Pairs of Interval Classes in Southeast Asian Tunings

Jay Rahn, York University, Toronto

Third International Conference on Analytical Approaches to World Music
London, UK

July 2, 2014

Abstract: Construed non-numerically (Rahn 2011, 2012, 2013), the following normal-Forte-order formulations accurately model southeast Asian fixed-frequency tunings: *sléndro* 11111…, the 'usual' pentatonic 22323…, Thai pentatonic 11212, 5-tone *pélog* 11313; Thai 'equiheptatonic' 1111111…, *diatonis*/diatonic 1222122, and 7-tone *pélog* 1112112.

In well-documented instances, two or more of these tunings appear in single pieces that have been realized in one or more cultural settings. In order to convey the consequences of such 'translations' from one tuning to another, seemingly distinct tuning, one can observe that since each tuning is 'well-formed' (Carey and Clampitt 1989), each maximizes the number of interval-pairs within particular generic-specific interval-classes. In ideal, mathematical terms, if d is the number of steps in a register, the number of such interval-pairs is $d^2(d-1)/2$in 'degenerate' *sléndro* and Thai equiheptatonic, and $d(d-1)(2d-1)/6$ in the remaining, 'non-degenerate' tunings.

The formulation outlined above identifies salient structural relationships between realizations of single instrumental pieces in otherwise contrasting tunings and between passages comprising 'exchange tones' (*métabole*) within individual pieces.

There are several starting points for this presentation.

The first starting point consists of models for the tunings of fixed-frequency instruments in Southeast Asian ensembles. As displayed in the handout's **Figure 1 (below)**, these models specify the **relative sizes** of intervals between successive tones in particular tunings.

Although they are expressed by means of numerals, these models are essentially non-numerical. If they were numerical, all the intervals represented by a particular numeral would be **precisely equal in size**. Acoustically, a particular numeral or pair of numerals would correspond precisely to a particular real-number ratio between fundamental frequencies. Perceptually, two numerals or two pairs of numerals would correspond to one or two pairs of fundamental frequencies heard as precisely the same pitch-intervallically.

Figure 1. Models of Southeast Asian tunings

	in relative step-sizes	**in ‘normal’ (Forte) order**
sléndro	1 1 1 1 1…	0 1 2 3 4 (5)
7-tone Thai	1 1 1 1 1 1 1…	0 1 2 3 4 5 6 (7)
‘usual’ pentatonic	2 2 3 2 3…	0 2 4 7 9 (12)
5-tone Thai	1 1 2 1 2…	0 1 2 4 5 (7)
5-tone *pélog*	1 1 3 1 3…	0 1 2 5 6 (9)
Diatonic/*diatonis*	1 2 2 1 2 2 2…	0 1 3 5 6 8 10 (12)
7-tone *pélog*	1 1 1 2 1 1 2…	0 1 2 3 5 6 7 (9)

Instead, the numerals specify only that any interval they represent is **smaller than** any interval represented by a **larger numeral**.

E.g., each interval represented by ‘1’ in the model for 7-tone *pélog* is **smaller than** any of the intervals represented by ‘2.’ However, in contrast to numbers, none of the intervals represented by a particular numeral, e.g., ‘1’ or ‘2’, is necessarily **precisely the same in size** as any of the other intervals represented by the same numeral.

Whereas particular numerals do not necessarily convey precise sameness of size, the relationship of being larger or smaller than another interval holds for individual intervals and for sums of successive intervals.

E.g, all the intervals in 7-tone *pélog* that span 2 successive steps represented by ‘1’ are of size ‘1+1,’ i.e., ‘2,’ but they are not necessarily the same in size as each other or the same in size as any of the intervals that span a single step represented by ‘2.’

Nonetheless, as shown in **Figure 2**, each interval of size ‘2,’ whether it spans 1 or 2 steps is smaller than any interval of size ‘3,’ whether it spans 1 or 2 steps. And so forth for all the intervals in a particular tuning—which might comprise more than 4 octaves, that is, intervals that span more than 28 steps.

Figure 2. Relationships between sizes of intervals in 7-tone *pélog*.

name: panunggul gulu dada pelog lima nem barang (bem alit) (gulu alit) . . .

numeral: 0 1 2 4 5 6 7 (9) (10) . . .

step size: 1 1 2 1 1 1 2 1 . . .

