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**Contrasts in Japanese: a contribution to feature geometry**

S.-Y. Kuroda  
UCSD

CORRECTIONS AND ADDITIONS AFTER MS WAS SENT TO TORONTO ARE IN RED.

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## 1. Introduction

In her paper on the issue of sonorants, Rice (1993: 309) introduces HER main theme by comparing Japanese and Kikuyu with respect to the relation between the features [voice] and [sonorant]: "In Japanese as described by Itô & Mester...obstruents and sonorants do not form a natural class with respect to the feature [voice].... In contrast ... in Kikuyu both voiced obstruents and sonorants count as voiced ...."

- (1) Rice (1993)
- |          |                                     |
|----------|-------------------------------------|
| Japanese | {voiced obstruents} ::: {sonorants} |
| Kikuyu   | {voiced obstruents, sonorants}      |

Here, "sonorants" includes "nasals." However, with respect to the problem of the relation between voiced obstruents and sonorants, the situation IN Japanese is not as straightforward as Itô and Mester's description might suggest. There Are three phenomena in Japanese phonology that relate to this issue:

- Sequential voicing in compound formation known as *rendaku*..
- A progressive voicing assimilation observed in the verb paradigm.
- A regressive process, which at first glance looks like a leftward nasalization triggered by a voiced segment.

This last process is exemplified in certain mimetic adverb constructions, as will be shown below.

These three phenomena group sonorants differently with respect to voiced obstruents:

- (2)
- |                     |   |
|---------------------|---|
| Rendaku/Lyman's Law | {voiced obstruents} ::: {nasals, liquids, glides} |
| The verb paradigm   | {voiced obstruents, nasals} ::: {liquids, glides} |
| Mimetic adverbs     | {voiced obstruents, nasals, glides}               |
|                     | [no examples with liquids]                        |

These phenomena were described in the early days of Japanese generative phonology in the 1960's

and in more recent works in the 1980s and 90s.<sup>1</sup> However, I have doubts about some aspects of recent treatments of these phenomena, and wish to resurrect the spirit of the earlier treatment, recasting it in the framework of feature geometry, which was not available in the 60's. In this respect, the present study is an attempt to defend an old description and bring it abreast with theoretical advancement in phonology. In doing so, however, I have come to realize, that the current conception of feature geometry does not suffice to achieve this goal in an insightful manner and have been led to the idea of a feature geometry more in conformity with the physical reality underlying phonology. This paper is a small beginning of explorations into a feature geometry structurally designed to be homomorphic to the aerodynamic architecture of the articulatory organs.

## 2. The difference between Itô & Mester's and my account

Itô and Mester maintain that the rendaku voicing and progressive voicing observed in the verbal paradigm are manifestations of the same voicing process. However, nasals behave differently in these two phenomena. Let us first consider rendaku. Rendaku is commonly described as the voicing of an initial voiceless obstruent of the second component of a compound word. This is exemplified in (3), with the affected voiced segments boldfaced:<sup>2</sup>

(3)	The rendaku voicing			
	susi	'sushi'	maki- <b>z</b> usi	'rolled-sushi'
	kami	'paper'	ori- <b>g</b> ami	'origami' (folding-paper)
	hasi	'chopstick'	wari- <b>b</b> asi	'split-chopsticks'

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<sup>1</sup>Kuroda (1960, 1965), McCawley (1965, 1968) for the former and Itô's and Itô and Mester's works cited below for the latter.

<sup>2</sup>Citation forms of Japanese examples are given largely following the conventions in Martin (1975:15). Phonetic representations at various levels of derivation are commonly, but not always, given between two slashes. At the phonetic level the manner and the place of articulation are not invariant under the rendaku voicing alternation due to allophonic and systematic phonemic variations. In particular, /b/ alternates with /h/ on the surface. See, for example, Itô & Mester (1986:52f) for details.

