*Fuzhou Tone-Vowel Interaction**

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1. Introduction

Previous studies on tone-vowel interaction have centered on two issues. The first is the correlation between tone and vowel quality (Pilszczikowa-Chodak 1972, 1975, Newman 1975 for Hausa; Cheung 1973 for Omei dialect of Mandarin; Wang 1968, Maddieson 1976, Yip 1980, Chan 1985 for Fuzhou), and the second is the directionality of the influence between tone and vowel, namely, whether tone affects vowel quality change, or whether vowel quality gives rise to tonal change (Wang 1968, Maddieson 1976, Yip 1980 for Fuzhou; Gandour 1977 for Thai dialects; Yue 1976 for Cantonese, Lianzhou, and Taishan).

There have been a number of experimental studies on the first issue. The principal finding[1] among these studies is the correlation between fundamental frequency (F_0) and vowel height. In particular, a high vowel has higher F_0 and a low vowel has lower F_0 (Lehiste and Peterson 1961 for English; Petersen 1976 for Danish; Di Cristo and Chafcouloff 1976 for French; Kim 1968 for Korean; Chuang and Wang 1976, Tsay and Sawusch 1994 for Mandarin; and Sawusch and Tsay 1994 for Fuzhou; etc.). Since **tone**, defined as linguistic use of **pitch**, is also primarily identified in terms of F_0 (Gandour 1978), it is natural to ask whether this phonetic correlation between F_0 and vowel height manifests itself phonologically in natural languages. In other words, the question is whether there is any empirical evidence suggesting a phonological correlation between tone and vowel height. The evidence for Hausa (an African language principally spoken in Nigeria), for example, is inconclusive. Data is offered both for (Pilszczikowa-Chodak 1972, 1975) and against (Newman 1975) this position. A highly controversial case is Fuzhou, (a Northern *Min* dialect spoken on the southern coast of China). In Fuzhou, a whole series of finals[2] participate in vowel alternations in accordance with their tonal environment. It has been claimed, on the one hand, that in a tone sandhi environment, a vowel undergoes raising when the tone it occurs with increases its F_0 (Wang 1968). This is characterized as a tone-induced vowel raising process (Yip 1980). I refer to this claim as the "*height-correlation*" hypothesis. On the other hand, it has been argued that the vowel alternations in Fuzhou involve not only differences

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[1] There are also other findings on this issue, such as that rounded vowels tend to have a higher F_0 than their unrounded counterparts (Sundberg 1969, Ewan 1975, Reinholt Petersen 1978, Iivonen 1987). It is also reported that lax vowels [ɪ] and [ʊ] have the same F_0 as the tense vowels [i:] and [u:], even though they are known to have much lower tongue height (Fischer-Jørgensen 1990). This suggests that duration, in addition to vowel height, is also a factor that influences the intrinsic F_0 for vowels.

[2] In traditional Chinese phonology, a syllable is divided into two parts: (i) the initial consonant and (ii) the rest of the syllable, called the final. For instance, the final in a syllable [biáo] 'quick, rapid' is **iāo**, which contains the on-glide **i**, and a tone-bearing nucleus **ao**.

in height, but also differences along other dimensions, such as a front/back axis, monophthongs versus diphthongs, etc. (Maddieson 1976, Chan 1985). The "height-correlation" hypothesis, therefore, is not sufficient to explain all instances of tone-related vowel alternation. The implicit assumption behind this debate is that tonal features and vocalic features may interact directly. This yields a more fundamental question as to the nature of this interaction. In other words, whether the interaction between tone and vowels is <u>direct</u> (i.e. feature-to-feature) or <u>indirect</u> (i.e. mediated by something else).

Although studies of the second issue are relatively rare, it has been shown that the influence of tones and vowels on each other is bi-directional cross-linguistically. For example, whereas Mandarin and Fuzhou have been cited as cases in which vowel alternations are conditioned by tonal environment (Wang 1969, Wang 1968, Yip 1980), the Yue dialects of Chinese, such as Cantonese, Taishan, and Lianzhou, illustrate the opposite direction of influence (Yue 1976). In Cantonese, for instance, the *Yin* "entering" tone historically splits into two tones according to their vocalic environment. It is realized with a higher register when the vowel is lax and short, and with a lower register when the vowel is tense and long (Yue 1976:49). A general question that relates to the first issue, then, is whether tone and vowel quality directly influence each other or whether this influence between them is mediated by something else.

This article provides a unified account for all vowel distribution and alternation patterns corresponding to tonal environments in Fuzhou, focusing on the prosodic anchor mediating between tones and vowels. Tones and vowels will be claimed not to interact directly (i.e., feature-to-feature), and it will be seen that there is no height correlation between them. Instead, tone-vowel interaction in Fuzhou must be mediated by a prosodic anchor; in this case, the mora; and distinct moraic structures (monomoraic/bimoraic) required by the prelinking of the lexically specified number of tonal roots are what trigger the vowel alternations.

The analysis is formulated within the constraint-based grammar of Optimality Theory (OT) (McCarthy and Prince 1993a, b; Prince and Smolensky 1993; Pulleyblank 1994, among others). Contrary to the rule-based approach, OT assumes that Universal Grammar (UG) contains two types of phonological representation: the input and the output. The function *Gen* freely generates a set of output candidates for each input. UG also contains a set of violable constraints that are ranked on a language-particular basis. The function *Eval* determines the optimal output, which either satisfies the higher ranked constraints, or has the least violations of the relevant constraints.

2. Fuzhou tone-vowel interaction

In this section, I will investigate tone-vowel interaction in Fuzhou, the most controversial case which has been cited repeatedly both for and against the intrinsic height correlation hypothesis. Particularly, I will examine vowel distributions and alternations with respect to their tonal environment, and identify the exact factors that trigger the vowel distributions and alternations.

The Fuzhou phonological system contains the 7 vowels (1) and the 7 citation tones (2).

(1) Vowels:	i	y		u
	e	ø		o
	ɛ	œ		ɔ
			a	

There is a wide range of variety concerning the realization of vowels and tones. The Fuzhou phonological system presented here is from Liang (1982, 1984) and Chen & Zheng (1990).

(2) Tones[3]:

	Tones in "tight" finals			Tones in "loose" finals	
	Ping	*Ru*	*Shang*	*Qu*	*Ru*
Yin	44 H		31ML	213 MLM	<u>23</u> ʔ MLM
Yang	53 HM	<u>5</u> ʔ HM		242 MHM	

The chart (2) only contains citation tones. Sandhi tones are not included. A citation tone refers to a tone in a monosyllabic morpheme. Historically, the tones in the *Yin* category are developed from syllables with initial voiceless obstruents, while those in the *Yang* category are from syllables with initial voiced obstruents. The tones <u>23</u> and <u>5</u> only occur in finals with a glottal stop coda. The tone letters H, M, L, are used here to facilitate exposition.

Fuzhou speakers distinguish two groups of finals: the "tight" finals and the "loose" finals. The seven citation tones in (2) are divided into two groups corresponding to the groups of finals. In particular, the tight finals contain either a high level tone (H) or a simple falling tone (HM, ML), while the loose ones have either a concave tone (MLM) or a convex tone (MHM) in (2).

2.1. Tone-vowel interaction in monosyllabic words

In this section, I investigate the vowel distributions in monosyllabic words (the citation forms), and explore the precise factors which trigger these distributional effects. Recall that tones in the tight finals are either level (H) or simple falling (HM, ML), whereas those in the loose finals are either concave or convex. (MHM, MLM). These cooccurrence restrictions are illustrated in all sets of data below.

(3)

	I "tight"	<u>Gloss</u>		**II** "loose"	<u>Gloss</u>	<u>Distribution</u>
a.	tsi^{ML}	'only'	d.	tsei^{MLM}	'will'	i ~ ei
b.	piŋ^{H}	'guest'	e.	peiŋ^{MLM}	'combine'	
a.	ku^{H}	'alone'	d.	kou^{MLM}	'old; reason'	u ~ ou
b.	tsuŋ^{ML}	'permit'	e.	tsouŋ^{MLM}	'handsome'	
a.	sy^{HM}	'must'	d.	søy^{MHM}	'sequence'	y ~ øy
c.	tyŋ^{HM}	'repeat'	f.	tøyŋ^{MHM}	'middle'	

The data in (3) show that a single high vowel in the tight finals ([i], [u], [y]) corresponds to a diphthong in the loose finals ([ei], [ou], [øy]), and that the diphthongs comprise a high vowel preceded by a mid vowel with the same feature value for frontness and roundness. However, non-high vowels behave differently from high vowels. The examples in (4) demonstrate that

[3] The checked tones <u>5</u> and <u>23</u> are assumed to have the tonal contours HM and MLM since they behave identical to 53 and 213, respectively. The shortening, presumably, is due to the glottal stop coda whose effect on tonal contour is open for further research.

underlying mid vowels and low vowels surface as tense ([e], [o], [a]) in tight finals and as lax ([ɛ], [ɔ], [ɑ]) in loose finals.

