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THE "ALGORITHM" FOR DETERMINING THE OPTIMUM OUTPUT IN SUHAID SOUND SYSTEM

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ABSTRACT

*Suhaid language is spoken in Western Kalimantan (Indonesia). This language consists of an aspirated occlusive voice which is derived from the deletion of /ə/ in the penultimate syllable position. The deletion of schwa and the forming of C+h will leave a floating mora, μ. This mora will attach to the immediate vowel and form a vowel lengthening. Based on Optimality analysis, the constraint *GEM (Consonant geminate is prohibited) plays a crucial role in terms of constraint satisfaction and violation. The candidate with geminate consonant will be ruled out as it fatally violate *GEM, in the set of rankings: *GEM >> MAX-C >> MAX-IO[μ] >> *COMPLEX >> MAX-V >> *LV >> PrWd=FT-BIN. Although this paper is related implicitly with science and technology fields, its concept has consolidated the general spirit of Tsear (2004)'s study on computing optimal form of a language.*

Key words: Aspirated occlusive, mora, constraint, satisfaction, violation

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1. INTRODUCTION

Suhaid language is spoken along the tributaries of Seberuang and Suhaid rivers, about 600 km upriver from the mouth of Kapuas river, West Kalimantan, Indonesia. This indigenous minority language is spoken by about 6000-6500 people as the first language and approximately 1000-2000 others who use it as a second language around the Sejiram town—the major town in this territory. Suhaid speaking villages are spread at the middle and upper of the Seberuang river. Historically, they were moved from the Suhaid river basin into the Seberuang river basin around 19th century due to the Iban incursions and Malay taxes (Enthoven 1903). The Suhaid ethnonym is pronounced as [suwayet] and is well-known in the colonial literature. Their language, the Suhaid language is strikingly complex in terms of the

sounds system and other linguistic features. This paper will limit the discussion on the voiceless aspirated stop existed in this language.

2. THE ASPIRATED VOICED STOPS IN SUHAID

According to Ladefoged & Maddieson (1991), the laryngeal setting of an aspirated stop is "having a greater rate of airflow than occurs in modal voice for a period before or after a stricture". The voiceless aspirated stops are produced with a glottal opening gesture that begins at about the moment that the oral closure is made and reaches its maximum at about the moment that the oral closure is released. This feature is commonly found in the Sino-Tibetan language family, Hindi, Igbo, Aslian language and Eastern Armenian. Since the phonemic aspiration of stops do not present in Austronesian languages family, the Suhaid which belongs to the subgroup of Austronesian (the Malayic subgroup), on the contrary is asserted by its speakers: "is quite like Chinese because consist of many *h*…Suhaid language is look like Chinese language" (Chinese is a family of languages with phonemic aspirated stops); see Collins (2005).

In fact, the motivation for this claim is due to the [h] is an allophone of /x/ in the initial and medial positions. In other words, the /x/ is correspondent with the voiced velar fricative /ɣ/ or /r/ in other Malayic variants in Western Borneo, see for example: /həkuəŋ/ (Suhaid) : /ɣəkuəŋ/ (Seberuang) : /rəkuəŋ/ (Iban) 'throat'; /uhaŋ/ (Suhaid) : /uɣaŋ/ (Sekadau Malay) : /uraŋ/ (Iban) 'person'. The occurrence of aspiration in Suhaid is due to the mid-central vowel [ə] in penultimate syllable position is deleted and appears as [ø] (especially the disyllabic words). When the [ə] is deleted, two consonants are juxtaposed and yielded consonant clusters. When the initial consonants is a voiceless occlusive and followed by [h], it will result in an aspirated occlusive, for example: [phu:ət] 'stomach', [pha:h] 'wring out', [kha:k] 'scorched rice crust', [thə:baŋ] 'fly' and etc.

