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A method for automatic gamelan music composition

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ABSTRACT

This study aims at designing a method for automatic gamelan music composition using rule-base expert system approach. The program is designed for non-expert user in order to help them composing gamelan music or analyzing their composition to achieve explanation and recommendation of ideal composition. There are two essential components in this method, those are knowledge and inference. Knowledge is represented into basic knowledge and melodic knowledge. Basic knowledge contains rules that control the structure of gamelan song, and melodic knowledge supports system in composing or analyzing notations sequence that fit the characteristics of melody in gamelan music. Basic knowledge represents basic rules of gamelan music that have quantitative value, so deterministic approach is used for basic knowledge acquisition. Melodic knowledge consists of dynamic data, so stochastic approach is used to create the melodic knowledge base. The rules of composing and analyzing a composition are defined based on basic knowledge and melodic knowledge. The inference engine is designed to compose and analyze a composition. Automatic composition for gamelan music is proposed using Generate and Test method (GAT) with random technique, and composition analysis is proposed using backward chaining method.

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I. Introduction

Algorithmic composition is an approach to create a music composition automatically using a certain algorithm [1][2]. Algorithmic composition has been developed since 1955 when Hiller and Isaacson used rule systems and Markov chains to design a computer-generated composition called Illiac Suite, and then followed by Xenakis which used stochastic algorithm to generate raw material for music composition [1]. Now algorithmic composition has used a wide variety of algorithmic approaches, such as generative grammars, Genetic Algorithm, cellular automata, neural networks, machine-learning techniques, expert systems, and others [1][3][4].

In this study, algorithmic composition is implemented for traditional music called *gamelan*. *Gamelan* is a traditional music ensemble came from the land of Java. *Gamelan* songs are called *gending*. The most important in composing a new *gending* is not to add or subtract something that is not necessary, and it is suggested to analyze existing *gendings* as references in composing a new *gending* [5]. In fact, arranging notations sequence in *gamelan* music composition is not as simple as duplicating and modifying existing *gending*. There is deep philosophy in *gamelan* music composition. *Gamelan* melodies are bound by rules and regulations of Java community which is sacred [6]. The use of Javanese culture concept must be considered in composing a *gending*; *Gamelan* is not only the means of performances, but also is a part of life of the Java community, in which there is the concept of cosmology as well as the other life concepts [7]. Based on description above, expert systems are considered as a proper approach to apply algorithmic composition for *gamelan* music.

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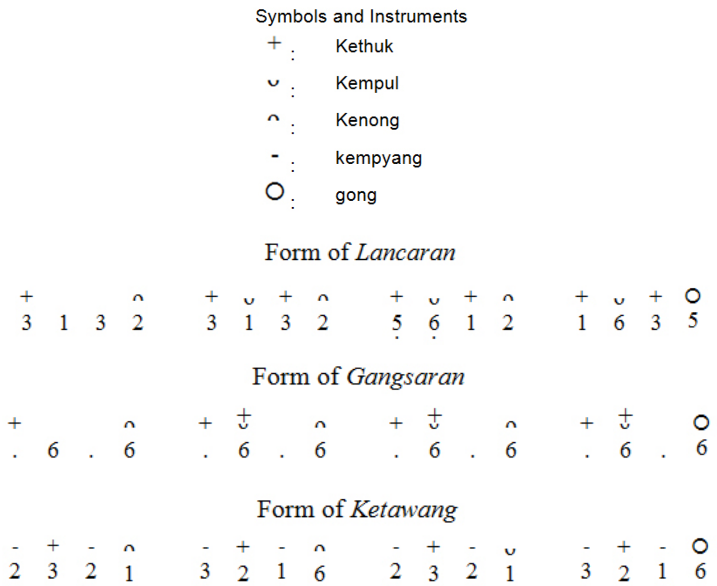
Expert systems are a form of knowledge-based systems [8][9][10]. The use of knowledge is an approach in developing knowledge-based systems. Expert system's program can solve complex problems in a particular domain, or can solve problems which cannot be solved by people who do not have knowledge about the problem [9]. Expert systems comprise two essential components which are knowledge and inference, knowledge base contains domain knowledge and inference engine consist of algorithm for manipulating the knowledge [11]. Rule is a technique to representing knowledge in expert systems [12]. CHORAL is a rule-based expert system for harmonizing four-part chorales in the style of J.S. Bach which uses more than 270 rules produced by multi-view points, such as the chord skeleton, individual melodic lines of each voice and the Schenkerian voice leading within the descant and bass, in order to represent knowledge [13]. Another example is McIntyre's work which used rules defined by musical scholars to govern Baroque harmony, and added pre-defined melody to control the search space [14].