(4)

	I "tight"	Gloss		II "loose"	Gloss	Distribution[4]
a.	tsieŋ^{H}	'stick'	b.	tsiɛŋ^{MLM}	'fight'	e ~ ɛ
c.	tsieŋ^{ML}	'exhibit'	d.	siɛŋ^{MHM}	'kind; be good at'	
e.	ko^{H}	'song'	f.	kɔ^{MLM}	'individual'	o ~ ɔ
g.	kyo^{HM}	'bridge'	h.	kyɔʔ^{MLM}	'decisive'	
i.	ka^{HM}	'false'	j.	kɑ^{MHM}	'holiday'	a ~ ɑ
k.	kua^{ML}	'few, scant'	l.	kuɑ^{MLM}	'hung up'	
m.	kau^{H}	'suburbs'	n.	kɑu^{MLM}	'enough'	

The corresponding patterns in (4) have not been treated in previous theoretical studies. These same patterns are also included in descriptive studies by Liang (1983, 1984, 1990), Zheng (1983; 1988), and Chen and Zheng (1990). Notice that the mid vowels alternating along the tense/lax dimension must not be followed by a high vowel. If a mid back vowel is followed by a high front rounded vowel, it appears as front in the tight finals and as back in the loose finals (ø ~ o), shown as in (5):

(5)

	I "tight"	Gloss		II "loose"	Gloss	Distributio n
a.	ts^{h}øy^{H}	'hurry; urge'	b.	ts^{h}oy^{MLM}	'break to pieces'	øy ~ oy
c.	ts^{h}øy^{ML}	'marrow'	d.	ts^{h}oy^{MLM}	'intensifier adv.'	

Comparing (5) with (4e-h), it is noticed that in (4e-h) the mid vowel distributes in tense/lax fashion regardless of whether it is preceded by a high vowel. However, when it is followed by the high vowel [y], as shown in (5), it distributes as front/back vowels respectively. This different distributional behavior clearly suggests that (i) the presence of another segment, and (ii) the relative syllabic position might also be factors that trigger the particular realization of vowel quality. Further examples of the presence of coda consonant affecting vowel distributions are found in (6):

(6)

	I "tight"	Gloss		II "loose"	Gloss	Distribution
a.	meiʔ^{HM}	'strange(lit.)'	b.	maiʔ^{MLM}	'strange(collq.)'	eiC ~ aiC
c.	teiŋ^{ML}	'wait'	d.	taiŋ^{MHM}	'surname'	
e.	tsouŋ^{H}	'stolen goods'	f.	tsauŋ^{MLM}	'to bury'	ouC ~ auC
g.	pouʔ^{HM}	'thin (lit.)'	h.	pauʔ^{MLM}	'explode'	

The examples in (6) demonstrate that a low vowel [a] in the loose finals, when followed by a high vowel plus a consonant, corresponds to a mid vowel [e] and [o] in the tight finals, respectively. Notice that in (4i-n), the low vowel [ɑ] in the loose finals does not raise to mid in the corresponding tight finals. Instead, it changes from lax to tense. The lack of vowel-raising

[4] Notice that the corresponding pair e ~ ɛ only occurs with a preceding high vowel [i]. No word is found in the "loose" finals with a mid front unrounded vowel without a preceding [i]. The lack of e ~ ɛ distribution without a preceding high vowel may be due to the absence of lexical items with such forms.

effect cannot be attributed tonal environment since the tones in the two types of finals in (4i-n) are the same as that in (6). What makes the low vowel in (6) different from that in (4i-n) is the presence of both a post nuclear glide and a coda consonant. This suggests that the presence of the number of segments in post nucleus position becomes a conditioning factor for the realization of a low vowel to a mid vowel.

Of more interest is the asymmetrical behavior of high vowels in different syllable positions. High vowels manifest the correspondence between single segments and diphthongs in (3), but not in (4). The only difference is the relative syllable positions in which they occur. Particularly, the high vowels in (3) are the only vowels in the tight finals, hence they can be regarded as in nuclear positions under the nuclear moraic model (Shaw 1992), whereas the ones in (4) are not necessarily treated as nuclei, since they cooccur with other non-high vowels in the tight finals. The syllable positions, therefore, may also be a factor influencing the realization of vowel quality. This effect of syllable position on vowel distribution is not expected in the height-correlation hypothesis, since the featural specification for a high vowel is the same regardless of its possible syllable positions.

The data in this section clearly suggest that tone is not the only factor affecting vowel realization. Other factors, such as the presence of a coda consonant, and the syllable position of vowels, can affect vowel quality change as well. Therefore, tone-vowel interaction in Fuzhou cannot be treated simply as "feature-to-feature correlation" (i.e., certain tonal feature(s) correlate with certain vocalic feature(s)).

2.2. Tone-vowel interaction in reduplication

In Fuzhou, adjectives can be reduplicated to denote intensity. The simple case is the reduplication of monosyllabic adjectives, exemplified in (7), (8), and (9) below. The tone and vowel changes are underlined. Data are from Chen and Zheng (1990).

(7)		Adj.	Gloss		Redup. Adj.	Gloss	Alternation
	a.	lɛi^{MHM}	'sharp'	→	li^{HM}lɛi^{MHM}	'very sharp'	ɛi → i
	b.	sou^{MLM}	'colourless'	→	su^{HM}sou^{MLM}	'very colorless'	ou → u
	c.	tøyʔ^{MLM}	'resentful'	→	ty^{H}tøyʔ^{MLM}	'very resentful'	øy → y

(8)		Adj.	Gloss		Redup. Adj.	Gloss	Alternation
	a.	ŋɔ^{MLM}	'big-headed'	→	ŋo^{HM}ŋɔ^{MLM}	'very big-headed'	ɔ → o
	b.	k^{h}ɑ^{MLM}	'quick'	→	k^{h}a^{HM}k^{h}ɑ^{MLM}	'very quick'	ɑ → a

(9)		Adj.	Gloss		Redup. Adj.	Gloss	Alternation
	a.	tɔyŋ^{MHM}	'heavy'	→	tøyŋ^{HM}tɔyŋ^{MHM}	'very heavy'	ɔy → øy
	b.	pɑiŋ^{MLM}	'stubborn'	→	pɛiŋ^{HM}pɑiŋ^{MLM}	'very stubborn'	ɑi → ɛi
	c.	mɒuʔ^{MLM}	'painful'	→	mou^{H}mɒuʔ^{MLM}	'very painful'	ɒu → ou

Data in (7) (8) and (9) show that when a monosyllabic adjective reduplicates into a disyllabic adjective, both vowel and tone in the first syllable of the reduplicated form undergo changes. In particular, four kinds of change take place in the reduplications. First, a diphthong comprised of a mid vowel and a high vowel lose the mid vowel in (7). Second, a mid or a low lax vowel becomes its tensed counterpart in (8). Third, a back mid vowel becomes front in (9a). Finally, a low vowel raises to a mid vowel in (9b-c). The tonal change, on the other hand, involves tonal simplification. Namely, a complex contour tone becomes a simple contour tone.

Notice that the vocalic changes involved are the exact same patterns as the patterns of vowel distributions in monosyllabic words. That is, the vowels in the loose finals become the corresponding ones in the tight finals. However, if an original monosyllabic adjective contains a level or a simple contour tone, as the tones in the tight finals in the monosyllabic words, there is no vocalic change along with the tonal change in the reduplicated form. The data in (10) below illustrates this pattern.

(10)		Monosyl. Adj.	Gloss		Redup. Adj.	Gloss
	a.	pa^{ML}	'full'	→	pa$^{\underline{MH}}$ pa^{ML}	'very full'
	b.	puəi^{HM}	'fat'	→	puəi$^{\underline{ML}}$ puəi^{HM}	'very fat'

(10) show that once a monosyllabic adjective reduplicates into a disyllabic adjective, the tone in the first syllable of a reduplicated form changes. In (10a), ML in the original monosyllabic form becomes a MH in the first syllable of a reduplicated form, while in (10b), HM in the original morpheme changes into a ML in the reduplicated form. Unlike examples in (7) (8) and (9), the tonal change in these cases is not accompanied by a vocalic change, since these tones are simple falling contour tones (i.e. the ones in the tight finals), but not complex contour tones (i.e. the ones in the loose finals).

To sum up, three findings emerge from our investigation of Fuzhou. First, there is a cooccurrence restriction on tonal categories and vowel distributions/alternations. This cooccurrence restriction is arguably due to the light-heavy distinction of syllable types (see the discussion in the next section). The segmental differences between the two types of finals involve (i) the differences in the number of segments; (ii) the differences in feature content (i.e. the tense/lax and the high/mid distinction); (iii) the harmonic restrictions on the tight finals. Second, high vowels behave differently with respect to syllable position. They are active in alternating between monophthongs and diphthongs when they are the only vowel in a syllable, whereas, they are inert when they occur with another non-high vowel within a syllable. Third, low vowels behave differently with respect to whether a coda consonant is present or absent. They alternate along the tense/lax dimension when they are followed by either a high vowel or a coda consonant. On the other hand, they raise to mid when they are followed by both a high vowel and a coda consonant. These two types of asymmetries, i.e., the asymmetrical behavior of high vowels with respect to syllable position and the asymmetrical behavior of low vowels with respect to presence/absence of coda, suggest that tone is not the only factor that affects vowel distributions and alternations. The prosodic structure plays an important role in triggering vowel distributions and alternations. I, therefore, conclude in this section that the nature of tone-vowel interaction is <u>indirect</u>. That is, neither tone nor vowel affect each other directly. Their apparent interaction lies in the prosodic anchor that mediates between them. The phonetic correlation between intrinsic fundamental frequency and vowel height cannot furnish any explanation for these asymmetries. These new findings demand an explanation in phonological theory which will be built up in the rest of this paper.

