

A computational expression of initial binary feet and surface ternary feet in metrical theory

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Abstract

Under the strict binary foot parsing (Kager 1993), stray elements may occur between bimoraic feet. The stray element may be associated to the preceding foot or following foot at surface level. Stray element adjunction is the mechanism for achieving surface exhaustivity. Each language has its own unique mechanism of stray element adjunction in order to achieve surface exhaustivity. In Japanese loanwords, the strict binary initial foot parsing creates stray moras. Inaba's (1996) phonetic experiment shows that the word-medial stray moras associate to preceding feet, and provides evidence for the initial unaccented mora as extrametrical. Since the theoretical points I advance are deeply embedded in other languages, I present a set of possible parameters. Based on the set of parameters, I create a computer program which derives the surface foot structures of input loanwords in Japanese, Fijian, and Ponapean.

1. Stray Moras and Surface Exhaustivity

Since the work of Liberman and Prince (1977), it has been assumed that stress is associated with a stress foot. Thus, as opposed to the taxonomic point of view that English stress is phonemic, theories of generative phonology assume that stress is predictable to an extensive degree. For instance, the word 'catamaran' is footed, as in (1), by employing Kager's (1993) moraic trochee. The main stress is assigned to the final visible foot. The upper-case sigma ' Σ ' indicates an isochronous unit called a foot, and the mu ' μ ' is used to refer to a mora. The main stress is marked by an acute accent "´" and the secondary by "˘".

(1) Feet in 'catamaran'

Σ						Σ
\ \	\			\ \		
μ μ μ				μ μ		
ca ta ma				ra n		

The feet in (1) comply with foot exhaustivity without allowing stray elements. Halle and Vergnaud (1987) argued that the exhaustivity condition should be respected in foot parsing.

- (2) Exhaustivity Condition (Halle and Vergnaud 1987)
 Rules constructing constituents apply exhaustively over the entire string.

Kager (1993), who clearly distinguishes initial parsing from surface representation, however, argues that exhaustivity is surface-representational rather than a condition of foot parsing. Under the bimoraic initial foot parsing, a stray mora may occur between bimoraic feet. Stray mora adjunction is the mechanism for achieving surface exhaustivity.

Each language has its own unique mechanism of stray mora adjunction. In English, it is assumed that stray elements attach to the preceding foot at the surface foot level. For instance, the word, 'catamaran', is footed as the result of strict binary initial parsing in (3-a), where feet are indicated by a pair of parentheses. The stray mora, which lacks its head element and is marked by '- ' without a pair of parentheses, is to be adjoined to the preceding foot at the surface foot level to achieve surface exhaustivity.

- | | | | |
|-----|-----------------|---|-----------------|
| (3) | a. Initial Feet | | b. Surface Feet |
| | (+ -) - (+ -) | | (+ - -) (+ -) |
| | catamaran | → | catamaran |

Schütz (1985) provides foot structures for Fijian loanwords. He uses neither the term stray mora nor the distinction between the initial foot and surface foot, but I interpret his representations as follows. A stray mora is incorporated under the following bimoraic foot at the surface foot level, as in (4-ii). The output forms of initial parsing are represented in (4-i). I adopt pairs of square brackets to indicate moraic elements on which feet are built.

- | | | |
|------|----------------------------------|-----------------------------------|
| (4) | a. <i>kònitara</i> ki 'contract' | b. <i>kòniferédi</i> 'conference' |
| | (+ -) - (+ -) | (+ -) - (+ -) |
| (i) | k[ɔ]n[i]t[a]r[a]k[i] | k[ɔ]n[i]f[e]r[e]d[i] |
| | (+ -) (- + -) | (+ -) (- + -) |
| (ii) | k[ɔ]n[i]t[a]r[a]k[i] | k[ɔ]n[i]f[e]r[e]d[i] |

In general, it is said that a stray mora is associated with the preceding foot in English, whereas it is associated with the following foot in Fijian.

A number of Japanese loanwords show that a stray mora appears word-initially, word-medially, and word-finally. Inaba (1996) provides evidence for surface feet and shows that the word-medial stray moras tend to be associated with the preceding feet rather than with the following feet at the surface level in Japanese. Moreover, the initial stray mora is extrametrical,

Japanese. Moreover, the initial stray mora is extrametrical, which is indicated by '<>', as in (5-b).