3. THE OPTIMALITY THEORY

The theoretical framework adopted in this study is the Optimality Theory (henceforth, OT) purposed by Prince & Smolensky (1993). The basic ideas of this theory is derived from the generative phonology approach introduced in 1970s and 1980s. This theory purposed that Universal Grammar (UG) consists a set of constraints on representational well-formedness, out of which individual grammars are constructed. This theory relies on the notion of constraints interaction whereby it allows violation of the satisfaction of one constraints can be designated to take priority over the satisfaction of another. In other words, violation is allowed in the universal constraints and it is an analysis of an input best satisfies – or least violates – a set of conflicting conditions. The grammar used to resolve conflicts is to rank constraints in a strict domination hierarchy, for example the lower ranked constraints can be minimally violated to ensure the satisfaction of high ranked constraints. The core components of OT are (Ahmad 2005):

- CON: The set of constraints out of which grammars are constructed.
- GEN: Short for 'generator', a function defining, for each possible input *i*, the range of candidate linguistic analyses available to *i*.
- Eval: Short for 'evaluator', a function that comparatively evaluates sets of forms with respect to a given constraint hierarchy Γ, a ranking of CON.

Explanation below illustrated the notion of constraint interaction in a constraint hierarchy. In OT analysis, the constraint ranking is represented with a constraint tableau. To make it simple, first of all, let us assume that a language *L* contains two universal constraints, A and B. In the underlying form ($input_i$/), language *L* is assumed to have two possible forms for the

surface form, that is [$Cand_1$] (short for 'Candidate') and [$Cand_2$]. Both of them are in conflict situation where the satisfaction of one constraint leads to the violation of the other. As shown in tableau below, suppose that [$Cand_2$] is the actual surface form (i.e. the output), for instance [$Cand_2$] satisfies A and violates B. On the contrary, [$Cand_1$] satisfies B and violates A. Finally, this conflict will be resolved by ranking the constraints in a strict dominance hierarchy. Since [$Cand_2$] is assumed the grammatical form, the grammar of L requires that constraint A dominates constraint B. The constraints dominance hierarchy of grammar L with the form A >> B. Hence, the [$Cand_2$] signaled by a pointing finger is the optimal output.

Constraint Tableau, A >> B, /$input_i$/→ [$Cand_2$]

Candidates	A	B
a. [$Cand_1$]	*!	
b. ☞ [$Cand_2$]		*

The explanations for the constraint tableau above are:

- The dominations of each constraint are arranged from left to right. The leftmost column is the highest-ranked constraints.
- Possible candidates are listed like "a. [$Cand_1$]", "b. [$Cand_2$])".
- Constraint violation is marked by " * "; unmarked cell means constraint satisfaction.
- " *! " = fatal violation and this candidate will be eliminated.
- ☞ = the pointing for an optimal candidate.

4. DATA ANALYSIS

The Suhaid vocabularies discussed in this paper were collected from several Suhaid hamlets, such as Bekuan, Geruk, Kenerak, Kerangas and Sejiram village. This paper will use one of the output forms, [kha:k] to explain the occurrence of this aspirated occlusive voice feature; see Table 1:

Table 1 The examples of aspirated occlusive voice in Suhaid

Suhaid	Underlying form	Meaning
[bha:t]	/bəɣat/	Heavy
[kha:ʔ]	/kəɣa/	Long tailed macaque
[kha:k]	/kəɣak/	Scorched rice crust
[phu:ət]	/pəɣut/	Stomach
[pha:h]	/pəɣah/	Wring out

This paper is a moraic phonology study that applied the framework of Optimality theory. The core analysis will cover the prosodic and segmental phonologies. In phonology, the term "mora" is a unit that determines syllable weight, i.e. the heavy syllable has two moras whereas a light syllable consists of one mora. In other words, syllables with long vowel are heavy and with an ordinary short vowel are light.