Algorithmic composition for *gamelan* music has been studied in several works. Grammar approach is used by Becker and Becker and Hughes to define rules of *gamelan* music composition [15][16]. Becker and Becker define rules using linguistic method for a type of *gending* composition called *srepegan* [15]. Instead of using linguistic method, Hughes uses a frame work of quasi-linguistic to describe melodic feature in *gending* entitled *Lampah* [16]. Another study was conducted by Surjodiningrat et al. [17] which identified the pattern of laras *slendro* (*laras* is a musical scale; *slendro* is a type of *laras*). Surjodiningrat analyzed the melodic features based on frequent *gatra*, which is the smallest unit in *gamelan* music which consists of 4 notations, and resulted data base of frequent *gatra* as recommendation for composing gamelan music *laras slendro* [17]. In this study, a method based on rule-based expert system is proposed to develop a program of automatic *gamelan* music composition. The program is designed for non-expert user in order to help them composing *gamelan* music or analyzing their composition to achieve explanation and recommendation of ideal composition.

II. Gamelan Music

Laras or musical scale in *gamelan* music consists of *slendro* and *pelog*. Notations in *laras slendro* consists of 1, 2, 3, 5, 6, and laras pelog consists of *1, 2, 3, 4, 5, 6, 7*. There are *gamelan* music orchestras which use both of *laras slendro* and *laras pelog*, or one of them. *Gending* is divided into 7 forms, which are *lancaran*, *gangsaran*, *ketawang*, *ladrang*, *ayak-ayakan*, *srepegan*, and *Sampak*. The forms of *gending* is differed by the number of *balungan* beats in one *gong* (*gong*: one of *gamelan* instrument), and setting of the play of gamelan instruments of *kethuk*, *kempul*, *kenong*, *kempyang* and *gong* [18]. Fig. 1 shows the different forms of *gendings* [19].



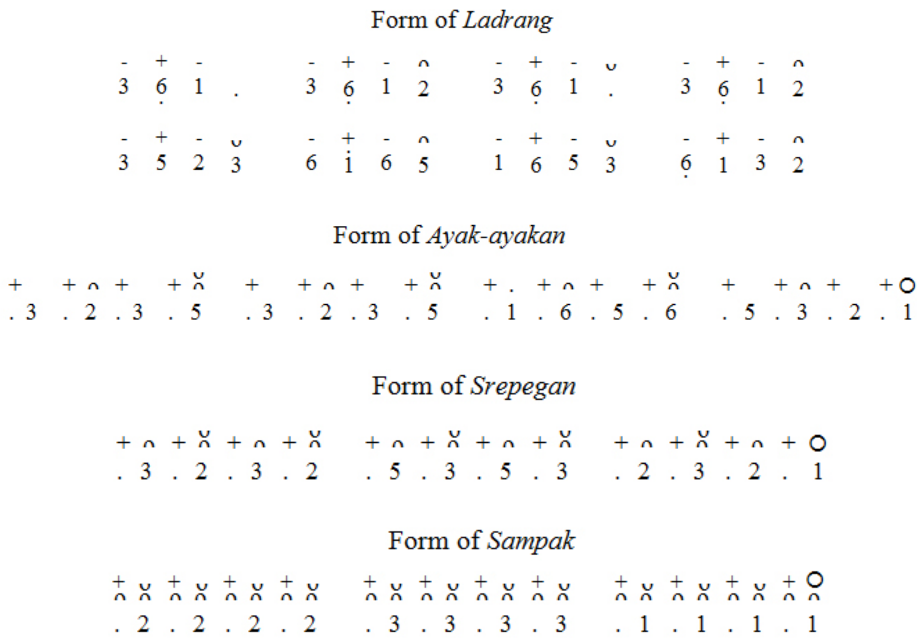


Fig. 1. Forms of *Gendings* [19]

Gamelan music consists of elements: (1) *Balungan* or skeleton, which is the structure of *gending* that functions as a reminder to *gamelan* players when they perform. (2) *Gatra*, which is the smallest unit in *gending* containing 4 beats (notations) of *balungan*. (3) *Irama* and *laya* (rhythm and tempo): rhythm controls the stretching and squeezing of *gatra*, and tempo control the speed of *gamelan* song [20].