3. The prosodic anchor hypothesis

If tone and syllable position are the factors that trigger vowel distributions and alternations in Fuzhou, it remains to be explained how these factors relate to each other. The proposed hypothesis is the following:

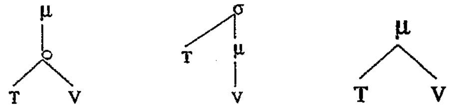
(11) Prosodic anchor hypothesis of tone-vowel interaction

a. Tone (tonal root) and vowel (vocalic root) must directly link to the same prosodic anchor;

b. One anchor per tonal root.

The hypothesis contains two conditions. Condition (11a) imposes certain restrictions on the representation of tone and vowel with respect to prosody. Among the three representations in (12), for instance, only (12c) satisfies (11a).

(12) a. b. c.



In (12a) both the tone and the vowel independently link to the same node, but not to a prosodic anchor. In (12b) they both link to prosodic anchors independently, but their prosodic anchors are different; the tone links to the syllable node, while the vowel links to the mora. In (12c) the tone and the vowel independently link to the same prosodic anchor, i.e., the mora, and so (12c) is the only valid representation in which tone and vowel may interact.

This claim is plausible for Fuzhou. Recall that high vowels alternate in the fashion of single segments versus diphthongs only when they occur in nuclear position, as in (13a ~ b). If they are in non-nuclear position, they do not alternate, as in (13c ~ d), where the high vowel is an on-glide, not a nucleus.

(13)

	I "tight"	Gloss		II "loose"	Gloss	Distribution
a.	tsi^{ML}	'only'	b.	tsei^{MLM}	'will'	i ~ ei
c.	tsieŋ^{H}	'stick'	d.	tsiɛŋ^{MLM}	'fight'	

The difference between a nuclear vowel and an on-glide with respect to tone is that the former contains moras (which are tone bearing units), whereas the latter does not. This suggests that syllable position and tone are related in that they bear a direct relationship to the prosodic anchor.

Condition (11b) imposes a one-to-one relation between a prosodic anchor and a tonal root. This implies that prosodic structure correlates with the number of tonal roots specified. To see how condition (11b) leads to a desirable consequence in Fuzhou tone-vowel interaction, it is necessary to examine the nature of the tonal distinction that triggers the vowel alternation. There have been two claims in this regard. The first is the "pitch" distinction. Yip (1980) claims that the tones in the tight finals are higher in pitch, whereas the ones in the loose finals are lower in pitch. This kind of pitch distinction is represented by the feature [±upper]. The [+upper] tones trigger vowel-raising in the tight finals. Hence, a low vowel in a loose final (14d) becomes a mid vowel in the corresponding tight final (14c).

(14)		"tight"	finals		"loose"	finals	Distribution
	a.	k^hai^{ML}	'change'	b.	$k^hɑi^{MLM}$	'approximate'	ai ~ ɑi
	c.	$teiŋ^{ML}$	'wait'	d.	$taiŋ^{MHM}$	'surname'	eiŋ ~ aiŋ

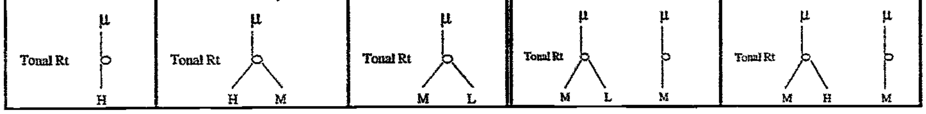
However, a low vowel does behaves differently in the same tonal environment. The pair 'ai~ ɑi' in (14a-b) shows that a low vowel alternates along the tense/lax dimension when only a high vowel follows it without a coda consonant present. This different behavior of a low vowel with respect to the presence or absence of the coda consonant is unexpected under Yip's proposal since tones in the tight finals (14a) and (14c) are [+upper] in both pairs, regardless of whether or not a coda consonant is present. If the tonal distinction in question is characterized solely in terms of pitch, it is not clear why the same tonal feature (i.e., [+upper]) would trigger different vowel alternations for low vowels in (14).

The second claim regarding the nature of the tonal difference that triggers the vowel alternations is the "shape" distinction. Chan (1985) claims that the tones in the loose finals contain a rising contour (MHM, MLM), while the ones (H, HM, ML) in the tight finals do not. The rising contour triggers vowel-lowering by increasing syllable length, assuming that the vowels in the tight finals are the underlying forms. Hence, a mid vowel [e] in the tight final (14c) becomes a low vowel [a] in the corresponding loose final (14d). The shape distinction, however, cannot explain the asymmetrical behavior of mid vowels exhibited in (4) and (6). Chan's proposal predicts that mid vowels in the tight finals should become low in the corresponding loose finals in both (4) and (6) since the tones in the loose finals in both (4) and (6) contain a rising tonal contour. However, what we find is that vowel lowering occurs only in (6) but not in (4). The mid vowels in (4) do not undergo lowering; rather, they alternate in the tense/lax dimension. What distinguishes (4) from (6) is precisely the relative position of a high vowel. Particularly, the high vowel precedes a mid vowel in (4), while it follows a mid vowel in (6). Again, the relative position of a high vowel influencing the way a mid vowel alternates is unexpected if tonal shape is the sole factor that triggers vowel lowering. Furthermore, Chan claims that the syllable is the tone bearing unit and that vowels link to the CVC skeleton. Since syllable length is represented by the number of moras, it is not clear how the rising contour as a whole unit that links to a syllable node can actually increase syllable length without referring to moraic structure. Although Chan's proposal fails to account for the different alternating behavior of the mid vowel, her insight regarding the possible correlation between syllable weight and tonal contour will be formally encoded into my proposal later.

The real distinction between tones in the two types of finals in Fuzhou, I propose, is quantity (the number of tonal roots involved) rather than quality (the feature or the shape). In particular, I claim that tones in the tight finals (H, HM, ML) consist of a single tonal root, while those in the loose finals (MHM, MLM) comprise two tonal roots. Thus, the seven tones in Fuzhou can be represented as in (15) below, assuming that moraic structure is underlying (Pulleyblank 1993):

(15)

a. Tones in the "tight" finals			b. Tones in the "loose" finals	
T1: /44/	T2: /53/, /5/	T3: /31/	T4: /213/, /23/	T5: /242/



(15) captures the cooccurrence restriction that holds between certain groups of tones and certain types of finals structurally. All tones in the tight finals contain only one tonal root, hence, one mora, even though they differ in tonal contour, whereas the tones in the loose finals contain two tonal roots, hence two moras, even though their shapes are divergent. My assumptions are that one prosodic anchor can bear a maximum of one tonal root and that each tonal root may contain a maximum of two tones. Thus, the quantitative distinction for the two groups of tones gives rise to distinct moraic structures for the two types of finals, represented within the nuclear moraic model (Shaw 1992):

(16) Distinctive moraic structures in Fuzhou
a. Monomoraic nucleus for "tight" finalsb. Bimoraic nucleus for "loose" finals

(16) suggests that the distinctive moraic structures in Fuzhou are determined by the number of tonal root(s) specified for each group of tones. It is the different moraic structures that trigger the vowel alternations. I will demonstrate in the next section how the presence of a coda consonant and the relative position of a high vowel can affect the different alternating behavior of mid and low vowels.

The hypothesis proposed in (11) crucially rests on certain theoretical claims regarding tone and moraic structure. The first claim relates to the issue of how a complex contour tone should be represented. Yip (1989) provides evidence from various Chinese dialects, such as Suzhou, Anqing, and Taishan, to argue that a simple contour tone behaves as a unit with respect to distribution and spreading. Therefore, it should be treated as a unit, namely, as a single tonal root. An extra-complex contour tone (concave or convex), on the other hand, can only occur in a domain final position, therefore, it can be treated as a simple contour tone plus a level tone. In other words, what Yip proposes is that a level or a simple contour tone consists of a single tonal root, while an extra-complex contour tone comprises two tonal roots. Condition (11b) is an extension of Yip's idea to the analysis of tone-vowel interaction.

The second theoretical claim relates to the issue of whether moras are underlyingly specified (Hayes 1989) or derived by the process of morification (McCarthy and Prince 1986). Pulleyblank (1993) provides evidence from Yoruba showing that the tonal patterns of polysyllabic words are unpredictable. Thus, tone must be underlyingly linked, and the prosodic anchor to which tone links is the mora. Therefore, moras must be underlying present.

The third theoretical claim is the nuclear moraic model. Shaw (1992, 1993) provides evidence from various languages and argues that the templates of the reduplicants in these languages need to make a reference to nucleus. Hence, Nuc(leus) must be incinerated into the moraic model as a formal prosodic constituent.

The inference from these claims gives rise to the distinct moraic structure of Fuzhou. The different prosodic structures, pre-determined by the lexically specified number of tonal roots, therefore trigger the vowel realizations and alternations in the two types of finals. The actual surface vowel corresponding pairs are derived from the interaction of constraints relevant to syllable structure in Fuzhou. Thus, the prosodic anchor hypothesis provides a unified account for all vowel distribution/alternation patterns corresponding to their tonal environment.

4. Constraints on syllabification

The distinctive moraic structures for the two types of finals in Fuzhou have been established above. It now remains to explore how syllabification that maps underlying segments to existing moraic structures can derive the correct output vocalic pairs . In this section, I discuss the constraints and their rankings that are relevant to Fuzhou vowel distributions, along with the evaluation of output candidates for each of the distribution pairs.