1 < 1+1
i.e., each of 0-1, 1-2, 4-5, 5-6, 6-7, (9)-(10), etc. is smaller than each of 0-2, 4-6, 5-7, etc.

1 < 2
i.e., each of 0-1, 1-2, 4-5, 5-6, 6-7, (9-)-(10), etc. is smaller than each of 2-4, 7-(9), etc.

1+1 < 1+2
i.e., each of 0-2, 4-6, 5-7, etc. is smaller than each of 1-4, 6-(9), etc.

1+1 < 2+1
i.e., each of 0-2, 4-6, 5-7, etc. is smaller than each of 2-5, 7-(10), etc.

2 < 1+2
i.e., each of 2-4, 7-(9), etc. is smaller than each of 1-4, 6-(9), etc.

2 < 2+1
i.e., each of 2-4, 7-(9), etc. is smaller than each of 2-5, 7-(10), etc.

And so forth, up to intervals of 28 or more steps and relative sizes of '36,' or more.

The second starting point is the observation that in various Southeast Asian traditions particular pieces have often been performed by ensembles whose tunings differ greatly. For instance, David Hughes long ago drew attention to a Central Javanese piece in 5-tone *pélog* tuning that was performed by a Thai ensemble in 5-tone Thai tuning.

Hughes also pointed out a piece that has been performed in Thailand in both diatonic tuning and 7-tone Thai tuning and in Central Java in *sléndro* tuning.

Moreover, there are dozens of individual Central Javanese pieces that have been performed not only in *pélog* tuning but also in *sléndro* tuning.

Further, Michael Wright has shown that in Cirebon (in northwestern Java) *pélog* tuning has been adapted to European-derived guitars in diatonic tuning, and Richard Anderson Sutton has reported instances of *sléndro* performed along with *sléndro miring* or *diatonis* tuning in Semarang music of northern Central Java. And so forth.

A few brief audio examples illustrate what is involved. First, the well-known Central Javanese piece Kebogiro performed in *sléndro*: https://www.youtube.com/watch?v=Hlap5WulHOw.

And now the same piece in *pélog*: http://youtu.be/iQhkeyqfNh4.

Next, the Thai royal anthem performed by a modern military band in diatonic: http://www.navyband.navy.mil/anthems/ANTHEMS/Thailand%20%28Royal%20Anthem%29.mp3.

And now, the same tune in 7-tone Thai tuning, recorded on a cylinder with much surface noise by a Thai classical ensemble, in 1900: https://www.youtube.com/watch?v=eRHzsy0TH-M (at 0:50).

And finally, the same tune, which, as Ladrang Siyem (cf. 'Siam,' i.e., Thailand) in *sléndro* tuning, has become part of the traditional Central Javanese repertoire, as in this version of the balungan opening, sequenced with samples from Kyahi Paridjata of the gamelan group Marsudi Raras of Delft, transposed up 3 semitones): http://yorkspace.library.yorku.ca/xmlui/handle/10315/28318

A question posed by such instances of 'tuning translation' is as follows: 'What do these tunings have in common?' Or more precisely, 'What aspects of structure do these tunings share?' Or more pointedly, 'What non-trivial aspects of structure do these tunings share?'

And another pointed question: 'Which shared structural aspects are retained when a piece in one of these tunings is translated into another one of these tunings?'

This brings me to my third starting point. Each of these tunings is—to use a term that Norman Carey and David Clampitt coined 25 years ago—'well formed.' To be sure, Carey and Clampitt originally framed the concept of well-formed-ness in the context of European-derived post-tonal theory. Moreover, they framed the concept of well-formed-ness in terms of numerical interval sizes rather than the non-numerical, relative interval sizes discussed at the outset.

Nonetheless, the sizes of a tuning's intervals need not be framed in terms of numbers in order for a tuning to be understood as well formed. Indeed, the concept of well-formed-ness is of such great generality that it can be applied to tunings far beyond the sort of tuning that originally served as its illustrations. Most important, well-formed tunings share a feature that, I believe, accounts for their recurrence in several cultural settings and helps explain the fact that that pieces in one tuning have been 'translated into' other tunings.

In post-tonal theory, intervals are sorted into classes depending on their sizes and the number of steps they span. As shown in **Figure 3.a**, all the intervals that span 1 step in *sléndro* belong to the same class insofar as they are smaller than any of the intervals that span 2 steps; similarly for intervals of 2 steps with regard to those of 3 steps. And so forth.