The creative process in composing *gamelan* music is usually started with humming. The composer hummed to construct the melody, and then it will be completed by performing *ricikan balungan*, *ricikan garap*, and *ricikan structural*. *Ricikan balungan* is based on *balungan* or structure of *gending*; *ricikan garap* refers to *balungan* in arranging the *gamelan* song; *Ricikan structural* is determined by the structure of *gending* which constructs the tone and defines the structure of *gending* [20]. The characteristics process in composing *gamelan* music is different with another type of music. *Gamelan* composers arrange *balungan* notations and the song, while rhythm, tempo and structure of the song are interpreted by *gamelan* players when they perform [21]. Fig. 2 shows notations for *ricikan balungan* arranged by composer, and notations for *ricikan garap* interpreted by *gamelan* players referring to ricikan balungan. Fig. 3 shows notations for *gending* entitled *Suwe Ora Jamu* in the term of *balungan* notations (skeleton or structure of *gending*).

Ricikan balungan 6 5 3 2

Ricikan garap 6 5 6 . 6 5 6 5 3 2 3 . 3 2 3 2

Fig. 2. Notation arrangement in *ricikan balungan* and *garap* [21]

Suwe ora Jamu

2 3 2 3 1 2 3 2

3 5 6 5 4 2 1 6

Fig. 3. *Balungan* notations of *gending* entitled *Suwe Ora Jamu*

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III. Discussion

Rule-based expert system is used as an approach for automatic *gamelan* music composition in this method. The system is designed to have knowledge of *gamelan* music, and the knowledge is represented by rules. Interaction between user and program allows user creating or analyzing *balungan* notation composition. Fig. 4 shows the schematic diagram between the user and the system.

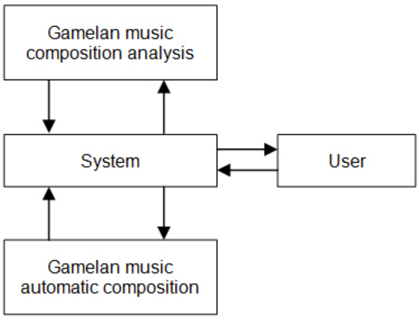

Fig. 4. Schematic diagram

Knowledge base and inference engine are the main components implemented in this system. The knowledge base creation is divided into 3 phases which are knowledge acquisition, knowledge base and production rules. The inference engine development contains implementation of chosen algorithm for generating notation sequence and user interface design. The system is designed to allow user creating or analyzing *balungan* notation composition through user interface. The inference engine in the system has to manage the user's request by using knowledge base, so the system can give explanation to user.

There are 2 types of knowledge used in this system, which are basic knowledge and melodic knowledge. Basic knowledge contains rules that control the structure of *gending*, such as type of *laras*, *gending*, *gatra*, and many others. In *gamelan* music, those rules are known as *pakem*, and a *gamelan* expert must understand *pakem*. Basic knowledge is *pakem* which contains variables with quantitative value, such as *laras slendro* consists of notations 1, 2, 3, 5, 6 and *laras pelog* consists of notations 1, 2, 3, 4, 5, 6, 7. The acquisition process uses *gamelan* music expert and literatures as the experts. The knowledge collected from the experts, and then it is formulated into data base containing variables that represent *pakem* of gamelan music composition. Melodic knowledge represents dynamic data. Data base of *gendings* are used as the expert and analyzed based on notation pattern recognition in order to identify the frequent pattern of attribute similarities among notation sequence.