My assumptions are as follows. First, a syllable node (σ) may contain one or two moras (μ). A syllable head is the nuclear mora which is indicated by a Nuc node. Onset and Coda link to the syllable node directly. They are daughters of the syllable node.

Second, following Archangeli and Pulleyblank (1994), I assume the theory of Combinatorial Specification in that featural elements combine to represent segments. Fuzhou vowels i, y, u, E (e/ε), ø, O (o/ɔ), A (a/ɑ), thus can be represented as in (17):

(17) Fuzhou vowel representation

a. F-elements: +Low, +Hi, +Rd, +Front

b.

E_1	A	i_1	O	E_2	u	i_2	ø	*	*	*	y	*	*	*	*
	+LO							+LO	+LO	+LO		+LO	+LO	+LO	+LO
		+HI			+HI	+HI		+HI			+HI	+HI	+HI		+HI
			+RD		+RD		+RD		+RD		+RD	+RD		+RD	+RD
				+FRT		+FRT	+FRT			+FRT	+FRT		+FRT	+FRT	+FRT

c. Conditions: Hi/Lo: if +Hi, then not +Lo.
Lo/Rd: if +Lo, then not +Rd.
Lo/Frt: if +Lo, then not +Frt.

I propose four active vowel features in (17a), whose combinations are represented in (17b). The *s indicates the absence of featural combinations ruled out by the three grounding conditions in (17c).

Third, I assume the faithfulness families of constraints (McCarthy & Prince 1993a, b; Prince & Smolensky 1993; Pulleyblank 1994; among others) in (18):

(18) Faithfulness constraints

a. PARSE-α: an F-element (feature or node) α must be parsed into an appropriate prosodic constituent.
b. FILL: A prosodic constituent must be filled by an underlying F-element.
c. RECOVER-α: an F-element (feature or node) α that is present in an output form is also present in the input: $[\ldots \alpha \ldots]_{output} \rightarrow [\ldots \alpha \ldots]_{input}$

Forth, I assume the prominence alignment constraints proposed by Prince & Smolensky (1993) which is re-formulated in (19):

(19) Prominence Alignment

a. PROMALIGN-R: the right edge of a mora in a nucleus must be aligned with the most sonorous F-element.
b. PROMALIGN-L: the left edge of a mora in a nucleus must be aligned with the most sonorous F-element.

Last, I assume the following default interpretations: (i) an empty mora is provided with a default vowel [e] in Fuzhou, which is the unspecified vowel in (17), and (ii) underparsed features are stray-erased and receive no phonetic interpretation.

4.1 The contrast between monophthongs and diphthongs

The vowel distributions in Fuzhou exhibit a correspondence between monophthongs in the tight finals and diphthongs in the loose ones. Given these contrastive moraic structures, linking an underlying high vowel would give a single high vowel in the tight finals on the one hand and a long high vowel in the loose finals on the other hand[5]. However, the expected vowel length distinction does not show up. Instead, the segmental contrast is represented by the difference between a monophthongal high vowel and a diphthong containing that high vowel. The vowel corresponding pairs are illustrated in (20) below.

(20)		I "tight"	Gloss		II "loose"	Gloss	Distribution
	a.	piŋ^{H}	'guest'	b.	peiŋ^{MLM}	'combine'	i ~ ei
	c.	ku^{ML}	'ancient'	d.	kou^{MLM}	'old; reason'	u ~ ou
	e.	tyŋ^{HM}	'repeat'	f.	tøyŋ^{MHM}	'middle'	y ~ øy

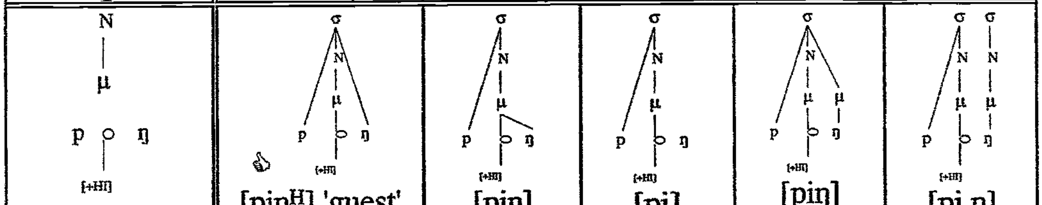
Moreover, the examples in (20) show that the component vowels of a diphthong share all vocalic features except [+HI]. The lack of the length contrast for high vowels can be captured by the constraint prohibiting a high vowel from being doubly parsed onto two moras, as stated in (21):

[5] There are two claims regarding which set of vowels should be underlying. One is to treat the high vowels in the tight finals as underlying, and the diphthongs in the loose finals as derived by the vowel-lowering rule (Chan 1985). The opposite claim is to treat the diphthongs in the loose finals as underlying and derive the high vowels in the tight finals by the vowel-raising rule (Yip 1980). My claim is that the single high vowel in the tight finals is underlying, because this is the only set of finals in which a single high vowel appears. If the diphthongs in the loose syllables were to be treated as underlying, then there would be no case in which a syllable contains a high vowel alone without other vowels. This is unusual for vowel system typologies.

(21) No Doubly Parsing [+HI] Constraint (*DOUBPARSEHI)
A F-element [+HI] cannot be parsed onto two prosodic anchors of the same type.

The constraint (21) entails that a high vowel cannot link to two moras. But it is possible for a high vowel to link to both a syllable and a mora, as in the well-known phenomenon of "glide formation"[6]. To ensure (i) that the outputs in the loose finals consist of a non-high vowel followed by a high vowel and (ii) that the two component vowels within a diphthong share all vocalic features but [+HI], as exemplified in (20g-l), the faithfulness constraint FILL-μ in (18b) and its interaction with *DOUBPARSEHI in (21) play an important role in deriving the alternating pairs. Mapping a high vowel /i/ to the monomoraic structure is relatively straightforward, and is demonstrated in the tableau (22) below. Following the notation convention, an exclamation mark ("!") signals a fatal violation; an asterisk ("*") represents a single violation; and shading indicates that constraints are not crucial in determining an optimal output.

(22) Output candidates [piŋ^H] 'guest'



Input	$Cand_1$	$Cand_2$	$Cand_3$	$Cand_4$	$Cand_5$
	[piŋ^H] 'guest'	[piŋ]	[pi]	[piŋ]	[pi.ŋ]
REC-μ				*!	*!
PARSE-RT			*!		
PROMALIGN-R		*!			
FILL-μ					

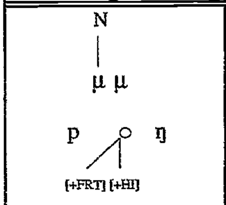
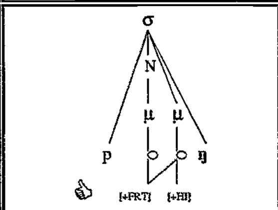
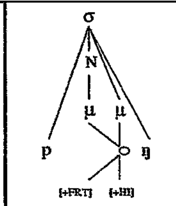
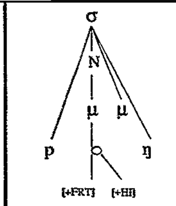
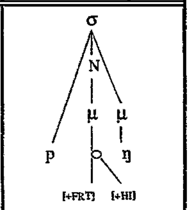
The last three candidates in (22) show that violation of REC-μ (which disallows adding moras that are not present underlyingly) or PARSE-RT is fatal, so they are out. Compare the first two candidates: $Cand_2$ violates PROMALIGN-R because the right edge of the mora does not align with the most sonorous segment [i] in the input string. Rather it aligns with the nasal velar [ŋ]. Only the first candidate violates nothing, and is therefore optimal. The two faithfulness constraints REC-μ and PARSE-RT are undominated in all cases. The candidates violate them will be out, thus will not be included in the following tableaux. Notice that the constraints *DOUBPARSEHI and FILL-μ are not crucial in this case but they will be important in deriving the diphthong [ei] in (23).

In (23), the last two candidate violates PROMALIGN-R, the higher ranked constraint. In $Cand_4$, the right mora aligns with the consonant [ŋ], but not the most sonorous vowel. In $Cand_3$, the right

[6] The representation in which a high vowel becomes a glide is assumed in the phonological literature. This representation is as follows:

mora is left unfilled, so another violation of PromAlign-R. $Cand_2$ violates *DoubParseHi by linking a high vowel /i/ to both moras, resulting in a long vowel [i:]. $Cand_1$ is the best one since it satisfies the *DoubParseHi and other constraints. The crucial ranking in this pair is: PromAlign-R, *DoubParseHi >> Fill-μ.