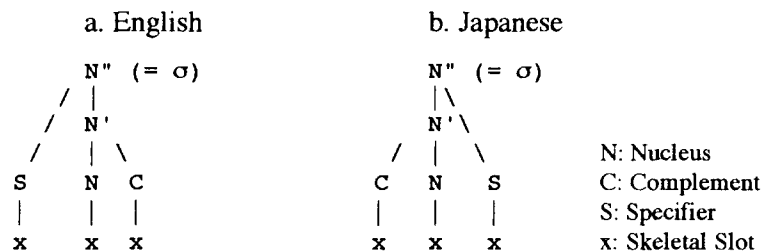
(5)	a. <i>résutoraN</i> 'restaurant'	b. <i>bakéesyoN</i> 'vacation'
(i)	(+ -) - (+ -) r[e]s[<u>u</u>]t[o]r[a][N]	- (+ -) (+ -) b[a]k[e][e]sy[o][N]
(ii)	(+ - -) (+ -) r[e]s[<u>u</u>]t[o]r[a][N]	(<-> + -) (+ -) b[a]k[e][e]sy[o][N]

High vowels between voiceless consonants get devoiced. Devoiced vowels are not allowed to be the head of a foot so that accent shifts to the next leftward mora in the right-to-left parsing direction. At surface level, the non-initial stray mora is associated to the preceding foot. This Japanese leftward surface-adjunction seems to be identical to the case in English, but is quite different from the type claimed for Fijian (Schütz 1985). This point is illustrated in (6).

(6)	i. Japanese & English	ii. Fijian
	a. Initial Feet	
	Σ Σ	Σ Σ
	\ \	\ \
	μ μ μ μ μ	μ μ μ μ μ
	+ - - + -	+ - - + -
	b. Surface Feet	
	Σ Σ	Σ Σ
	\ \ \	\ / \
	μ μ μ μ μ	μ μ μ μ μ
	+ - - + -	+ - - + -

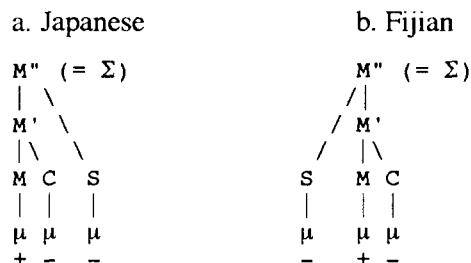
It is very clear that the surface foot structures are either binary or ternary, but the relationship among moras is not yet clear in flat structures, as in the representations in (6). The head element, marked by '+', must be closer to one of the non-head elements, marked by '-', than the other. Interestingly, they are very similar to syllable structures represented based on the x-bar theory (Inaba 1996), expanding the syllable internal structure proposed by Levin (1985). As I discussed, the syllable is viewed as the maximal projection (N'') of the nucleus (N), and thus it becomes very clear that nucleus and coda as the complement are tied up together in a single unit (N') in English, and onset and nucleus as the complement in Japanese. The syllable internal structures are as follows:

(7) Syllable Internal Structures



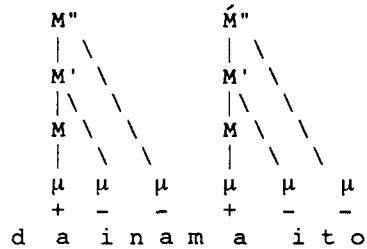
Following the discussion for the syllable internal structure above, the foot can be seen as the maximal projection of the head mora marked by '+'. We then arrive at the following surface foot structures for Japanese and Fijian.