A. Basic Knowledge Base Creation

Basic knowledge is defined based on *pakem*, which is a basic rules in *gamelan* music with quantitative value. Below are the examples of *pakem* of *gending lancaran*:

- *Gending lancaran* has 16 beats (notations) which are divided into 4 groups called *gatra*.
- One row or one *gong* consists of 4 *gatra*.
- Each *gatra* consists of 4 notations (*balungan* beats).
- The first and third beats are *ricikan kethuk*.
- The second of even beat is *ricikan kempul*.
- The fourth beat is *ricikan kenong*.
- The fourth beat of last *gatra* in each row is *ricikan gong*.

Fig. 5, with *s* represents *balungan* notations, shows the structure of *gending lancaran* which consists of 4 *gatras* (16 beats/notations).

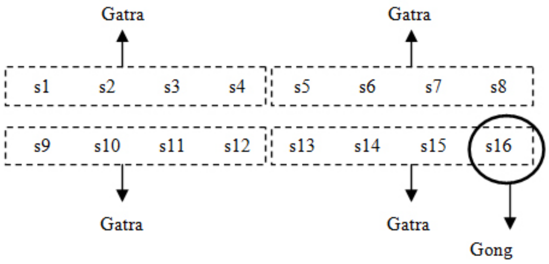

Fig. 5. Structure of *gending lancaran*

All the information and fact of *pakem* can be analyzed by consultation and explanation from *gamelan* music experts and literatures. Basic knowledge is represented with data base containing *pakem*'s variables. Table 1 shows examples of *gamelan* music basic knowledge base, where types of *gamelan* music are denoted as *J*: *lancaran (J1), gangsaran (J2), ketawang (J3), ladrang (J4), ayak-ayakan (J5), srepegan (J6), sampak (J7).*

Table 1. Examples of basic kKnowledge base

Rules	**Type of Gamelan Music**						
	J1	***J2***	***J3***	***J4***	***J5***	***J6***	***J7***
The number of notation in a gatra	4	4	4	4	4	4	4
Minimum gatra in a composition	4	4	8	4	4	4	4
The number of notation variant in *laras* pelog	7	7	7	7	7	7	7
The number of notation varian in *laras* slendro	5	5	5	5	5	5	5
Notation variants in *laras* pelog	1, 2, 3, 4, 5, 6, 7						
Notation variants in *laras* slendro	1, 2, 3, 5, 6						

B. *Melodic Knowledge Base Creation*

Melodic knowledge is focused on the ability of systems in choosing and arranging notations that fit the characteristic sound of *gamelan* melody. Notation pattern recognition technique is used to identify the notation pattern of *gending* based on frequent attribute similarities among notation sequences. *Balungan* notations which are collected from a number of *gendings* sample are analyzed to identify the melodic features of *gending*. There are 2 types of the analysis, which are construction analysis and correlation analysis. Construction analysis focuses on identifying of notation construction in a *gending*, such as total number of *gatra*, notation variant, notation variant composition, notation variant distribution, identical notation pairs and identical *gatras*. Construction analysis results knowledge of notations construction for composing or analyzing *gendings*. Correlation analysis deals with identifying of attribute similarities between notations to identify the ideal arrangement of notations sequence in composition. The analysis consists of inter-notations correlation, inter-groups correlation and *inter-gatras* correlation.

1) Construction Analysis

A *gending* composition is formed based on notations arrangement; therefore the element of notations construction defines the structure of a composition. For example, the notations construction of *gending laras pelog* entitled *Suwe Ora Jamu* are containing 4 *gatras* (16 notations), using 6 of 7 available notations variant, using 1, 2, 3, 4, 5, 6 as notations variant composition, arranging notations variant distribution (variant notations:distribution number) as (1:2), (2:5), (3:4), (4:1), (5:2), (6:2), using 2 identical notation pairs, in which each pair contains (2 3). *Gending Suwe Ora Jamu* does not have identical gatras, but many other *gendings* have identical *gatras* in their notations construction. For instance, *gending* entitled *Kebo Giro* has both of identical notations pairs and identical *gatras* as shown in Fig. 6.