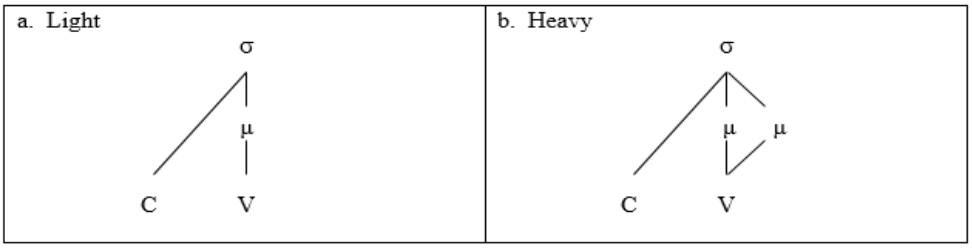


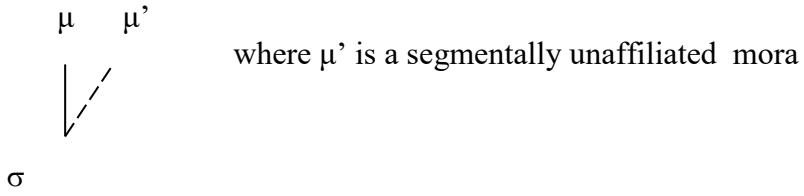
Figure 1

For the case of [kha:k] (or other similar output) in Suhaid, as explained above, the deletion of mid-central vowel [ə] in penultimate syllable position triggered the occurrence of aspiration in Suhaid, [Ch-]. After the deletion of schwa, what happens to this stray element? Does the [ə] disappear without a phonetic trace? To provide a clear solution for this question, we should refer to the Moraic Theory purposed by Hayes[6]. In Latin, he found that when the segment /s/ was deleted before an anterior sonorants. When the deleted /s/ is followed by a vowel, the vowel becomes long, for example: /kasnus/ → [ka:nus] 'gray'. The linear theory of phonology approach had failed to describe this phenomenon. The Moraic theory on the other hand can overcome this difficulty. Hayes used the terms "compensatory lengthening" to give an insight into this phonological issue. According to him, "*compensatory lengthening can be defined as the lengthening of a segment triggered by the deletion or shortening of a nearby segment*". The moraic account for this fact is as the rules stated below[6]:

a. /s/ deletion

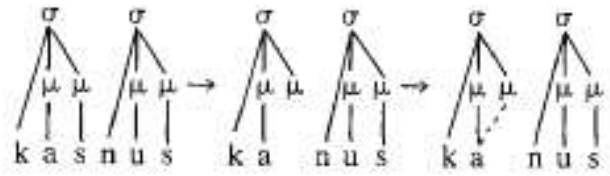
$$s \rightarrow \emptyset / \_\_\_\_ \begin{pmatrix} +son \\ +ant \end{pmatrix} \qquad \text{(segmental tier only)}$$

b. Compensatory Lengthening



where μ' is a segmentally unaffiliated mora

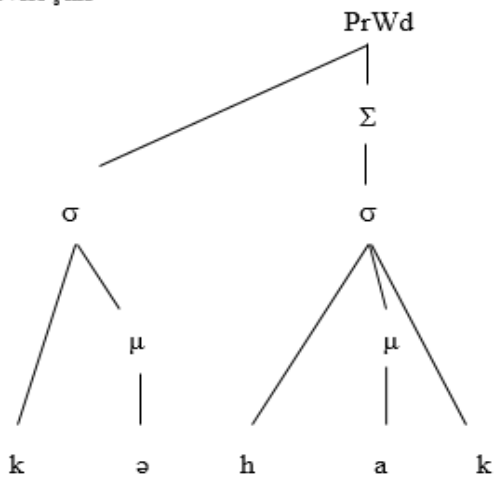
c.