(23) Candidate Outputs for [peiŋ^{MLM}] 'combine'

Input	$Cand_1$	$Cand_2$	$Cand_3$	$Cand_4$
	 [peiŋ^{MLM}]'combine'	 [pi:ŋ]	 [pieŋ]	 [piŋ]
PromAlign-R			*!	*!
*DoubParseHi		*!		
Fill-μ			*	

The alternating pair **u ~ ou** can be derived in the same way as the pair **i ~ ei**. The difference is that the F-element [+Rd] is involved in the **u ~ ou** pair, but not in the **i ~ ei** pair. The sharing of all features other than [+Hi] within a diphthong can be captured by the interaction between *DoubParseHi and Fill-μ, the former prevents the left mora in a syllable from being filled by [+Hi], while the latter demands that all moras are filled by any of the vocalic features that are underlyingly specified. This conflict between constraints triggers parsing any feature other than [+Hi] to the first mora. Consequently, the roundness and frontness harmony exhibited in (20g-l) has been ensured. The corresponding pair **y ~ øy** exemplified in (20e, f, k, l) is the same as the pair **u ~ ou**. The difference is that the **y ~ øy** pair involves feature agreement in both roundness and frontness: [y] occurs with [ø], not *ey, *oy. These feature agreements within a diphthong can also be attributed to the interaction between *DoubParseHi and Fill-μ. The ranking suggested in this subsection is given in (24) below:

(24) The constraint ranking for the contrast between monophthongs and diphthong
Rec-μ, Parse-rt >> PromAlign-R >> *DoubParseHi >> Fill-μ

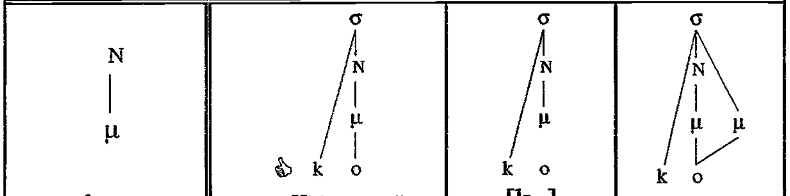
4.2. The tense/lax distinction

The investigation shows that there is a tense/lax distinction between the two types of finals when a nucleus contains a non-high vowel. That is, mid vowels surface as [e] and [o] in the tight finals, while they appear as [ɛ] and [ɔ] respectively in the corresponding loose ones. Similarly, a low vowel also varies along the tense/lax dimension. It appears as [a] in the tight finals and [ɑ] in the corresponding loose ones. Since Fuzhou does not have underlying length distinction for vowels, the **e ~ ɛ**, **o ~ ɔ** and **a ~ ɑ** pairs can be derived by linking an underlying non-high vowel to different moraic structures. Consequently, [e], [o] and [a] are short in the tight finals with a monomoraic nucleus, while [ɛ] [ɔ] and [ɑ] are long in the loose finals with a bimoraic structure.

The tableaux (25) and (12) below demonstrate how linking of an underlying non-high vowel to the different moraic structures can automatically derive the length distinction for tense/lax vowels.

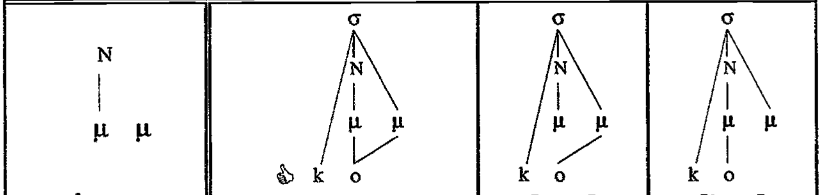
In (25), each of the last two candidates incurs a fatal violation mark since the constraints REC-μ and PARSE-RT are undominated. The first candidate wins since it does not violate anything.

(25) Output candidates for [ko^{H}] 'song'



Input	$Cand_1$	$Cand_2$	$Cand_3$
k o	☞ [ko^{H}]"song"	[ke]	[kɔ]
REC-μ			*!
PARSE-RT		*!	
FILL-μ		*	

(26) Output candidates for [kɔ^{MLM}] 'individual'



Input	$Cand_1$	$Cand_2$	$Cand_3$
k o	☞ [kɔ^{MLM}]'individual'	[keo]	[koe]
PROMALIGN-R			*!
FILL-μ		*!	*

(12) differs from (25) in that the input contains two moras which are determined by the tonal specifications. Linking the mid vowel to either mora alone violates FILL-μ, as in $Cand_2$ and $Cand_3$. In addition, $Cand_3$ also violates PROMALIGN-R, the higher ranked constraint. Only $Cand_1$ violates nothing, hence is the optimal one. Notice that the tense/lax distinction is interpreted as length distinction rather than vowel quality distinction (see Jiang-King 1995 for detailed discussions).

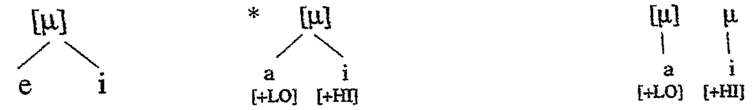
4.3. The harmonic restrictions on the tight finals

The harmonic restrictions on the tight finals, as observed in section 2, are of two types. The first type is that when a high vowel and a coda consonant (either a glottal stop or a nasal velar) are both present after a low vowel, the low vowel becomes mid, shown as in (27).

(27)		I "tight"	Gloss		II "loose"	Gloss	Distribution
	a.	teiŋ^{ML}	'wait'	b.	taiŋ^{MHM}	'chair'	eiC ~ aiC
	c.	tsouŋ^{H}	'stolen goods'	d.	tsauŋ^{MLM}	'to bury'	ouC ~ auC

The data in (27) raise a question as to why the low vowels in the loose finals become mid in the corresponding tight ones. To answer this question I propose that the presence of a coda consonant may force the high vowel to link to the mora, resulting in both a high vowel and a low vowel linked to the same mora in the "tight" finals, as in (28a); whereas they link to two different moras in the "loose" finals, as in (28b). The square brackets indicate the nuclear mora in a syllable.

(28) a. Short diphthongs in "tight" finals — b. Long diphthongs in "loose" finals



To account for the corresponding pairs **eiŋ** ~ **aiŋ** and **ouŋ** ~ **auŋ**, I propose that the condition HI/LO (i.e. if +HI, then not +LO) proposed by Archangeli and Pulleyblank (1994) applies to the domain of a mora[7], thus forcing either [+LO] or [+HI] to be unparsed in the "tight" finals. This condition can be formulated as in (29) below:

(29) HI/LO Condition extended into the domain of mora

*HI/LO$^{\mu}$: a mora cannot be filled by both [+HI] and [+LO] F-elements.

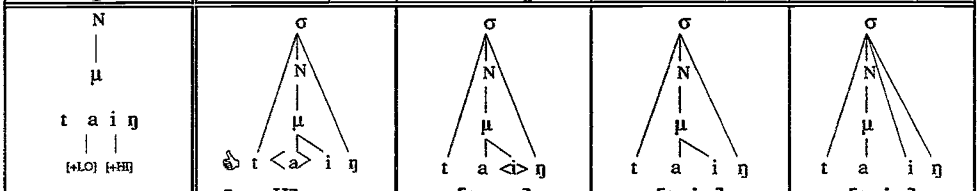
The function of (29) is to prevent the features [+HI] and [+LO] from linking to the same mora. If that happens, one of these two features must be underparsed. In terms of Optimality Theory, the constraint *HI/LO$^{\mu}$ must rank above PARSE-HI, which in turn ranks above PARSE-LO[8]. In other words, it is better to underparse [+LO] than to violate *HI/LO$^{\mu}$ and PARSE-HI. The following tableaux (30) and (31) illustrate how syllabification governed by the interaction of *HI/LO$^{\mu}$, PARSE-HI and PARSE-LO derives the alternating pair **eiŋ** ~ **aiŋ**.

---

[7] The grounding condition originally proposed by Archangeli and Pulleyblank (1994) is the path condition that prohibits two phonetically incompatible F-elements occur on a single path. For instance, the HI/LO condition prevents the feature [+HI] and [+LO] from linking to a single segmental root. The HI/LO condition used here differs from that proposed by Archangeli and Pulleyblank in that it involves two segmental root nodes. In other words, it prevents a high vowel and a low vowel from linking to the same mora rather than prevent them from linking to the same segmental root node.

[8] I am grateful to Pat Shaw and Doug Pulleyblank (p.c.) for suggesting the use of the ranking PARSE-HI >> PARSE-LO to account for this case.

(30) Candidate outputs [teiŋ^{ML}] "wait"



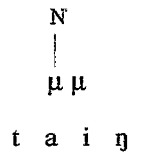
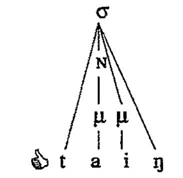
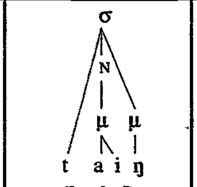
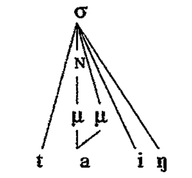
Input	$Cand_1$	$Cand_2$	$Cand_3$	$Cand_4$
	[teiŋ^{H}] 'lamp'	[taeŋ]	[taiŋ]	[taiŋ]
*COMPLEX-COD				*!
PROMALIGN-R	*	*	*	
FILL-μ				
*HI/LO$^{\mu}$			*!	
PARSE-HI		*!		
PARSE-LO	*			

The last candidate in (30) incurs a fatal violation mark since *COMPLEX-COD is undominated. The first three candidates all violate PROMALIGN-R, and satisfy FILL-μ. These two constraints, therefore, play no role in determining the optimal output. $Cand_3$ violates *HI/LO$^{\mu}$ which ranks above the rest of constraints, so is out. Compare the first two candidates, both of them satisfy *HI/LO$^{\mu}$ in different ways: underparsing [+HI] in $Cand_2$ results in the diphthong [ae], whereas underparsing [+LO] in $Cand_1$ gives rise to the diphthong [ei]. The former violates PARSE-HI, while the latter violates PARSE-LO. Since PARSE-HI ranks higher than PARSE-LO, the first candidate wins.