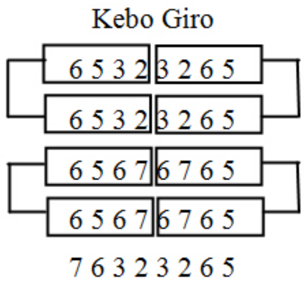

Fig. 6. Identical *gatras* in *gending Kebo Giro*

Construction analysis is conducted to identify element features of notations construction in *gending* based on type of *laras*. There are 2 types of laras which are *pelog* and *slendro*. The data base for *laras pelog* and *laras slendro* is created separately, and each data base is represented by analyzing a number of *gending* collected from 7 type of *gending*s. The construction analysis results 14 data base of notations construction based on type of *laras* and *gending*. The construction analysis then is conducted by identifying notations construction as follows:

- Total number of *gatra*: the analysis is to identify the frequent use of *gatra* in *gending* composition.
- Notations variant: the analysis is to identify the frequent use of notations variant in *gending* composition.
- Notations variant composition: the analysis is to identify the frequent use of notations variant composition in *gending* composition.
- Variant notations distribution: the analysis is to identify the frequent use of notations variant distribution in *gending* composition.
- Identical notations pairs: the analysis is to identify the frequent use of identical notations pairs in *gending* composition.
- Identical *gatras*: the analysis is to identify the frequent use of identical *gatras* in *gending* composition.

2) Correlation Analysis

A correlation between notations is analyzed to identify ideal pattern in arranging notations. The analysis uses term of frequent antecedent and consequent to define ideal notation sequence. The correlation analysis is divided into inter-notations, inter-groups and inter-gatras analysis.

a) Inter-Notations Analysis

Inter-notations correlation analysis is to identify attribute similarities between 2 notations in sequences. The fitness is measured by determining frequent value of previous and following notations pattern. The fitness is used to provide weighting in dominant value scale as recommendation of ideal notation sequence. A number of *gendings* are collected as data set, and then the procedures of analysis are implemented to each *gending*. The analysis begins with arranging *gending* notations into sequence data. Fig. 7 shows an illustration of arranging *gending* notations entitled *Suwe Ora Jamu* into sequence data.

<2, 3, 2, 3, 1, 2, 3, 2, 3, 5, 6, 5, 4, 2, 1, 6>

Fig. 7. Arranging *gending* notations into sequence data

The sequence data which contains *gending* notations is extracted into partition, which each partition consists of 2 notations based on odd and even sequences. Odd sequence is determined by position of the first notation which starts from odd order, while even sequence has first notation which starts from even order. With *P* represents odd sequence, *W* represents even sequence and *s* represents a notation, then P1 = <s1, s2>, P2= <s3, s4>, and so on; W1 = <s2, s3>, W2= <s4, s5>, and Wend = <s_{end}, s1>. Fig. 8 shows the illustration of odd and even sequences. Result of inter-notations analysis of *gending Suwe Ora Jamu* is data base of odd and even notations sequences.

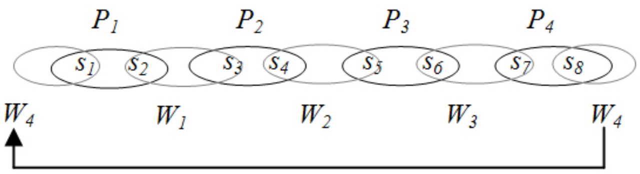

Fig. 8. Illustration of odd and even sequences

The odd and even sequences are used as item set, and then the procedure of fitness measurement based on frequent value is implemented to all item set. The procedures of inter-notations analysis are implemented to all data set separately, and then the result is accumulated in order to collect frequent notation pattern based on odd and even sequences. Table 2 shows the example of odd and even sequences of *gending Suwe Ora Jamu*.

Table 2. Database of odd and even sequences

Odd Sequences (P)		Even Sequences (W)	
P_1	<2, 3>	W_1	<3, 2>
P_2	<2, 3>	W_2	<3, 1>
P_3	<1, 2>	W_3	<2, 3>
P_4	<3, 2>	W_4	<2, 3>
P_5	<3, 5>	W_5	<5, 6>
P_6	<6, 5>	W_6	<5, 4>
P_7	<4, 2>	W_7	<2, 1>
P_8	<1, 6>	W_8	<6, 2>

b) Inter-Groups Analysis

Inter-groups analysis is to identify attribute similarities between groups of notation, where each group contains 2 notations sequence. The fitness is measured by determining frequent value of previous and following groups pattern. The fitness is used to provide weighting in dominant value scale as recommendation of ideal group sequence. A number of *gendings* are collected as data set, and then the procedures of analysis are implemented to each *gending*. The analysis begins with arranging *gending* notations into sequence data, and then notations are grouped by multiple of two notations. Fig. 9 shows groups of notations sequence of *gending Suwe Ora Jamu*.