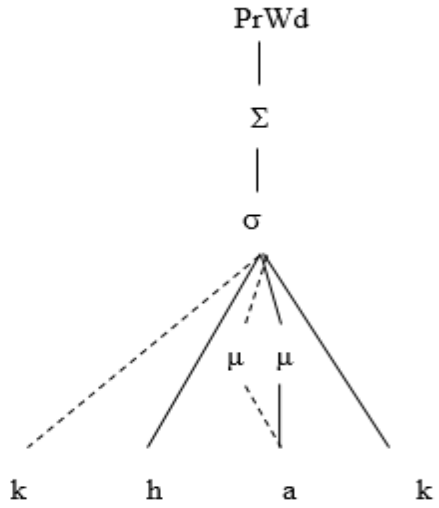
= [ka:nus]

Under the moraic theory, the /s/ deletion in (a) is occurred in the segmental tier only. As the /s/ has moraic value, once a mora is stranded, it is filled by spreading from an immediately preceding vowel as stated in (c) and finally lengthened the vowel [a] adjacent to the consonant that deleted. In short, the Compensatory Lengthening of moraic theory has provided an adequate account of vowel or consonant lengthening in prosodic phonology. The schwa deletion in Suhaid is observed parallel to the Latin case explained in Hayes (1989). Below are the representation of /kəɣak/ → [kha:k] 'Scorched rice crust':

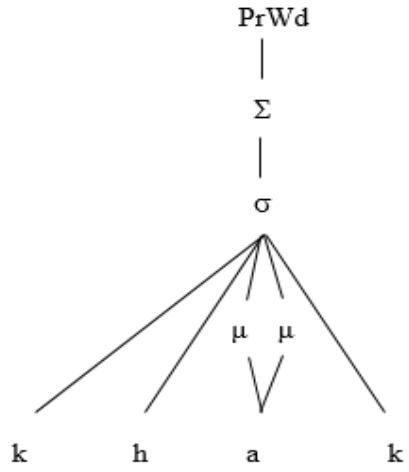
a. Input: /kəɣak/



b. Schwa deletion and compensatory lengthening



c. Output



Phonetic Representation: [kha:k] 'Scorched rice crust'.

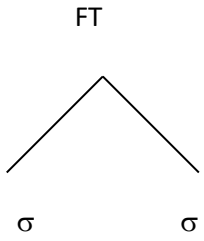
Indicator: PrWd = Prosodic Word; Σ = (foot); σ = Syllable; μ = Mora

Based on the representation in Figure 1, after the penultimate position [ə] is deleted in segmental tier, it will leave a stray mora and hence get vowel length by linking it to the nearby vowel melody. The final result is the C and /h/ merged as an aspirated voice [kh-] in the surface representation.

From OT perspective, recall that the syllable structure of dwi-syllabic words in Suhaid will be realized as mono-syllabic output after the deletion of [ə] indeed has violated the Foot-Binarity (FT-BIN) constraint. According to McCarthy & Prince (2001), “the Prosodic Hierarchy, any instance of the category Prosodic Word (PrWd) must contain at least one Foot (Ft). By Foot Binarity, every Foot must be bimoraic or disyllabic”. This constraint is defined as below:

Foot Binarity (FT-BIN)

Feet must be binary under syllabic or moraic analysis.



The consonant cluster C+h that formed after the deletion of [ə] also seems violated the faithfulness constraint *COMPLEX. This constraint disallows the association of more than one segment to any one syllabic constituent (i.e. onset, nucleus. Coda). It is considered as an unviolated constraint in Malay (a variety of Malayic language; see Ahmad (2005)).

*COMPLEX

No more than one segment may associate to any syllable position node.

As shown in Figure, the surface form of /kəhak/ is an output with vowel lengthening or long vowel, [kha:k]. According to Aziz & Ahmad (2008), the existence of long vowel leads to the violation of Long Vowel or *LV constraint.