Notice that decomposing the PARSE family plays a crucial role in this case. Its internal ranking, namely, PARSE-RT >> PARSE-HI >> PARSE-LO, is important in deriving the correct output. Compare (23) and (30), the former contains a diphthong [ei] in a loose syllable ([peiŋ^{MLM}] 'combine') while the latter with a diphthong [ei] in a tight syllable ([teiŋ^{ML}]). The difference between them, however, is that the diphthong [ei] in a loose syllable is long since it links to two moras required by the complex contour tone, whereas the one in a tight syllable is short because it links to a single mora with only a simple tonal contour.

Tableau (31) below shows that once a input contains two moras and a string with a low vowel followed by both a high vowel and a consonant, PARSE-HI and PARSE-LO play no role in determining the optimal output. Since the syllable contains two moras, both a high vowel and a low vowel are able to be parsed to different moras. Therefore no feature conflict occurs, even though the presence of a coda consonant forces a high vowel to be linked to a mora.

(31) Output candidates for [taiŋ^{MHM}] "chair"

Input	Cand$_1$	Cand$_2$	Cand$_3$
	 [taiŋ] 'chair'	 [taiŋ]	 [tɑiŋ]
*COMPLEX-COD			*!
PROMALIGN-R	*	*	
*HI/LO$^{\mu}$		*!	
PARSE-HI			
PARSE-LO			

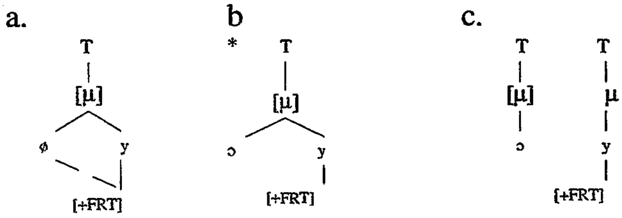
The last candidate in (31) is ruled out by *COMPLEX-COD. Both of the first two candidates violate PROMALIGN-R, this constraint cannot be used to determine the optimal output. Looking down further, we find that Cand$_2$ violates *HI/LO$^{\mu}$ while Cand$_1$ does not. The first candidate, therefore, is better than the second. The crucial ranking in this case is *COMPLEX-COD >> *HI/LO$^{\mu}$.

The second type of harmonic restrictions on the tight finals, as observed in section 2, is that both of a mid vowel and a high vowel must agree in value for the feature [FRONT]. In other words, a mid round vowel **ø** can only be followed by a high front rounded vowel **y** rather than **i** or **u** (i.e. *øu, *øi) in the tight finals. However, this restriction is relaxed in the corresponding loose finals. This alternating pair **øy ~ ɔy** is exemplified below. The data in (32) suggest that an off-glide must link to a nuclear mora no matter whether a coda consonant is present or not.

(32)		I "tight"	Gloss		II "loose"	Gloss	Alternation
	a.	tsʰøy^{ML}	'marrow'	b.	tsʰɔy^{MLM}	'break to pieces'	øy ~ ɔy
	c.	tøyŋ^{H}	'winter'	d.	tɔyŋ^{MHM}	'hole'	

Notice that the mid back vowel **ɔ** in the loose finals corresponds to the mid front rounded vowel **ø** in the tight ones. The difference between the two types of finals, as I proposed in section 2 and 3, is that the tight finals contain a monomoraic nucleus, whereas the loose finals contain a two moras. The change from a back vowel in the loose finals to a front vowel in the tight finals can be attributed to the frontness harmony which takes place within a mora. In other words, vowels within a mora must agree with the feature value for [FRONT]. This can be represented in the chart (33) and the constraint to capture this frontness agreement within a mora is given in (16):

(33) Frontness harmony within a mora



(34) Frontness Harmony within a mora (FRTHARM$^{\mu}$)

A mora may be filled by *x* and *y*, iff both *x* and *y* share the same F-element [+FRT].

(16) requires a mora to be filled by two vowels sharing the feature [+FRT], shown as (33a). It rules out the representation where only one of the two vowels have the feature [+FRT], shown as in (33b). (33c) is well-formed since two vowels are parsed onto separate moras, hence there is no FRTHARM$^{\mu}$ violation.

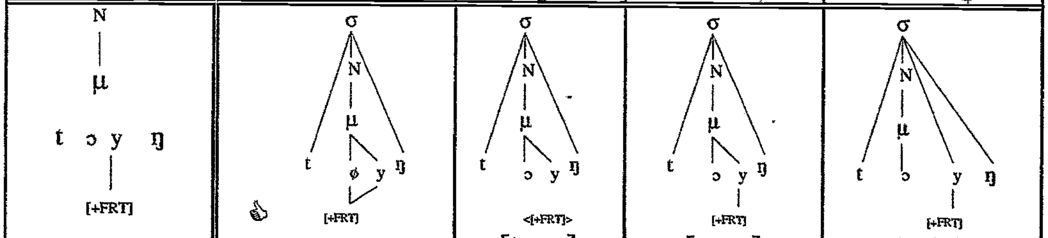
(35) Candidate Outputs for [tɔyŋ^{MHM}] 'hole'

Input	Cand$_1$	Cand$_2$	Cand$_3$
N, μ μ, t ɔ y ŋ	σ, N, μ μ, ☞ t ɔ y ŋ, [tɔyŋ^{MHM}] 'hole'	σ, N, μ μ, t ɔ y ŋ, [toyŋ]	σ, N, μ μ, t ɔ y ŋ, [tɔyŋ]
*COMPLEX-COD			*!
PROMALIGN-R	*	*	
FRTHARM$^{\mu}$		*!	

The input in (35) contains two moras and the segmental string /ɔy/. Cand$_3$ *COMPLEX-COD, an undominated constraint. Hence, Cand$_3$ is out. The first two candidates all violates PROMALIGN-R since the right mora does not align with the most sonorous vowel in the input. Therefore, PROMALIGN-R does not play a role in determining the optimal output. Looking down further, Cand$_2$ violates FRTHARM$^{\mu}$ while Cand$_1$ does not. Hence Cand$_1$ wins.

The input in (36) below contains the same segmental material as in (35). The difference is that the input in (36) has one mora but two in (35). In (36) the Frontness Harmony plays a crucial role in determining the optimal output.

(36) Output candidates for [tøyŋ^{H}] 'winter'



Input	$Cand_1$	$Cand_2$	$Cand_3$	$Cand_4$
	☞ [tøyŋ^{H}] 'winter'	[toyŋ]	[toyŋ]	[tɔiŋ]
*COMPLEX-COD				*!
PROMALIGN-R	*	*	*	
FRTHARM$^{\mu}$			*!	
PARSE-F		*!		

In (36), the last candidate incurs a fatal violation mark for the undominated constraint *COMPLEX-COD. The rest of candidates all violate PROMALIGN-R hence this constraint cannot determine the optimal output. $Cand_3$ violates FRTHARM$^{\mu}$, the next higher ranked constraint. $Cand_2$ satisfies FRTHARM$^{\mu}$ by underparsing [+FRT], whereas $Cand_1$ does so by spreading the feature [+FRT]. $Cand_1$ is better than $Cand_2$. The crucial ranking suggested by (36) is: *COMPLEX-COD >> *HI/LO$^{\mu}$ FRTHARM$^{\mu}$ >> PARSE-F

4.4. The asymmetric behavior of the high vowels

The investigation of Fuzhou tone-vowel interaction also reveals that a high vowel behaves differently with respect to its relevant syllable positions. It manifests a correspondence between a monophthong and a diphthong when it appears as a nucleus of a syllable, whereas it does not alternates at all when it precedes or follows another non-high vowel. In the latter case, the vowel distribution effect takes place in the non-high vowels along the tense-lax dimension. The asymmetric behavior of the high vowels are given in (15).

(37)

	I "tight"	Gloss		II "loose"	Gloss	Distribution
a.	ku^{ML}	'ancient'	b.	kou^{MLM}	'old; reason'	u ~ ou
c.	kua^{ML}	'few, scant'	d.	kuɑ^{MLM}	'hung up'	*u ~ ou
e.	kau^{H}	'suburbs'	f.	kɑu^{MLM}	'enough'	*u ~ ou

(15) show that when a high vowel occurs as a nuclear vowel, it surfaces as [u] in the tight finals and as [ou] in the loose ones. This corresponding pair **u ~ ou** does not show up in (15c-f) when it precedes or follows a non-high vowel [a]. The asymmetry can be solved by the constraint prominence alignment, stated in (19). That is, both edges of the mora must align with the most sonorous vowel in an input string. The tableaux (38) and (39) demonstrate how the alert behavior of a high vowel following a non-high vowel can be accounted for.

(38) Output candidates for [kau^{H}] 'suburbs'

Input	Cand$_1$	Cand$_2$	Cand$_3$	Cand$_4$
N – μ – k a u	σ – N – μ; ☞ k a u [kau^{H}]"suburbs"	σ – N – μ; k <a> u [keu]	σ – N – μ; k a<u> [kae]	σ – N – μ; k a u [kau]
PromAlign-R		*	*	*
*HI/LO$^{\mu}$				*
Parse-hi			*!	
Parse-lo		*!		