(8) Prosodic Surface Feet

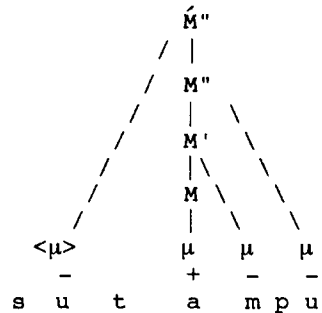


Each hierarchical foot structure above is viewed as the maximal projection of the head element marked by '+'. It clearly shows that the complement (obligatory) is closer to the head than specifier (optional). Moreover, it is more constrained than a flat representation, as in (6), in the sense that only strictly binary branching is allowed at each level. This strict binarity is parallel to the labels S (strong) and W (weak), which are relationally defined in major metrical theories. Another parallelism is that in both the syllable-based and the foot-based analyses, the specifier either precedes or follows the head, depending on the language. With the foot structure, non-initial stray moras (specifier) in Japanese are associated with the preceding foot. The two words *dainamáito* 'dynamite' and *sutáNpu* 'stamp' are assumed to have the following surface foot structures. Following Halle's (1982) extension of Archangeli (1981) with regard to a word-initial extrametricality, I assume that the mora with a low tone must be adjoined to an expanded M'' (Chomsky Adjunction).

(9) *dainamáito* 'dynamite'



sutáNpu 'stamp'



The representation above only allows binary branching at each level, and reveals a structural symmetry in the proposed syllable internal structure.

2. Computational Expression of the Approach

2.1. A Set of Parameters

Parameterizing the theory is important in providing generalizations underlying parsing mechanism. Here is a possible set of parameters incorporating my proposals for the accent patterns of Japanese, Fijian, and Ponapean loanwords. For a detailed discussion of accent patters of Japanese, Fijian, and Ponapean, see Inaba (1996).

Table: Parameters for Accent Patterns of Loanwords

	Japanese	Fijian	Ponapean
LEXICALEXM	NO	NO	CONSONANT EXM
MORAIC ASSIGN	NUCLEUS(N) SPEC. (N*)	NUCLEUS(N)	NUCLEUS(N) SPEC. (N*)
HEAVYSYLL	YES	YES	YES
SPECIALFOOT	NO	PENULT.MORA	NO
CONSTRAINT	SHORT VOWELS	1st VOWEL	NO
TARGETMORA	RIGHT	LEFT	RIGHT
PARSING	RIGHT'TOLEFT	LEFT'TORIGHT	RIGHT'TOLEFT
ADJUSTMENT	DEACCENTING	NO	TJ
FOOTEXM	YES	NO	NO
ADJUNCTION	LEFTWARD	RIGHTWARD	RIGHTWARD

Notes:

LEXICAL EXM (LEXICAL EXTRAMETRICALITY):
Certain segments are lexically extrametrical.

MORAIC ASSIGN (MORAIC ASSIGNMENT):
 Moraic values are assigned to designated elements.

HEAVY SYLL (HEAVY SYLLABLE):
 Heavy syllables attract accent.

SPECIAL FOOT:
 Accents are fixed in special cases. (Top-down construction)

CONSTRAINT:
 Certain moraic elements are not allowed to become the head of a foot.

TARGET MORA:
 Parsing starts at the right or left peripheral mora.

PARSING:
 Parsing takes place from left to right or right to left.

ADJUSTMENT:
 A degenerated foot is adjusted to meet the binary foot requirement.

FOOT EXM (FOOT EXTRAMETRICALITY):
 The final foot is extrametrical.

ADJUNCTION:
 A stray mora is attached to the preceding (leftward) or following foot (rightward).

TJ (TRANSITIONAL JUNCTURE):
 The final degenerate foot is associated with a transitional juncture (TJ) to meet the bimoraic foot requirement.

2.2. Computational Programming by MaxSpitbal

2.2.1. Introduction

Based on the set of parameters above, I created a MaxSPITBOL program by incorporating the present proposals for parsing mechanism in the three languages. MaxSPITBOL is a text parsing programming language developed by Dewar, Emmer, and Goldberg (1990).

The program which I created takes typed-in words, and reports the evidence of rule application and their output foot structures. The final result shows the accent position of a loanword. To avoid possible redundancy, I will only show a computational expression of the approach to Japanese in details. At first, a copy of the computational derivation of a nonsense word, *katakikatakika* is given in (11). I use this nonsense word to show more derivational processes than by using real loanwords.