Figure 3(a) Steps between tones and relative interval sizes in *sléndro*.

name:	**barang**		**gulu**		**dada**		**lima**		**nem**		**barang (alit)**	**etc.**
numeral:	0		1		2		3		4		(5)	etc.
step size:		1		1		1		1		1		

steps:	1	2	3	4	5	6	etc.
relative size:	1	2=1+1	3=1+1+1	4=1+1+1+1	5=1+1+1+1+1	6=1+1+1+1+1+1	etc.

Figure 3(b) Intervals that i) span a particular number of steps and ii) are of the same relative size in *sléndro*.

number of steps:	1	2	3	4	5	etc.
relative sizes:	1	2	3	4	5	etc.
intervals in class:	barang-gulu gulu-dada dada-lima lima-nem nem-barang	barang-dada gulu-lima dada-nem lima-barang nem-gulu	barang-lima gulu-nem dada-barang lima-gulu nem-dada	barang-nem gulu-barang dada-gulu lima-dada nem-lima	barang-barang gulu-gulu dada-dada lima-lima nem-nem	
number of intervals in each class:	5	5	5	5	5	

Accordingly, as **Figure 3.b** shows, in *sléndro* there are 5 1-step intervals whose sizes can be represented by the numeral '1.' And there are 5 2-step intervals whose sizes can be represented by the numeral '2.' And so forth.

In abstract terms, each of the 5 1-step intervals in *sléndro* belongs to the same interval class as each of the other 4 1-step intervals. In terms of high-school algebra, there are 5*4/2 = 10 such pairs of intervals in the 1-step class; that is, C(5,2), the number of combinations of 5 things taken 2 at a time—as shown in **Figure 3.c**. Similarly, each of the 5 2-step intervals in *sléndro* belongs to the same interval class as each of the other 4 2-step intervals, so that there are 10 such pairs of intervals in the 2-step class. And so forth.

Figure 3(c) Pairs of intervals that span a particular number of steps and are of the same relative size in *sléndro*.

number of steps:	1	2	etc.
relative size:	1	2	etc.
pairs of intervals:	barang-gulu & gulu-dada barang-gulu & dada-lima barang-gulu & lima-nem barang-gulu & nem-barang gulu-dada & dada-lima gulu-dada & lima-nem gulu-dada & nem-barang dada-lima & lima-nem dada-lima & nem-barang lima-nem & nem-barang	barang-dada & gulu-lima barang-dada & dada-nem barang-dada & lima-barang barang-dada & nem-gulu gulu-lima & dada-nem gulu-lima & lima-barang gulu-lima & nem-gulu dada-nem & lima-barang dada-nem & nem-gulu lima-barang & nem-gulu	barang- lima & gulu-nem etc.
number of interval-pairs:	10 i.e., C(5,2) = 5*(5-1)/2 = 5*4/2 = 10	10 i.e., C(5,2) = 5*(5-1)/2 = 5*4/2 = 10	etc.

i.e., in general, C(c,2) = c*(c-1)/2, where c = the number of intervals in a class of intervals that span a particular number of steps and are of the same relative size.

Total number of interval-pairs: 50 = 10+10+10+10+10

i.e., generally, in any degenerate well-formed tuning having d steps,
d*(d*(d-1)/2)

= $d^{2}(d-1)/2$, where d is the number of degrees in the tuning

e.g. (above), 5*5*(5-1)/2 = 50 for *sléndro*, which is a degenerate well-formed tuning having 5 degrees.

In sum, among all 5 classes of intervals in *sléndro*, there are 5*10 = 50 such pairs of intervals that belong to the same class.

Carey and Clampitt coined the arguably unfortunate term 'degenerate well-formed' to designate such tunings. In any event, one can observe, again in abstract terms, that in any degenerate well-formed tuning, the number of pairs of intervals that belong to the same class is **d-squared times d-1 divided by 2**.

More important than this abstract formulation is the observation that among all possible tunings that comprise a particular number of degrees (e.g., 5 or 7), a **degenerate well-formed tuning comprises the greatest number of pairs of intervals that belong to the same class.** Of immediate relevance here, *sléndro* and 7-tone Thai are degenerate well-formed tunings.