In (38), the last three candidates each incur a violation of PromAlign-R, because the right edge of the mora in the nucleus in each case does not align with the most sonorous vowel [a]. Also, parsing both [a] and [u] to the same mora, as shown in Cand$_4$, violates *HI/LO$^{\mu}$. Cand$_2$ and Cand$_3$ satisfy *HI/LO$^{\mu}$, but they violate Parse-hi and Parse-lo respectively. The first one violates nothing, therefore, is the optimal one.

(39) Output candidates for [kɑu^{MLM}] 'enough'

Input	Cand$_1$	Cand$_2$	Cand$_3$	Cand$_4$
N – μ μ – k a u	σ – N – μ μ; ☞ k a u [kɑu^{MLM}] 'enough'	σ – N – μ μ; k a u [keau]	σ – N – μ μ; k a u [kaeu]	σ – N – μ μ; k a u [kau]
PromAlign-R			*!	*!
Fill-μ		*!	*	

In (39), Cand$_3$ and Cand$_4$ each violate PromAlign-R, they are out. The first two candidates violate *DoubParseHi. The crucial constraint that chooses Cand$_1$ over Cand$_2$ is Fill-μ. The ranking suggested in this case is PromAlign-R >> *DoubParseHi >> Fill-μ.

5. Implications and concluding remarks

The hypothesis proposed has certain implications and predictions. First, it implies that tone-vowel interaction is not a direct feature-to-feature correlation, but must be mediated by the prosodic anchor. Second, it predicts that tonal change and vocalic change are potentially independent. They appear to interact when the prosodic anchor between them is affected. This prediction is borne out for disyllabic words in Fuzhou. When a word contains two finals (each syllable is a morpheme in Fuzhou, and in Mandarin Chinese in general), the first syllable undergoes tonal change, which is arguably triggered by stress. The tone sandhi effect is illustrated in (40):

(40)		Morph	Gloss	+	Morph.	Gloss	→	Disyl. Nouns	Gloss
	a.	hai^{HM}	'earthenware'		kuo^{H}	'pot	→	hai^{ML} uo^{H}	'earthenware pot'
	b.	tiaŋ^{ML}	'tripod'		p'iɛŋ^{MLM}	'sheet'	→	tiaŋ^{H} miɛŋ^{MLM}	'lid'
	c.	mi^{ML}	'rice'		tɔy^{MHM}	'bag'	→	mi^{H} lɔy^{MHM}	'rice bag'
	d.	kie^{H}	'platform'		tsɔ^{MHM}	'step'	→	kie^{HM} ʒɔ^{MHM}	'steps'

In (40a), the tone HM of the first morpheme 'earthenware' becomes a ML when it occurs as the first syllable within a disyllabic word 'earthenware pot'. In (40b), the tone ML in the first morpheme 'tripod' changes into a H tone when it appears as the first syllable within a disyllabic word 'lid'. Tone sandhi also takes place in the same position of the words in (40c-d). Of most interest are the examples in (41), in which tonal change is accompanied by a vocalic change:

(41)		Morph.	Gloss	+	Morph.	Gloss	→	Disyllabic Nouns	Gloss
	a.	kiɑŋ^{MLM}	'mirror'		suoŋ^{H}	'box'	→	kiaŋ^{H} nuoŋ^{H}	'jewelry box'
	b.	houŋ^{MHM}	'neck'		liɛŋ^{MHM}	'chain'	→	huŋ^{HM} liɛŋ^{MHM}	'necklace'

In (41a), MLM in the first morpheme 'mirror' changes into H in the disyllabic words 'jewelry box'. Meanwhile, the nuclear vowel [ɑ] becomes [a], a change in the tenseness/laxness dimension. In (41b), MHM in the first morpheme changes into HM in the disyllabic words 'necklace'. Correspondingly, the nucleus [ou] becomes [u], representing a contrast between a single segment versus a diphthong. Observe that the tones accompanied by the vocalic change in (41) are complex contour tones (MLM or MHM), whereas those in finals not undergoing vocalic change in (40), are either high level tone H or simple falling contour tones (HM, ML).

The observation from the comparison of (40) with (41) is further supported by evidence from the adjectival reduplication forms. In Fuzhou, adjectives can be reduplicated to denote intensity. The simple case is the reduplication of monosyllabic adjectives, exemplified in (10) below:

(42)		Monosyl. Adj.	Gloss		Redup. Adj.	Gloss
	a.	pa^{ML}	'full'	→	pa^{MH}pa^{ML}	'very full'
	b.	puəi^{HM}	'fat'	→	puəi^{ML}puəi^{HM}	'very fat'

The data in (10) show that once a monosyllabic adjective reduplicates into a disyllabic adjective, the tone in the first syllable of a reduplicated form changes. In (10a), ML in the original monosyllabic form becomes a MH in the first syllable of a reduplicated form, while in (10b), HM in the original morpheme changes into a ML in the reduplicated form. It is important to note that the tonal change in these cases is not accompanied by a vocalic change, since these tones are simple falling contour tones. However, if an original monosyllabic adjective contains a complex contour tone, there is a vocalic change along with the tonal change in the reduplicated form. Examples in (7), (8), and (9) in section 2 also illustrate this effect (the tone sandhi and the vocalic changes are underlined for ease of reading).

The interesting observation from the above data is that the vocalic change is not random. It follows the vowel alternating patterns exemplified in monosyllabic words, namely, the tight/loose distinction. In particular, if an adjective contains a vowel belonging to the tight finals, it changes tone only. On the other hand, if it contains a vowel belonging to the loose finals, it changes both tone and vowel. The questions, then, are: (i) why is tone sandhi sometimes accompanied by a vocalic change, and sometimes not? (ii) why is it that only the change in the complex contour tones is accompanied by a vocalic change? (iii) why is it that vowel change occurs in the disyllabic forms with loose finals, but not in the tight finals?

The answer is simple: tone sandhi and vowel change are independent to each other, they are affected by different constraints related to stress, as argued by Wright (1983) and Chan (1985). The difference between Wright's and Chan's proposals is that the former treats the vowel changes as a reduction from the loose finals to the tight ones, while the latter treats it as vowel lowering from the tight group to the loose group. I propose that the tone sandhi in the disyllabic words is triggered by the Tonal Stability Constraint (44), while the vowel alternation by the Weight-to-Stress Principle (45). Fuzhou stress in general is assigned by the End Rule Right, stated in (43) below.

(43) End Rule-R (Prince 1983)

Stress the rightmost syllable within a prosodic domain (PD). PD = Ft, PrWd, etc.

(44) Tonal Stability Constraint

a. Stressed syllables must retain their lexical tones;
b. Unstressed syllables tend to change their lexical tones.

(45) The Weight-to-Stress Principle (WSP) (Prince 1990:358)

a. If heavy, then stressed;
b. If unstressed, then light.

(43) states that only the rightmost syllable within a foot, or a prosodic word, presumably a phonological phrase as well, can bear stress. (44) permits any syllable except the rightmost one within a prosodic domain, a foot in this case, to change its tone, no matter whether the syllable is heavy or not. Tone sandhi in both tight and loose finals is subject to this constraint, which explains why the first syllable within disyllabic words always changes tone. The relevance of (45) to Fuzhou is the second clause, which requires that unstressed syllables must be light. Since Fuzhou stress is assigned by End Rule Right, any syllable other than the rightmost one within a prosodic domain must be light. In other words, only the rightmost syllable can be heavy within certain domains. This is indeed the case in Fuzhou. The data above show that only the vowels with complex contour tones undergo vowel change, since these syllables contain bimoraic nuclei, therefore they are heavy. However, the vowels in a syllable with a simple contour tone do not change, since these syllables contain only a monomoraic nuclei, therefore they are light, and are not subject to the WSP in (45b). Thus, the hypothesis proposed in Section 3 correctly predicts the stress effect on the two independent processes of tone sandhi and vowel change.

The research presented here advances our understanding of the nature of tone-vowel interaction. The argumentation furnishes further support for certain theoretical claims regarding tonal phonology and syllable structure. First, it argues for the claim that the mora is the tone-bearing unit. If tone links to the syllable, there would be no correlation between tones and moraic structure; hence, the vowel alternations discussed cannot be captured by different moraic structures. On the other hand, if tone were link to the root node, the fact that the loss of tone does not affect the non-tonal features in the sandhi forms would not be expected. Second, by characterizing the complex tones as involving two tonal root nodes which determine the nuclear moraic structure, the vowel alternations (with respect to the tonal condition) are accounted for by associating a set of segments to the different moraic structures. Moreover, it provides a testable base for further investigation of other languages in which tone-vowel interaction is found.

References

Archangeli D. and D. Pulleyblank (1989) "Yoruba Vowel Harmony," *Linguistic Inquiry* 20, 173-217.

Archangeli, D. and D. Pulleyblank (1994) *Grounded Phonology*, MIT Press, Cambridge, MA.

Black, J. W. (1949) "Natural Frequency, Duration, and Intensity of Vowels in Readings," *Journal of Speech and Hearing Disorders* 14, 216-221.

Chan, M. (1985) *Fuzhou Phonology: A Non-Linear Analysis of Tone and Stress*, Doctoral dissertation, University of Washington.

Chen, Y. C. and Y. D. Zheng (1990) "Fuzhou hua xingrongci chongdesi de yinbian fangsi jiqi leixing (The Reduplication Patterns and Classes of Adjectives in Fuzhou)," *Zhongguo Yuwen* 5, 362-370.