*LV

Long Vowel is prohibited

According to Hayes (1989), there is certain language which fills an empty syllable-final position not by lengthening the vowel (as described above) but by spreading the following consonant leftward to create a geminate. During the Suhaid data collection in the field, indeed it is quite difficult to differentiate the pronunciation of *[kh:ak] (a geminate pronunciation) and [kha:k] (by lengthening the vowel). After detailed examination with the informants, it was found that [kha:k] is the proper pronunciation. Hence, [kh:ak] with geminate consonant is identified violated the constraint of *GEM.

*GEM

Consonant geminate is prohibited.

In Suhaid, this language is observed to have maintained the mora in the output. In the underlying tier, the deleted segment will leave a floating mora that then link to an immediate vowel producing a vowel lengthening (Aziz & Ahmad 2008). In other words, the truncated mora is attached to the segment nearby and formed a vowel lengthening. The constraint that proposed for mora maintaining in the output is MAX-IO$_{[\mu]}$; see Aisyah & Ahmad (2017).

MAX-IO$_{[\mu]}$

Mora deletion is prohibited.

The schwa deletion in penultimate position and the retaining of consonants in Suhaid is obviously governed by the MAX-IO constraints, namely the MAX-V and MAX-C respectively, as defined as follow:

MAX-V

Every segment of the input has a correspondent in the output (Vowel deletion is prohibited

MAX-C

Every segment of the input has a correspondent in the output (Consonant deletion is prohibited).

Consider the Suhaid "aspiration" case under discussion, we have seen that after the deletion of [ə], the segment that undergoes deletion yielded compensatory lengthening and the position that occupied is within the syllable-final position. In other words, the stranded mora or vowel melody is spread onto the vowel in syllable final position. Thus, the constraints of germination (GEM) must rank higher than other constraints in the constraint hierarchy for Suhaid. Seven constraints defined above are the constraints for the occurrence of aspirated occlusive in Suhaid. The relevant ranking is *GEM dominates other constraints. The interaction between the seven constraints is controlled by the following ranking: *GEM >> *MAX-C >> MAX-IO$_{[\mu]}$ >> *COMPLEX >> MAX-V >> *LV >> PrWd = FT-BIN. The following tableau illustrated this interactions.

Table 2

/kəhak/	***GEM**	**MAX-C**	**MAX- IO[μ]**	***COMPLEX**	**MAX-V**	***LV**	**PrWd = FT-BIN**
a. ka:k		*!			*	*	*
b. kh:ak	*!			*	*		*
c. khak			*!	*	*		*
d. ☞ kha:k				*	*	*	*

As can be seen in the above tableau, the candidate in (*b*) will be excluded earlier because it fatally violates the higher constraint of *GEM. The first candidate [ka:k] who is undergoing C-deletion has led to a violation of the faithfulness constraint MAX-IO, especially MAX-C, hence it is also a failed candidate. The candidate in (*c*) who deletes the mora in the output has obviously violated the constraint of MAX-IO$_{[\mu]}$. The candidate (*d*) emerges as the victor as it minimally violates only the lower ranked constraints *COMPLEX, MAX-V, *LV and PrWd = FT-BIN.

A computer can perform four operations of data processing activities: (i) input/output operations, (ii) calculation and text manipulation operations, (iii) logic/comparison operations and (iv) storage and retrieval operations. The main component involved in data processing is the CPU (Central Processing Unit). The CPU can be divided into two main parts, namely the Arithmetic Logical Unit (ALU) and Control Unit (CU). In ALU, three operations will be performed: Arithmetic operations (performing calculation), Comparison operations (comparing the data input greater that, equal to or less than) and Logical operations (work with logical operators). Meanwhile, in CU, the operations that involved are fetching,

decoding, executing and storing. The figure below outlined the basic concept of data processing operations by a computer.

