.

[6] Eigenfeldt A and Pasquier P 2010, *Realtime Generation of Harmonic Progressions Using Controlled Markov Selection*, Proceedings of the First International Conference on Computational Creativity.

[7] Surjodiningrat W, Khandelwal V K, Soesianto F 1977, *Gamelan dan Komputer: Analisa Patet dan Komposisi Gending Jawa Laras Slendro*, Universitas Gadjah Mada, Yogyakarta.

[8] Becker J and Becker A 1982, *A Grammar of the Musical Genre Srepegan*, University of Texas Press, Texas.

[9] Hughes D W 1988, *Deep Structure and Surface Structure in Javanese Music: A Grammar of Gendhing Lampah*, University of Illinoi Press, Illinois.

[10] Hastuti K, Azhari, Musdholifah A, Supanggah R 2016, *Building Melodic Feature Knowledge of Gamelan Music Using Apriori Based on Functions in Sequence (AFiS) Algorithm*, International Review on Computers and Software, **Vol 11**, No 12.

[11] Hastuti K, Azhari, Musdholifah A, Supanggah R 2017, *Rule-Based and Genetic Algorithm for Automatic Gamelan Music Composition*, International Review on Modelling and Simulations, **Vol 10**, No 3.