Rendaku voicing, however, is not observed if the second component contains a non-initial voiced obstruent. This constraint is known as Lyman's Law:

(4) Lyman's Law: a constraint on rendaku

kaze	'wind'	kami-kaze	(*kami-gaze)	'divine wind'
kotoba	'speech'	onna-kotoba	(*onna-gotoba)	'women's speech'

We must note, however, that liquids and glides, as well as nasals, though they are phonetically voiced, do *not* block rendaku voicing:

(5) Liquids, glides as well as nasals do not block rendaku voicing

kokoro	'heart'	onna-gokoro	'women's feeling'
kayu	'rice porridge'	asa-gayu	'breakfast porridge'
tanuki	'raccoon dog'	oo-danuki	'big raccoon dog'

Next, let us observe the second phenomenon mentioned above, progressive assimilation in the verb paradigm. A stem final consonant triggers voicing assimilation of /t/ in three suffixes /ta~da/ 'past/perfect', /te~de/ 'gerund' and /tari~dari/ 'representative'.<sup>3</sup> This process of assimilation is shown in the minimal pair given in (6), although a later process of lenition affects the velars, /k/ and /g/, and makes the effect of the voicing assimilation opaque. In (7), the stem-final /b/ gets voiced and then nasalized due to a general constraint, Coda Nasalization, to which I will return later.

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<sup>3</sup>For the REPRESENTATIVE *tari*, see Martin (1975:566).

## Voicing after verb stems

- (6) kak-u 'write' kak-ta (> kai-ta) 'wrote'  
 kag-u 'smell' kag-ta > kag-da (> kai-da) 'smelled'.  
 (7) tob-u 'fly, jump' tob-ta > tob-da (> ton-da) 'flew, jumped'<sup>4</sup>

In this process, nasals are grouped together with voiced obstruents and voice the following /t/:

- (8) yom-u 'read' yom-ta > yom-da (> yon-da) 'read' (past)

However, glides and liquids as well as vowels do not cause this voicing assimilation:

- (9) kar-u 'trim' kar-ta (>kat-ta) 'trimmed'  
 kaw-u > ka-u 'buy' kaw-ta (>kat-ta) 'bought'  
 (10) tabe-ru 'eat' tabe-ta 'ate'  
 oki-ru 'wake up' oki-ta 'woke up'

To sum up, nasals behave differently for the two phenomena we considered, rendaku voicing on the one hand and voicing assimilation in the verb paradigm on the other.<sup>5</sup> However, Itô and Mester

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<sup>4</sup>The nasalization observed in (7) is due to Coda Nasalization, which nasalizes a voiced consonant in syllable coda position; see (29) below. If Coda Nasalization applies before the voicing of the suffix initial /t/, then it would also apply to /kag-ta/ and yield \*/kan-da/, unless we change the stem-final /g/ to /i/ (or insert /i/ between /g/ and /t/) before Coda Nasalization and complicate the voicing rule considerably, an unwelcome consequence,

<sup>5</sup>Besides the verb paradigm discussed above, we also observe the effect of Progressive Voicing triggered by prefix-final nasals in verbs with the implication of intense action such as the following:

Prefixed intense action verbs	
bun-toru > bun-doru	'rob'
hum-sibaru > hun-zibaru	'fasten violently'

Itô & Mester (1996:24) cite *bun-doru* as an example of *verbal root compounding*, analyzing it as derived from *but-toru* 'strike+take'. I follow here the analysis given in *Kojien* of prefixed verbs. My view is that the data cited as examples of VERBAL ROOT COMPOUNDS in the recent literature (or SPECIAL CONSONANT-BASE VERB COMPOUNDS (Martin 1952: 89)) divide into compound verbs and prefixed verbs, though drawing a boundary between them raises delicate questions, THE not unfamiliar tension one faces when one has to choose between analysis and etymology. A full-fledged discussion of this topic is beyond the scope of this paper.

take both of these phenomena as manifestations of a general process of assimilation that is triggered by voiced obstruents, excluding liquids, glides and nasals.<sup>6</sup> Itô and Mester deal with the voicing observed after a nasal in the past/perfect form like *yon-da* in (8) by means of another separate process of voicing: Post-Nasal Voicing:

(11) C -> [+voice] / [+nasal]\_\_\_ (Itô & Mester 1986: 69, (42))

Nasals thus can be taken out of the triggers of voicing assimilation. This is why Japanese, in opposition to Kikuyu, is characterized as in (1) by Rice, based on Itô and Mester.