(11) An Example of Actual Computational Derivation

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TYPE INPUT: katakikatakika

JMORA:
  WORD
  FOOT
  MORA   k[a]t[a]k[i]k[a]t[a]k[i]k[a]

JHS:
  WORD
  FOOT
  MORA   k[a]t[a]k[i]k[a]t[a]k[i]k[a]

```

JSHORTHV:
WORD
FOOT
MORA k[a]t[a]k[0i]k[a]t[a]k[0i]k[a]

RMOST:
WORD
FOOT (+)
MORA k[a]t[a]k[0i]k[a]t[a]k[0i] k[a]

LWARD:
WORD
FOOT - (+ -) - (+ -) (+)
MORA k[a] t[a]k[0i] k[a] t[a]k[0i] k[a]

DEACT:
WORD
FOOT - (+ -) - (+ -) -
MORA k[a] t[a]k[0i] k[a] t[a]k[0i] k[a]

SFPL:
WORD
FOOT (<MEX> + - -) (+ - -)
MORA k[a]t[a]k[i]k[a] t[a]k[i]k[a]

Abbreviations:

JMORA: JAPANESE MORA ASSIGNMENT (Vowels and elements in the coda position are moraic in Japanese.)
JHS: JAPANESE HEAVY SYLLABLE ASSIGNMENT (Heavy syllables inherently attract accent.)
JSHORTHV: JAPANESE SHORT HIGH VOWEL (High vowels between voiceless consonants cannot be the head of a foot.)
RMOST: TARGET MORA: RITGHT MOST (The final mora is associated with a high tone; thus a '+' is assigned to the mora.)
LWARD: LEFTWARD (Parsing takes place from right to left.)
DEACT: DEACCENTING (The final degenerate foot, marked by '(+)', becomes '-' to meet the bimoraic requirement.)
SFPL: SURFACE FOOT PARSING LEFTWARD ADJUNCTION (A stray mora is attached to the preceding foot.)
MEX: MORA EXTRAMETRICALITY (The first stray mora is extrametrical.)

In the program, I employed a means of representing moraic elements by a pair of square brackets. On the left is a set of three layers. The lowest layer contains a string of the word with a pair of square brackets indicating moraic elements. This row, therefore, is called the mora row. The second row is called the foot row, and the top row is the word row. SFP (Surface Foot Parsing) includes MEX (Mora Extrametricality) and the Accent Assignment. In other words, the first mora, marked as '-', is considered to be extrametrical in Japanese, and the plus sign on the word level indicates the position of the accent

of the word. The foot extrametricality does not apply for this word because a stray mora intervenes between the word boundary and the final foot. The next section describes the organization of this program, but the real ten-page program is not included in this paper to save space.

2.2.2. Modules

In order to capture the generalizations underlying the parsing mechanism, I have four systematic divisions called modules.

- (12) Four Modules
- | | |
|---------------------|-----------------------------|
| a. Parameter Module | b. Language Specific Module |
| c. Universal Module | d. Housekeeping Module |

2.2.2.1. Parameter Module

The parameter module contains a set of parameters. Each function is executed according to these parameters. For instance, the parameters for Japanese loanwords based on the Table are set as follows.

- (13) Parameters for Japanese Loanwords

LEXM	=
MORA	= 'J'
HS	= 'J'
LHEAD	=
CONSTRAINT	= 'JSHORTHV'
TARGET	= 'RMOST'
IFP	= 'LWARD'
ADJUSTMENT	= 'DEACT'
FEXM	= 'FEXM'
SFP	= 'SFPL'

Abbreviations:

LEXM (LEXICAL EXTRAMETRICALITY):

This is applied in Ponapean, but not in Japanese; thus, it is null after '=' above.

MORA (MORA ASSIGNMENT):

Vowels and elements in the coda position are moraic in Japanese.

HS (HEAVY SYLLABLE ASSIGNMENT):

Heavy syllables inherently attract accent.

LHEAD (LEXICAL HEAD ASSIGNMENT):

A plus sign '+' is assigned to the penultimate mora in Fijian, but not in Japanese and Ponapean.

CONSTRAINT:

Specified short vowels cannot be the head of a foot in Japanese.

TARGET (TARGET MORA ASSIGNMENT):

A plus '+' is assigned to the right peripheral mora in Japanese.

IFP (INITIAL FOOT PARSING):

Initial parsing takes place from right to left in Japanese.

ADJUSTMENT (ADJUSTMENT RULE):

The final degenerate foot, marked by '(+)', becomes '-' to meet the bimoraic requirement in Japanese. (It may associate with the following transitional juncture [TJ] to meet the bimoraic requirement, as in Ponapean.)