<<2, 3>, <2, 3>, <1, 2>, <3, 2>, <3, 5>, <6, 5>, <4, 2>, <1, 6>>

Fig. 9. Notations sequences

The array of groups of notations then is extracted into sequences containing two notations based on odd and even group sequences. The procedure of data extraction into odd and even sequences is implemented in this analysis. With *PP* represents odd group sequence, *PW* represents even group sequence, and *s* represents a notation, then PP1 = <<s1, s2>, <s3, s4>>, PP2= <<s5, s6>, <s7, s8>>, and so on; PW1 = <<s2, s3>, <s4, s5>>, PW2= <<s6, s7>, <s8, s9>>, and PW_{end}= <<s_{end-1}, s_{end}>, <s1, s1>>. Fig. 10 shows the illustration of odd and even group sequences. Result of inter-group analysis of *gending Suwe Ora Jamu* is data base of odd and even group sequences.

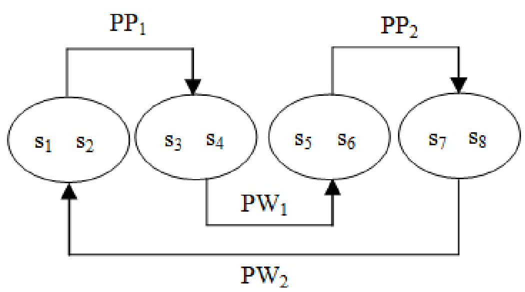

Fig. 10. Illustration of odd and even group sequences

The odd and even group sequences are used as item set, and then the procedure of fitness measurement based on frequent value is implemented to all item set. The procedures of inter-groups analysis are implemented to all data set separately, and then the result is accumulated in order to collect frequent notation group pattern based on odd and even sequences. Table 3 shows the example of odd and even group sequences of *gending Suwe Ora jamu*.

Table 3. Database of odd and even group sequences

Odd Group Sequences (P)		**Even Group Sequences (W)**	
PP$_1$	<<2, 3>, <23>>	PW$_1$	<<3, 2>, <3, 1>>
PP$_2$	<<1, 2>, <32>>	PW$_2$	<<2, 3>, <2, 3>>
PP$_3$	<<3, 5>, <65>>	PW$_3$	<<5, 6>, <5, 4>>
PP$_4$	<<4, 2>, <16>>	PW$_4$	<<2, 1>, <6, 2>>

c) Inter-Gatras Analysis

Inter-gatras analysis is to identify attribute similarities between particular notations in 2 connected *gatras*. The fitness is measured by determining frequent value of previous and following *gatras* pattern. The fitness is used to provide weighting in dominant value scale as recommendation of ideal connected *gatras*. A number of *gendings* are collected as data set, and then the procedures of analysis are implemented to each *gending*. The analysis begins with arranging *gending* notations based on its *gatra*. With *GP* represents odd *gatra* sequence, *GW* represents even *gatra* sequence, and *s* represents a notation, then GP1a = <s1, s5>, GP2a= <s5, s9>, GP3a= <s9, s13> and GPa$_{end}$= <s13, s1>; GP1b = <s3, s7>, GP2b= <s7, s11>, GP3b= <s11, s15> and GPb$_{end}$= <s15, s3>; GW1a = <s2, s6>, GW2a= <s6, s10>, GW3a= <s10, s14> and GWa$_{end}$= <s14, s2>; GW1b= <s4, s8>, GW2b= <s8, s12>, GW3b= <s12, s16>, and GWb$_{end}$= <s16, s4>. Fig. 11 shows the illustration of odd and even *inter-gatras* correleation. Result of inter-gatras analysis of *gending Suwe Ora Jamu* is data base of odd and even gatras sequences.