As Carey and Clampitt pointed out, there is only one other kind of well-formed tuning: namely, to invoke their arguably doubly unfortunate term, tunings that are 'non-degenerate well-formed.' Unlike degenerate well-formed tunings, non-degenerate well-formed tunings comprise intervals that span a particular number of steps and have two different relative sizes. For instance, as **Figure 4.a** shows, in 7-tone *pélog*, 5 of the 1-step intervals, namely, those whose size-numeral is '1,' are smaller than the other 2 1-step intervals, namely, those whose size-numeral is '2.'

There is more variety among the step-size classes in non-degenerate well-formed tunings than there is in degenerate well-formed tunings. Nonetheless, among all possible tunings that comprise a particular number of degrees (e.g., 5 or 7) and in which there is any variety at all among the sizes of 1-step intervals, **non-degenerate well-formed tunings maximize the numbers of pairs of intervals that belong to the same step-and-size class**.

For instance, **Figure 4.a** shows that in *pélog* there are 5 1-step intervals of size 1 and 2 1-step intervals of size 2. As well, there are 3 2-step intervals of size 2 and 4 2-step intervals of size 3. Also, there are 6 3-step intervals of size 4 and 1 3-step interval of size 3. And so forth.

In general abstract terms, the number of pairs of intervals that belong to the same step-and-size class is 91. Or most generally, in any non-degenerate well-formed tuning that comprises d degrees, there are **d(d-1)(2d–1)/6** pairs of intervals that belong to the same step-and-size class.

In particular, **among all 7-step tunings, *pélog* and diatonic are non-degenerate well formed tunings.**

And **among all 5-step tunings, the usual pentatonic, 5-step Thai, and 5-step *pélog* are non-degenerate well-formed tunings.**

Again, of greater importance than the precise number of interval-pairs in this abstract formulation is the fact that **among all tunings that comprise a particular number of degrees and in which there is any step-and-size variety, that is, among all tunings that comprise a particular number of steps and that are not degenerate well-formed, the greatest number of interval-pairs that belong to the same step-and-size class appear in a tuning that is non-degenerate well-formed**.

In this regard, one can point out that, as a European-derived example, there are fewer interval-pairs that belong to the same step-and-size class in a melodic-minor scale than in a diatonic scale, and there fewer interval-pairs that belong to the same step-and-size class in a harmonic-minor scale than in a melodic-minor scale, and so forth.

Figure 4(a) Number of interval-pairs in *pélog* that i) span a particular number of steps and ii) are of the same relative size

relative sizes of steps	**degrees**
1 1 2 1 1 1 2	0 1 2 4 5 6 7 (9)

number of steps	**relative size**	**number of intervals**	**number of interval-pairs**
1	1	5	5*4/2 = 10
1	2	2	2*1/2 = 1
2	2	3	3*2/2 = 3
2	3	4	4*3/2 = 6
3	3	1	1*0/2 = 0
3	4	6	6*5/2 = 15
4	5	6	6*5/2 = 15
4	6	1	1*0/2 = 0
5	6	4	4*3/2 = 6
5	7	3	3*2/2 = 3
6	7	2	2*1/2 = 1
6	8	5	5*4/2 = 10
7	9	7	7*6/2 = 21
total:			91

i.e., 2*{C(1,2)+C(2,2)+C(3,2)+C(4,2)+C(5,2)+C(6,2)}+C(7,2)
= 2*(0+1+3+6+10+15)+21
= 2*(35)+21
= 70+21
= 91

i.e., in general, for a non-degenerate well-formed tuning,

<u>d(2d-1)</u>, where d = the number of degrees

e.g. (above), 7*(2*7 – 1) = 7*13 = 91 for any non-degenerate well-formed 7-degree tuning

Figure 4(b) Number of interval-pairs that span a particular number of steps and are of the same relative size in diatonic.