FEXM (FOOT EXTRAMETRICALITY):

The final foot is extrametrical in Japanese.

SFP (SURFACE FOOT PARSING):

A stray mora is attached to the preceding foot in Japanese.

2.2.2.2. Language Specific Module

This module contains the rules that are considered to be language specific. More specifically, major rules in the Japanese Module are summarized as follows.

(14) Japanese Module

MORA ASSIGNMENT:

Vowels and elements in the coda position are moraic.

HEAVY SYLLABLE ASSIGNMENT:

[a] followed by [u, i, o, e, or a] is marked by '+'.
[e] followed by [u, i, or e] is marked by '+'.
[o] followed by [u, i, or o] is marked by '+'.
[i] followed by [u or i] is marked by '+'.
[u] followed by [u or i] is marked by '+'.
C followed by [N, p, b, t, d, k, g, s, z, or f] is marked by '+'.
CONSTRAINT (JSHORTHV):
High vowel between voiceless consonants cannot be the head of a foot.

2.2.2.3. Universal Module

This module contains rules that are considered to be universal. In (15) are these rules.

(15) Universal Module

TARGET (TARGET MORA ASSIGNMENT):

A parametric setting by 'LMOST' assigns a '+' to the left peripheral mora and 'RMOST' assigns a '+' to the right peripheral mora.

IFP (INITIAL FOOT PARSING):

A parameter setting by 'RWARD' indicates that Initial Parsing takes place left to right and 'LWARD' indicates that Initial Parsing takes place right to left.

ADJUSTMENT (DEACCENTING):

The final mora marked by '+' becomes '-'.

FEXM (FOOT EXTRAMETRICALITY):

The final foot is extrametrical.

SFP (SURFACE FOOT PARSING):

A parameter setting by 'SFPL' forces a stray mora to attach to the preceding foot, and 'SFPR' forces a stray mora to attach to the following foot. A degenerate foot associates with [TJ] to meet the binary foot requirement (Adjustment). The main accent is assigned to the final visible foot. (Accent Assignment).

2.2.2.4. Housekeeping Module

This module contains housekeeping functions, such as Printing Functions. The main functions in this module are given in (16).

(16) Housekeeping Module

WEV (WORD EVIDENCE): It reports a derivational process.

CLEAN: It cleans remaining unnecessary signs such as '\$' and '0'.

GRID: It converts one-dimensional outputs to metrical grid-like outputs.

2.3. Summary

Parameterizing the theory is important in providing the generalizations underlying the parsing mechanism. I have proposed a possible set of parameters incorporating my proposals for the accent patterns of Japanese, Fijian, and Ponapean loanwords in terms of parameters. It has been demonstrated that the theoretical points, which were originally adopted to account for the accent patterns in Japanese, are deeply embedded in Fijian and Ponapean. Finally, in an attempt to disclose the underlying parsing mechanism in each language, I provide the foot structures of the nonsense word *katakikatakika*, which are actually derived by the parsing program as follows. (Their derivational processes are omitted. The '+' on the top row predicts the main accent in each language.)

(17) Foot Structures of the Nonsense Word 'katakikatakika'

JAPANESE:

WORD
FOOT (<MEX> + - -)(+ - -)
MORA k[a]t[a]k[i]k[a] t[a]k[i]k[a]

FIJIAN:

WORD
FOOT (+ -)(+ -)(- + -)
MORA k[a]t[a] k[i]k[a] t[a]k[i]k[a]

PONAPEAN:

WORD
FOOT (+ -)(+ -)(+ -)(+ -)
MORA k[a]t[a] k[i]k[a] t[a]k[i] k[a] [TJ]

In my proposals, the syllable is divorced from the foot. This allows moras to become direct subconstituents of feet freeing syllables into a separate hierarchy. Based on the set of parameters, I created a parsing program which derives the surface foot structures of input words. Consequently, this computational expression makes it possible to explicitly reveal various mechanisms of the prosodic hierarchy by using the same word in the three different languages.

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