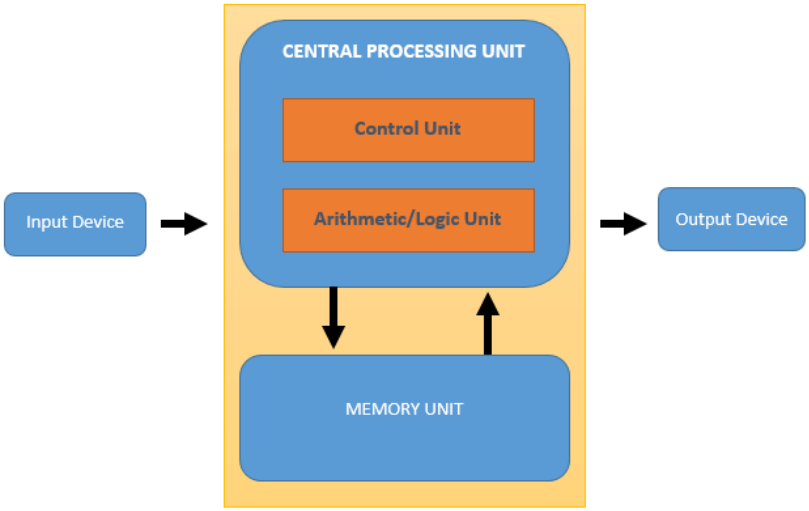


Figure 2

The equivalent of the Optimality framework and the operations of data processing for a computer can be summarized in Table 2 below:

Table 3 The Similarity Between Computer Data Processing and Optimality Model

	Computer Operations	**Optimality Model**
INPUT	Raw data	The underlying form of words
DATA PROCESSING	CPU component: Searching, sorting of data, calculating and decision-making	GEN 'generator': A function defining, for each possible input *i*, the range of candidate linguistic analyses available to *i*. EVAL 'evaluator': A function that comparatively evaluates sets of forms with respect to a given constraint hierarchy Γ, a ranking of CON. CON: The set of constraints out of which grammars are constructed.
OUTPUT	The processed data that is useful to the user	The actual surface form (or output) of word that satisfies the constraint of A and violates the constraint of B.
Components of Data Processing	Processor—Central Processing Unit (Arithmetic Logical Unit and Control Unit).	A Tableau with: (i) a set of universal constraints, e.g. Constraints A, B, C… (ii) several possible candidates for surface form, e.g. $Cand_1$, $Cand_2$, $Cand_3$, $Cand_x$

5. CONCLUSION

The occurrence of aspirated voiced stop disyllabic words in Suhaid is due to deletion of [ə] in penultimate syllable position. Hence the remaining consonants in this syllable are juxtaposed and yielded a consonant clusters. When the initial consonant is a voiceless occlusive and followed by [h], it will result in an aspirated occlusive. The analysis of this paper which is

grounded in the framework of Optimality by Prince and Smolensky (1993) has revealed that there is a restriction of gemination (*GEM) in Suhaid language. Due to the constraints of *GEM and other constraints subsumed under the constraints family, namely MAX-C, MAX-$IO_{[\mu]}$, *COMPLEX, MAX-V, *LV and PrWd=FT-BIN. Putting all the constraints together yields the following set of rankings: *GEM >> MAX-C >> MAX-$IO_{[\mu]}$ >> *COMPLEX >> MAX-V >> *LV >> PrWd=FT-BIN. This study has concluded that Optimality theory is also an algorithm to determine the existence of aspirated voiced stop in the surface form. This fact had also remarked in Tesar (2004), namely: "…in Optimality Theory, the parsing problem is easily understood as an optimization problem: search the Space of candidate structural descriptions for the one that optimally satisfies the ranked constraints. The general spirit of Optimality Theory is to generate a large and general space of candidate structural descriptions for an input, leaving much of the work to the constraints to determine grammaticality… Intuitively, the algorithm operates by gradually constructing a few candidate parses as it works through the input. When the end of the input is reached, only a few complete parses have been constructed, one of which is guaranteed to be optimal." Although this paper is related implicitly with science and technology fields but its concept has consolidated the general spirit of Tsear (2004)'s study on computing optimal form of a language.

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