relative sizes of steps	**degrees**
1 2 2 1 2 2 2	0 1 3 5 6 8 10 (12)

number of steps	**relative size**	**number of intervals**	**number of interval-pairs**
1	1	2	2*1/2 = 1
1	2	5	5*4/2 = 10
2	3	4	4*3/2 = 6
2	4	3	3*3/2 = 3
3	5	6	6*5/2 = 15
3	6	1	1*0/2 = 0
4	6	1	1*0/2 = 0
4	7	6	6*5/2 = 15
5	8	3	3*2/2 = 3
5	9	4	4*3/2 = 6
6	10	5	5*4/2 = 10
6	11	2	2*1/2 = 1
7	12	7	7*6/2 = 21
total:			91

i.e., 2*{C(1,2)+C(2,2)+C(3,2)+C(4,2)+C(5,2)+C(6,2)}+C(7,2)
= 2*(0+1+3+6+10+15)+21
= 2*(35)+21
= 70+21
= 91

i.e., in general, for any non-degenerate well-formed tuning,

<u>d(2d-1)</u>, where d = the number of degrees

e.g. (above), 7*(2*7 – 1) = 7*13 = 91 for any non-degenerate well-formed 7-degree tuning

A **fourth starting point** for this presentation is that one can provide a cognitive interpretation of the abstract formulation I have just outlined. Specifically, having relatively many interval-pairs that belong to the same step-size class can be understood in terms of the Gestalt Grouping Principle of Similarity.

According to the Similarity Principle, things that are perceived as the similar in some respect—in the present instance, by virtue of belonging to the same step-and-size class—are perceived as belonging to a single group of things. By extension, if more things in a group are perceived as similar, they are perceived as part of a single group to a greater extent: they are more thoroughly grouped or 'groupier.'

And by further extension, if the number of things that are perceived as similar is maximized, they are perceived as maximally grouped. In this sense, then, the tunings considered here are cognitively privileged, for their parts are perceived as constituting a single group to a greater extent than all other possibilities.

To summarize briefly, **the tunings considered here are not just any tunings**.

Arguably, then, maximization of interval-pairs belonging to the same step-and-size class provides an answer to the first, pointed question I raised earlier: namely, 'What non-trivial aspects of structure do these tunings share?'

At this point, one can also advance an answer to the remaining question I raised: namely, 'Which shared structural aspects are retained when a piece or idioms in one of these tunings is translated into another one of these tunings?'

Within each non-degenerate tuning, certain intervals contribute most to the extent to which that tuning is thoroughly grouped. The greatest number of interval-pairs belonging to the same step-and-size class results from the 8ve, or in post-tonal terms, 'the modular interval.' In abstract terms, and as shown earlier (**Figures 4.a and 4.b**), 91 interval-pairs belong to the same step-size class in any non-degenerate well-formed tuning that consists of 7 steps. Among the 12 kinds of interval in such a tuning, 7*6/2 = 21 interval-pairs belong to the 8ve interval-class.

Next in their capacity for grouping are a special kind of 4th and a special kind of 5th. **Figure 4.b** shows that in a diatonic tuning, there are 6 perfect 4ths and they comprise 6*5/2 = 15 step-size interval-pairs, and there are 6 perfect 5ths and they too comprise 15 step-size interval-pairs.

As **Figure 4.a** shows in similarly abstract terms, among the 12 step-size classes in 7-tone *pélog*, the 7 8ves as well as 6 of the 5ths and 6 of the 4ths result in 21+15+15 = 51 step-size interval-pairs: that is, **more than half of the step-size interval-pairs result from only 3 of the 12 step-size classes**. Accordingly, one can regard the 8ves and such 5ths and 4ths as a 'cognitive core' or 'skeleton' that would be retained if *pélog* was translated into diatonic, as appears to have occurred in Cirebonese tarling, where a *pélog* tradition was adapted to European-derived guitar tuning.

As **Figure 5(a)** shows, the 5-degree tunings outlined earlier manifest a parallel sort of cognitive core consisting of 8ves and certain intervals that span 3 of the 5 steps and 2 of the 5 steps; that is, approximately half of the 5 steps, just as the special 5ths and special 4ths of the well-formed 7-degree tunings span approximately half of the 7 steps: specifically, 4 and 3 of the 7 steps. What, then, of translations from a 7-step tuning to a 5-step tuning?

As mentioned earlier, dozens of Central Javanese pieces are performed both in *pélog* tuning and in *sléndro* tuning. This might seem impossible, rather like Schroeder in the Peanuts cartoon strip accurately playing highly chromatic pieces on a toy piano whose black keys are merely painted on (**Figure 6**). However, as it turns out such inter-translatable pieces comprise only 5 of the 7 degrees in *pélog*. Moreover, the 5 degrees constitute a non-degenerate well-formed tuning of their own: specifically, the non-degenerate well-formed tuning represented by the numerals 11313.