However, Post Nasal Voicing is problematic. It is descriptively equivalent to the constraint Itô and Mester call \*NT in later work:

(12) \*NT (Itô & Mester 1995)

A nasal may not be followed by a voiceless obstruent.

I agree with Rice (1997) and Vance (to appear) that \*NT does not hold.<sup>7</sup> Some counterexamples:

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<sup>6</sup>Itô & Mester (1986:57) assume that "rendaku is essentially a morphological process introducing a linking morpheme in a certain morphological context," i.e., between two components of a compound word. Voicing spreads from this inserted linking morpheme to the initial segment of the second component.

<sup>7</sup>The voicing of the suffix-initial /t/ observed in the verbal morphology we are concerned with is an innovation that took place in Middle Japanese, when the original strictly open syllable structure of Old Japanese started to collapse. Before this innovation, the verb stem took the /i/-ending form (the *renyo*-form, in the traditional terminology) before the relevant suffixes. For example, we have the following historical derivation: *tobi-te* > *ton-de* 'fly'. The issue of \*NT does not arise for Old Japanese, as there was no closed syllable in the language. One might be able to identify an intermediate stage between Old and Modern Japanese where arguably \*NT held in the Yamato Stratum of the vocabulary. But the invasion of words of the Sino-Japanese origin into the common usage through time has made it impossible to clearly demarcate the division in Modern Japanese between the native and the Sino-Japanese stratum along with the historical origin. The existence of a Sino-Japanese stratum is arguably real for morphological reasons, but such a stratum can hardly justify a Yamato stratum with the phonological constraint \*NT. Besides, violations of open syllable structure and \*NT have also arisen within the part of the etymologically native part of the vocabulary.

Itô & Mester (1986:69) originally introduced \*NT as a constraint for the Yamato stratum, but they later dissociated it from such a sublexicon stratum in the constraint domain model of lexical

(13) intiki 'trickery'; anta 'you'; kenka 'quarrel'; nantomo '(not) at all'

If the constraint \*NT is out of place, we cannot have Post-Nasal voicing. Thus, I conclude that we have to formulate a progressive assimilation rule which includes nasals as triggers.

There is an apparent contradiction in what I have said. On the one hand, I am claiming that we cannot have Post Nasal Voicing. On the other hand, I maintain that nasals trigger Progressive Voicing Assimilation. But there is a crucial difference in these two rules. Post Nasal Voicing, as intended by Itô and Mester, is a general rule with a phonotactic consequence. In contrast, Progressive Assimilation in the verbal paradigm is restricted to cross-morphemic context, or, more specifically, between verb stems and affixes.<sup>8</sup>

### 3. Feature geometry

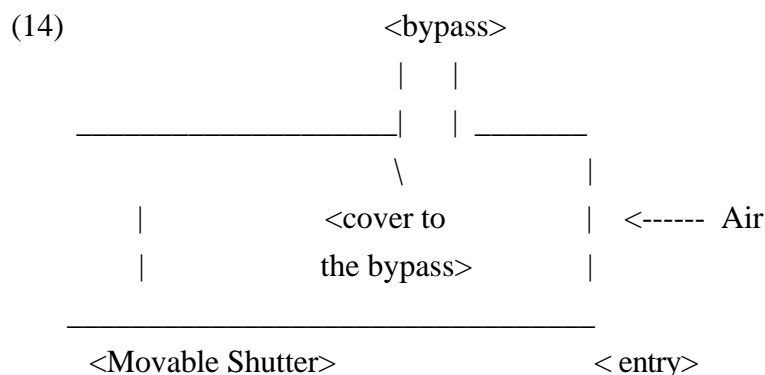
#### 3.1. Feature trees

At this point, let us shift our attention to feature geometry. My vision is to construct a feature geometry that is faithful to the aerodynamic design of the articulatory organ. The articulatory organ is schematized in the figure in (14)

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organization (Itô & Mester 1995; the constraint domain of \*NT contains, but is not limited to, the [Yamato] class. (ibid:823) The domain is specific for \*NT and those items that violate it do not count as [Yamato].