Cheung, S. H. N. (1973) "Tonal Redistribution in the Omei Dialect," paper presented at the 6th International Sino-Tibetan Conference, San Diego.

Chuang, C. K. and Wang, W. S. Y. (1976) "Influence of Vowel Height, Intensity, and Temporal Order on Pitch Perception," *Journal of the Acoustical Society of America* 60(1),(A), LL13.

Di Cristo, A. and Chafcouloff, M. (1976) "An Acoustic Investigation of Micro prosodic Effects in French Vowels," Paper presented at the 14th Conference on Acoustics, High Tatra, Czechoslovakia.

Ewan, W. G. (1975) "Explaining the Intrinsic Pitch of Vowels," 5th Calif. Lin. Ass. Conf., San Jose.

Fischer-Jørgensen, E. (1990) "Intrinsic F_0 in Tense and Lax Vowels with Special Reference to German," *Phonetica* 47, 99-140.

Fromkin, V. A. (ed.) (1978) *Tone: a linguistic survey*, Academic Press, New York.

Gandour, J. (1977) "On the Interaction between Tone and Vowel Length: Evidence from Thai dialects," *Phonetica* 34, 54-65.

Gandour, J. (1978) "The Perception of Tone," in V. Fromkin (ed) *Tone: a linguistic survey*, Academic Press, New York.

Halle, M., S. Ambler, & M. Callow (1971) "A Note on Laryngeal Features," *Quarterly Progress Report* 101, Research Laboratory of Electronics, MIT, Cambridge, Massachusetts.

Hayes, B. (1989) "Compensatory Lengthening in Moraic Phonology," *Linguistic Inquiry* 20, 253-307.

Hombert, J. M. (1976) "Development of Tones from Vowel Height," UCLA *Working Papers in Linguistics* 33, 55-66.

House, A. S. and Fairbanks, G. (1953) "The Influence of Consonant Environment Upon the Secondary Acoustical Characteristics of Vowels," *Journal of the Acoustical Society of America* 25, 105-11?)

Howie, J. M. (1976) *Acoustical Studies of Mandarin Vowels and Tones*, Cambridge University Press, Cambridge.

Hyman, L. M. (1985) *A Theory of Phonological Weight*, Foris, Dordrecht.

Hyman, L. M. and D. Pulleyblank (1988) "On Feature Copying: Parameters of Tone Rules," in L. M. Hyman and C. N. Li (ed.), *Language, Speech and Mind*, Routledge, London.

Iivonen, A. K. (1987) "Regional Differences in the Relation of Standard German Vowels," in Proc. 11th Int. Congr. Phon. Sci., Tallinn, Academy of Sciences of the Estonian SSR.

Jiang-King, P. (1994) "An Optimality Account of Fuzhou Diphthongisation," *CLA Proceedings*.

Jiang-King, P. (1995) Tone-Vowel Interaction in Optimality Theory, Doctoral dissertation in progress, University of British Columbia, Vancouver.
Kim, C. W. (1968) "Review of Lieberman 1967," *Language* 44, 830-842.
Lehiste, I. and Peterson, G. E. (1961) "Some Basic Considerations in the Analysis of Intonation," *Journal of the Acoustical Society of America* 33, 419-425.
Liang, Y. (1982) "Fuzhou fangyan de 'qiejiaoci' (The "cutting foot words" in Fuzhou)," *Fangyan* 1, 37-46.
Liang, Y. (1983) "Fuzhou fangyan chongdieshi mingci (The nominal reduplications in Fuzhou)," *Zhonggou Yuwen* 3, 177-184.
Liang, Y. (1984) "Fuzhou hua de wen bai yidu (The Literary and Colloquial distinctions in Fuzhou)," *Zhongguo Yuwen* 6, 434-440.
Liang, Y. (1990) "Fuzhou hua de 'GEI' (The verb "to give" in Fuzhou)," *Zhongguo Yuwen* 4, 28-283.
Maddieson, I. (1976) "The Intrinsic Pitch of Vowels and Tones in Foochow," UCLA *Working Papers in Linguistics* 33, 191-202.
McCarthy, J. (1993) "The Parallel Advantage: Containment, Consistency, and Alignment," handout from the Rutgers Optimality Workshop I.
McCarthy, J. and A. Prince (1986) "Prosodic Morphology," ms. University of Massachusetts and Brandeis University.
McCarthy, J. and A. Prince (1993a) *Prosodic Morphology I*, ms., University of Massachusetts, Amherst, and Rutgers University.
McCarthy, J. and A. Prince (1993b) *Generalized Alignment*, ms., University of Massachusetts, Amherst, and Rutgers University.
Newman, P. (1975) "The Non-correlation of Tone and Vowel Height in Hausa," *Studies n African Linguistics* 6, 207-213.
Peng, L.(1992) *A Unified Theory of Tone and Voice*, Doctoral dissertation, University of Arizona.
Petersen, N. R. (1976) "Intrinsic Fundamental Frequency of Danish Vowels," *Annual report of the Institute of Phonetics*, University of Copenhagen, 1-27.
Peterson, G. E. and H. L. Barney (1952) "Control Methods Used in a Study of the vowels," *Journal of the Acoustical Society of America* 24, 175-184.
Pilzczkowa-Chodak, N. (1972) "Tone-Vowel Height Correlation and Tone Assignment in the Patterns of Verb and Noun Plurals in Hausa," *Studies in African Linguistics*, 3:3, 99-422.
Pilzczkowa-Chodak, N. (1975) "On the Correlation of Tone and Vowel Height in Hausa: reply to Newman," *Studies in African Linguistics*, 6:3, 399-422.
Prince, A. (1983) "Relating to the Grid," *Linguistic Inquiry* 14, 19-100.
Prince, A. (1990) "Quantitative Consequences of Rhythmic Organization," Proceedings of LS 26, vol. 2, *The parasession on the syllable in phonetics and phonology*.
Prince, A. and P. Smolensky (1993) *Optimality Theory: Constraint Interaction in Generative Grammar*, ms., Rutgers University, and University of Colorado, Boulder.
Pulleyblank, D. (1993) "Underlying Mora Structure," *Linguistic Inquiry*.
Pulleyblank, D. (1994) "Vowel Harmony and Optimality Theory," Proceedings of the workshop on phonology, University of Coimbra, Portugal, September 1993.
Reinholt Petersen, N. (1978) "Intrinsic Fundamental Frequency of Danish Vowels," *Journal of Phonetics* 6, 177-189.
Reinholt Petersen, N. (1986) "Perceptual Compensation for Segmentally Conditioned Fundamental Frequency Perturbation," *Phonetica* 43, 31-42.
Sawusch, J. R. and J. S. Tsay (1994) "The interaction of F_0 and F_1 in tonal and non-tonal languages," Poster at *Acoustic Society of America annual meeting*, June 1994.
Sundberg, J. (1969) "Articulatory Differences between Spoken and Sung Vowels in Singers," Quarterly Progress Status Report, Speech Transm. Lab., R. Inst. Technol. Stockh., No. 1, 33-42.
Shaw, P. (1992) "Templatic Evidence for the Syllable Nucleus," *Proceedings of NELS* 23.

Shaw, P. (1993) "The Prosodic Constituency of Minor Syllables," *Proceedings of WCCFL* 12.
Valdman, A. (1972) (ed.) *Papers in Linguistics and Phonetics to the Memory of Pierre Delattre*, Mouton, The Hague.
Wang, S. Y. (1968) "The many uses of F_0," *Project on Linguistic Analysis Reports*, 2nd series 8: w1-w35. (Reprinted in: Valdman (ed.). 1972. 487-503.)
Wang, T.-C. (1969) *Phonetic Research on The Foochow Dialect*, Tunghai University, published with the assistance of the Sun Yat-Sen Cultural Foundation, Taiwan.
Wright, M. (1983) *A Metrical Approach to Tone Sandhi in Chinese Dialects*, Doctoral dissertation, University of Massachusetts.
Yip, M. (1980) *The Tonal Phonology of Chinese*, Doctoral dissertation, MIT.
Yip, M. (1989) "Contour Tones," *Phonology* 6, 149-174.
Yue, O.-K. (1976) "Interplay of Vocalic Segments and Tones in The Yueh Dialects," In *Genetic Relationship, Diffusion and Typological Similarities of East and Southeast Asian Languages*, Papers for the 1st Japan-US Joint Seminar on East and Southeast Asian Linguistics, Japanese Society for The Promotion of Science.
Zec. D. (1988) *Sonority Constraints on Prosodic Structure*, Doctoral dissertation, Stanford University.
Zee, E. and J. M. Hombert (1976) "Intensity and Duration as Correlates of F_0," *Journal of the Acoustic Society of America* 60, S44.
Zee, E. (1978) "Duration and Intensity as Correlates of F_0," *Journal of Phonetics* 6, 213-220.
Zee, E. (1980) "Tone and Vowel Quality," *Journal of Phonetics* 8, 247-258.
Zheng, Y. (1983) "Fuzhou fangyan danyin dongci chongdieshi (The reduplication of the monosyllabic verbs in Fuzhou)," *Zhonggou Yuwen* 130-39.
Zheng, Y. (1988) "Fuzhou fangyan xingrongci chongdieshi (The adjective reduplications in Fuzhou)," *Fangyan* 4,301-311.