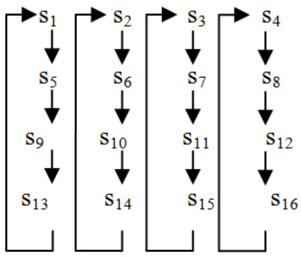

Fig. 11. Illustration Inter-Gatras Odd and Even Sequences

The odd and even *inter-gatras* sequences are used as item set, and then the procedure of fitness measurement based on frequent value is implemented to all item set. The procedures of *inter-gatras* analysis are implemented to all data set separately, and then the result is accumulated in order to collect frequent notation group pattern based on odd and even sequences. Table 4 shows the example of odd and even *inter-gatras* sequences of *gending Suwe Ora jamu*.

Table 4. Database of inter-gatras notations sequences

Odd Inter-gatras Sequences (GP)		**Even Inter-gatras Sequences (GW)**	
GP$_{1a}$	<2, 1>	GW$_{1a}$	<3, 2>
GP$_{2a}$	<1, 3>	GW$_{2a}$	<2, 5>
GP$_{3a}$	<3, 4>	GW$_{3a}$	<5, 2>
GP$_{4a}$	<4, 2>	GW$_{4a}$	<2, 3>
GP$_{1b}$	<2, 3>	GW$_{1b}$	<3, 2>
GP$_{2b}$	<3, 6>	GW$_{2b}$	<2, 5>
GP$_{3b}$	<6, 1>	GW$_{3b}$	<5, 6>
GP$_{4b}$	<1, 2>	GW$_{4b}$	<6, 2>

C. Production Rules

There are three types of production rules that used as described below.

1) Rules for Identifying Type of Laras

Laras slendro notations contain combination of 1, 2, 3, 5, or 6, and *laras pelog* notations contain combination of 1, 2, 3, 4, 5, 6, 7. Basically, if notation 4 or 7 is in a composition, then type of the composition can be identified that the *laras* is *pelog*, but if a composition contains combination of 1, 2, 3, 5, 6, then the type of *laras* can be both of *slendro* or *pelog*; therefore the system needs to search more by matching the composition notations with data in notations construction data base, thus the rules of determining type of *laras* can be defined as follows:

```
IF laras is slendro.
THEN available notations are 1, 2, 3, 5, 6.

IF laras is pelog.
THEN available notations are 1, 2, 3, 4, 5, 6, 7.

IF notation 4 or 7 is in a composition.
THEN laras is pelog.

IF notation 4 or 7 is not in a composition
AND notations construction of composition is match with those in data base of laras slendro
THEN laras is slendro.
ELSE laras is pelog.
```

2) Rules for Identifying Type of Gending

Types of *gending* consist of *lancaran, gangsaran, ketawang, ladrang, ayak-ayakan, srepegan,* and *sampak*. There are two techniques in determining type of *gending*, by using basic knowledge or melodic knowledge. Type of *gending* is differed by beats of instrument of *kenong, kethuk* and *gong*. Basic knowledge of data base contain beat symbols of those instruments, so type of *gending* can be determined by comparing beat symbols in composition with those in basic knowledge data base. The second technique which is using melodic knowledge is conducted if beat symbols in composition cannot be identified accurately. In these circumstances, the notations construction of composition can be compared with melodic knowledge data base for notations construction

```
IF beat symbols in composition are match with those in basic knowledge data base.
THEN set type of gending.
ELSE start notation pattern recognition.

IF beat symbols in composition are match with those in melodic knowledge data base.
THEN set type of gending.
```

3) Rules for Arranging Notations

Melodic knowledge data base which contains of frequent inter-notations data base, frequent inter-groups data base and frequent *inter-gatras* data base is used to arrange notations sequences that fit with sound characteristics of *gamelan* music. Rules defined based on melodic knowledge controls the creation of notations sequence and connected *gatras*. Below are rules of arranging notations, where *a1, b1, c1, d1, a2, b2, c2, d2* stand for notations sequences.

```
IF <a1, b1> is frequent.
AND <c1, d1> is frequent.
AND <b1, c1> is frequent.
THEN set <a1, b1, c1, d1> as candidate of first gatra

IF <a2, b2> is frequent.
AND <c2, d2> is frequent.
AND <b2, c2> is frequent.
THEN set <a2, b2, c2, d2> as candidate of second gatra

IF <a1, d2> is frequent
THEN connect first gatra and second gatra as sequences <a1, b1, c1, d1, a2, b2, c2, d2>
```