Figure 5. Non-degenerate 5-tone tunings aligned.

a) aligned by small and large 1-step intervals

5-tone *pélog*	0		1		2		5		6		(9)
		1		1		3		1		3	
5-tone Thai	0		1		2		4		5		(7)
		1		1		2		1		2	
'usual' pentatonic	0		2		4		7		9		(12)
		2		2		3		2		3	

b) aligned by same-relative-size 2-step intervals

5-tone *pélog*	2		6		10(=1)		5		9(=0)
		+4		+4(=-5)		+4		+4(=-5)	
5-tone Thai	2		5		8(=1)		4		7(=0)
		+3		+3(=-4)		+3		+3(=-4)	
'usual' pentatonic	4		9		14(=2)		7		12(=0)
		+5		+5(=-7)		+5		+5(=-7)	

Figure 6. One Way of Performing Pieces that Modulate on an Instrument Comprising only 7 Tones Per Octave

Figure 5(a) shows that in such a 11313 tuning, there is a cognitive core that comprises intervals which span 2 steps or 3 steps, that is, approximately half of the 5 steps. Similarly, in *sléndro*, there is a cognitive core that comprises intervals which span 2 steps or 3 steps. And as the following audio illustrations and **Figures 7(a) and 7(b)** demonstrate, the correspondence between the *sléndro* performance and the *pélog* performance is clear.

Sléndro Lancaran Kebogiro: http://youtu.be/Hlap5WulHOw
Pélog Kebogiro temanten: http://youtu.be/iQhkeyqfNh4

Figure 7. Degrees of *sléndro* and 5-degree *pélog* aligned.

a) aligned in general

	degrees:	**2-step cycles:**					
sléndro	0 1 2 3 4 (5)	2 steps, size-2 (of 5)	2	4	6(=1)	3	5(=0)
5-tone *pélog*	0 1 2 5 6 (9)	2 steps, size-4 (of 9)	2	6	10(=1)	5	9(=0)

b) in passages of *Sléndro* Lancaran Kebogiro and 5-tone *pélog* Kebogiro Temanten

sléndro	1 0 1 0 4 3 4 3 …	1 0 1 0 1 2 1 2 …
5-tone *pélog*	1 0 1 0 6 5 6 5 …	1 0 1 0 1 2 1 2 …

Indeed, there is a cognitive core consisting of step-size intervals of approximately half an 8ve in each of the tunings displayed at the beginning of this presentation. Moreover, such a cognitive core comprises all 5 degrees of any well-formed 5-degree tuning and, as **Figure 5(b)** shows, all 7 degrees of any well-formed 7-degree tuning. In fact, although they employed different, post-tonal terms, Carey and Clampitt effectively defined well-formed tunings in terms of such a core.

Unlike Kebogiro, and as indicated above, the similarly well-known Thai royal anthem has been performed both in 5-degree tuning and in 7-degree tunings. Ca. 1900, during the reign of Chulalongkorn, it was performed by military bands and notated in diatonic tuning (**Figure 8.i**): http://www.navyband.navy.mil/anthems/ANTHEMS/Thailand%20%28Royal%20Anthem%29.mp3.

As well, Thai classical music ensembles performed the anthem in 7-tone Thai tuning. Carl Stumpf and Erich von Hornbostel, both well trained in European solfege, reported that in the equiheptatonic recording they analyzed, the 7th sounded relatively low and the 4th relatively high (**Figure 8.ii**). Both of these are highlighted in bold typeface in the schematic transcription that you can follow while listening to the equiheptatonic recording referred to above: https://www.youtube.com/watch?v=eRHzsy0TH-M (at 0:50).

The instances of the 4th degree in the final measures are metrically much more prominent than the 7th and 4th degrees that appear on offbeats earlier in the piece.

In terms of exchange tones and *métabole*, these prominent 4th-degree tones can be understood as replacing the earlier instances of the 3rd degree and as being replaced by the 3rd degree in the last measure.

In terms of the present formulation, the last half of the piece can be understood as comprising two 5-degree non-degenerate well-formed scales whose 7-degree counterparts correspond to the numerals 0 1 2 4 5 and 3 4 5 0 1.