4) Rules for Composing

Composing a *gending* is started by defining type of *laras* and *gending*, then followed by determining the number of *gatra*. The number of *gatra* for composition can be defined using data of frequent *gatra* stored in basic knowledge data base. The next step is determining notations variant, notations variant composition, notations variant distributions, so the population of notations for composition is created. Further, notation sequence generating process can be implemented. Below are the rules for composing *gamelan* music.

```
IF laras is slendro.
THEN available notations are 1, 2, 3, 5, 6.

IF laras is pelog.
THEN available notations are 1, 2, 3, 4, 5, 6, and 7.

IF laras has been defined
THEN set type of gending.

IF laras has been defined
AND gending has been defined.
THEN define number of gatra based on data of frequent gatra in basic knowledge data
base.

IF laras has been defined.
AND gending has been defined.
AND number of gatra has been defined.
THEN define notations variant based on data of frequent notations variant in basic
knowledge data base.

IF laras has been defined.
AND gending has been defined.
AND number of gatra has been defined.
AND notations variant has been defined.
THEN define notations variant composition based on data of frequent notations variant
composition in basic knowledge data base.

IF laras has been defined.
AND gending has been defined.
AND number of gatra has been defined.
AND notations variant has been defined.
AND notations variant composition has been defined.
THEN define notations variant distribution based on data of frequent notations variant
distribution in basic knowledge data base.

IF laras has been defined.
AND gending has been defined.
AND number of gatra has been defined.
AND notations variant has been defined.
AND notations variant composition has been defined.
AND notations variant distribution has been defined.
THEN notations population has been created.

IF notations population has been created.
THEN choose for using identical notations pairs or identical gatras, and save the
setting in working memory.

IF notations population has been created.
AND identical notations pair and identical gatras have defined.
THEN start generating notations sequence for composition.

IF pattern in notations sequence is match with those in melodic knowledge database.
THEN set notations sequence as composition.
```

D. *Inference Engine*

Generate and test method (GAT) is used to inference engine in composing a *gending*. After notations population is created, system starts to generate notations sequence using random technique, and then test the result. Composition is stated succeed when notations sequence fit with basic and melodic rules, otherwise the system will randomize the notations population again, until composition is created.

Analyzing a composition can be conducted using backward chaining method. Notations in a composition are extracted based on inter-notations correlation, inter-groups correlation and *inter-gatras* correlation, and then the procedures of notation pattern recognition is used to match the notations pattern in the composition with those in basic and melodic knowledge base. Result of the analysis can be a recommendation of changing some notations in the composition, or explanation of gending types.

E. Evaluation Method

The method of automatic *gamelan* music composition proposed in this paper is to compose or analyze a *gending* in the form of *ricikan balungan*. Composing a *gending* results notation sequences in the form of *ricikan balungan* as described in Fig. 3 and Fig. 6, and analyzing a *gending* results a recommendation of the fitness of inputted notation sequences to the characteristic of *gamelan* music. The evaluation for automatic *gamelan* music composition is to measure accuracy and performance of the program in arranging notation sequences which fit with the characteristic of *gamelan* music. The accuracy of the program is evaluated by randomly deleting some notations in *gending* samples, and then asking the program to answer the deleted notations. The program is expected to answer the deleted notations correctly based on its knowledge. The accuracy is measured based on the number of correct and wrong answers. The more correct answers show the more accurate for the program in arranging notation sequences. The performance of the program involves the algorithm chosen for generating a composition. It is evaluated by limiting the duration in generating a composition. The good performance can be achieved when the program can generate a composition in a certain time.

IV. Conclusion and Perspectives

Rule-based expert system approach is proposed as a method for automatic *gamelan* music composition. Knowledge base is gathered from *gamelan* musician expert, literatures and data set containing a number of *gendings*. Knowledge base for gamelan music composition is categorized into basic and melodic knowledge. Data set which contains gendings are analyzed based on notation pattern in order to represent melodic knowledge base. The number of *gending* for data set affects the accuracy of production rules. As the method for automatic *gamelan* music composition has been proposed, next we plan to develop the program using the method proposed in this paper.

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