In the equiheptatonic tuning the steps of both of these 5-tone scales can be represented by 1 1 2 1 2; in the diatonic tuning, by 2 2 3 2 3. In such a metabolic passage, not only do both 5-tone scales maximize step-size interval-pairs; as well, because they involve transposition by the core half-8ve interval, both maximize what in post-tonal theory are termed common tones. Specifically, whereas the degree represented by 4 replaces, and is subsequently replaced by, the degree represented by 3, all the other degrees are retained: namely, 0, 1 4, and 5.

For more than 80 years, the Thai royal anthem has also been performed by Central Javanese musicians in *sléndro* tuning. The metabolic analysis just discussed hinges on distinguishing degree 3 from 4, whether in diatonic or equiheptatonic. However, as is clear in **Figure 8.iii** and its accompanying audio example (http://yorkspace.library.yorku.ca/xmlui/handle/10315/28319), there is no direct counterpart to the distinction between degrees 3 and 4 in the *sléndro* realization.

Nonetheless, as has been shown for exchange-tone and metabolic practice in East Asia and for diatonic and the so-called 'usual' pentatonic in European-derived music, the step-and-size classes of well-formed 7- and 5-tone scales are thoroughly coordinated. In particular, within a context of diatonic and the usual pentatonic, degrees 3 and 4 are alternative versions of one another, as are degrees 1 and 7. And as **Figure 9** shows, one can extend such a coordinated formulation of step-and-size intervals to include well-formed 7- and 5-tone scales of Southeast Asia.

In conclusion, despite their surface differences Southeast Asian tunings are unified by their intervallic structures, in particular by the ways in which they maximize interval-pairs that belong to the same step-and-size classes and the ways in which these most thoroughly grouped structure are coordinated with each other.

Figure 8. Notations of Thai royal anthem's main melody and balungan in:

- **i) diatonic (top row, 0 2 4 5 7 9 11: mainly 0 2 4 7 9),**
- **ii) 7-degree Thai (middle row, 0 1 2 3 4 5 6: mainly 0 1 2 4 5), and**
- **iii) *sléndro* (top row, 0 1 2 3 4 throughout)**

Audio illustrations begin at asterisk (*).

```
i)   0         2 0 2  4  | 0                  | 0          0 11,  0 4 | 2                  |
ii)  0         1 0 1  2  | 0                  | 0          0 6,   0 2 | 1                  |
iii) 0       0 1 0 1  2  | 0 4, 0 2 3         | 0       4, 0 4,   0 2 | 1                  |

i)   2 4 2 4 0   2402 | 4                     | 4        2    4 2 4 7 | 4    47 9 7 9 0'  |
ii)  1 2 1 2 0   1201 | 2                     | 2        1    2 1 2 4 | 2    24 5 4 5 0'  |
iii) 1 2 1 2 0   1201 | 2 3 0 1 2         3   | 2        1    2 1 2 3 | 2    3   4 3 4 0  |

i)   7         9 7 9 0   | 2                  | 2        22   2 5 4 2 | 0                  |
ii)  4         5 4 5 0   | 1                  | 1        11   1 3 2 1 | 0                  |
iii) 3       4 3 4 0 2   | 1                  | 1        11   1 3 2 1 | 0                  |

                                              *
i)   2       4 2 4 0     | 2                  | 2        4  2 4   0   | 9         2'    0' |
ii)  1       2 1 2 0     | 1                  | 1        2  1 2   0   | 5         1'       |
iii) 1       2 1 2 0     | 1                  | 1      2 1  2     0   | 4,        1        |

                                              prominent métabole . . . . . . . . . . . . . . . . . . . . . . . .
i)   0'        9 7 9 0'  | 7              9   | 5          7          | 9 0'  5  7  9      |
ii)  0'        5 4 5 0'  | 4              5   | 3          4          | 5 0'  3  4  5      |
iii) 0       3 4 3 4 0'  | 3              4   | 2          3 4   2 3  | 4 0'  2  3  4   0  |

     . . . . . . .
i)   7 9 0 4 2     0     | 0                  ||
ii)  4 5 0 2 1           | 0                  ||
iii) 3       3 2 3 0 2   | 1          3       | 2          1          | 0                  ||
```

Figure 9. Corresponding Transpositions of Non-degenerate 5-tone Tunings Available within 7-tone Tunings

7-tone tunings:		**transpositions of non-degenerate 5-tone tunings:**									
7-tone *pélog*	0 1 2 4 5 6 7 (9)	0	1	2		5	6		9(=0)		
					4	5	6		9(=0)	10(=1)	
						5	6	7		10(=1)	2
7-tone Thai	0 1 2 3 4 5 6 (7)	0	1	2		4	5		7(=0)		
					3	4	5		7(=0)	8(=1)	
						4	5	6		8(=1)	2
diatonic	0 2 4 5 7 9 11 (12)	0	2	4		7	9		12(=0)		
					5	7	9		12(=0)	14(=2)	
						7	9	11		14(=2)	4

In conclusion, despite their surface differences Southeast Asian tunings are unified by their intervallic structures, in particular by the ways in which they maximize interval-pairs that belong to the same step-and-size classes and the ways in which these most thoroughly grouped structure are coordinated with each other.

Sources and Studies for the Presentation's Four Starting Points

1. Non-Numerical Models of Southeast Asian Tuning

Charoensook, Sugree, Sangad Pookhaothong, James Upton, Anak Charanyananda, Sakchai Hirunrux, and Sanong Klangphrsri. 1997. *Research for Standard Pitch and Scale of Thai Music*. Salaya, Thailand: College of Music, Mahidol University.

Rahn, Jay. 2013. Remodeling Southeast Asian Tunings. Annual Conference, Society for Music Perception and Cognition. http://www.smpc2013.com/wp-content/uploads/2012/08/SMPC-2013_conference-program.pdf , p. 81

______. 2012. The Analytical Outlook of A Theory for All Music: Numbers, Measurements, and Perceptible Scale Structure in Thai Classical Music. Annual Conference, Society for Ethnomusicology, New Orleans.

______. 2011. Perceptually Based Theory in World Music Tradition. Annual Conference, Society for Music Theory, Minneapolis. http://societymusictheory.org/events/meeting2011/igactivities

Surjodiningrat, Wasisto, P. J. Sudarjana, and Adhi Susanto. 1972. *Tone Measurements of Outstanding Javanese Gamelans in Jogjakarta and Surakarta*. Jogjakarta: Gadjah Mada University Press.

2. Southeast Asian Pieces Performed in More than One Tuning

Diamond, Jody, I.M. Harjito, and Djoko Waluyo, eds. 1995. *The Vocal Notation of K.R.T. Wasitodiningrat*. Lebanon, N.H.: American Gamelan Institute: http://www.gamelan.org/library/

Drummond, Barry, ed. n.d. Gendhing Jawi: Javanese Gamelan Notation: http://www.gamelanbvg.com/gendhing/index.php

Hughes, David. 1992. Thai Music in Java, Javanese Music in Thailand: Two Case Studies. *British Journal of Ethnomusicology* 1: 17-30: http://www.academia.edu/3716008/Thai_music_in_Java_Javanese_music_in_Thailand_two_case_studies

Lim, V. King, ed. n.d. Javanese Gamelan Notation. Sydney: Langen Suka: http://www.langensuka.asn.au/notation/

Sutton, R. Anderson. 1991. *Traditions of Gamelan Music in Java*. Cambridge, UK: Cambridge University Press.

Wright, Michael. 1978. *The Music Culture of Cirebon*. Ph.D. dissertation, UCLA (Ann Arbor, Mich.: University Microfilms International, 1978)

3. Well-Formed Tunings

Carey, Norman. 1998. *Distribution Modulo 1 and Musical Scales*. Ph.D. dissertation, University of Rochester: http://www.academia.edu/3385414/Distribution_modulo_one_and_musical_scales

Carey, Norman and David Clampitt. 1989. Aspects of Well-Formed Scales. *Music Theory Spectrum* 11: 187–206.

4. Gestalt Grouping Principle of Similarity

Rahn, Jay. 2011. The Hurrian Pieces, ca. 1350 BCE: Part Two—From Numbered Strings to Tuned Strings. *Analytical Approaches to World Music Journal* 1/2: 204-69, esp. 252-61: http://www.aawmjournal.com/articles/2011b/Rahn_AAWM_Vol_1_2.htm

Wertheimer, Max. 1923. Untersuchungen zur Lehre von der Gestalt II. *Psychologische Forschung* 4: 301-350. English translation: http://psychclassics.yorku.ca/Wertheimer/Forms/forms.htm