<sup>8</sup>Not all morphemes that attach directly to verb stems are affected by Progressive Voicing Assimilation; in fact, only three suffixes are: *ta*, *te*, *tari*. For example, the causative verb stem *sase* directly attaches to verb stems, but we do not get \*/yonzase/ < /yom+/sase/ for 'make read.' Rather, the initial obstruent /s/ is elided after a stem-final consonant and we have /yom-ase/. It would seem fair to assume that there are some morpho-syntactic reasons why the three suffixes *ta*, *te* and *tari*, but not other suffixes, undergo voicing assimilation. Progressive Voicing Assimilation must specify a proper morpho-syntactic environment for its application, but I leave this matter aside.

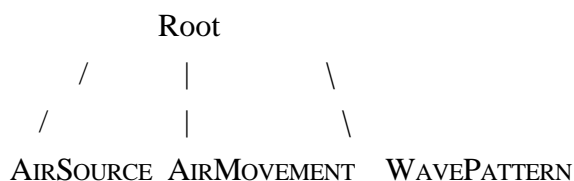


The device consists of a main air path (the oral cavity), a bypass (the nasal cavity) and a movable shutter (the lips and tongue). Three parameters in this design are relevant:

- The states of the entry to the main air path and the cover to the bypass. This parameter determines the quality of the AIRSOURCE.
- The degree and manner in which the shutter is opened/closed. This parameter determines the quality of AIRMOVEMENT
- The positioning of the shutter. This last parameter determines the quality of the WavePattern.

The feature geometry I propose, Aerodynamic Geometry (ADG) is structurally homomorphic to this aerodynamic design of the articulatory organ. We have three nodes corresponding to these parameters immediately dominated by Root, as shown in (15):

(15) Tree diagram for ADG: the top level.

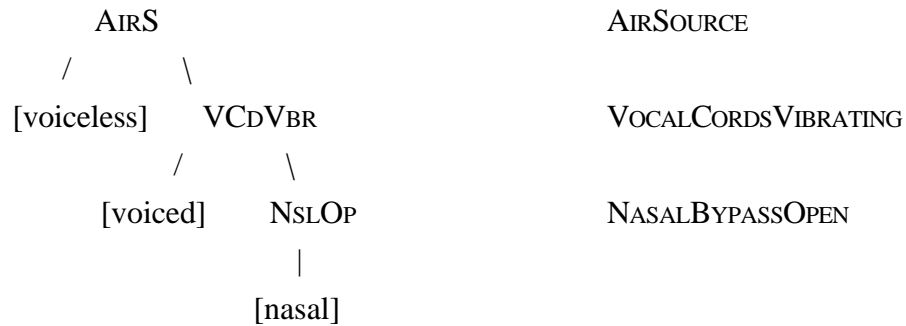


For the topic in Japanese phonology we are now concerned with, voicing and nasalization, what matters is the branch AIRSOURCE. AIRMOVEMENT mostly concerns manner-of-articulation features,

and I will return to it later. WavePattern largely concerns place-of-articulation features.

I assume that AIRSOURCE has the structure represented by the tree in (16)

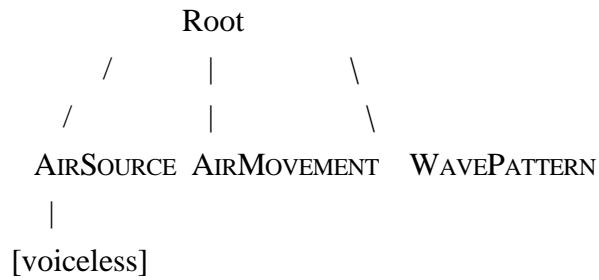
(16) Tree diagram for geometry under AIRSOURCE



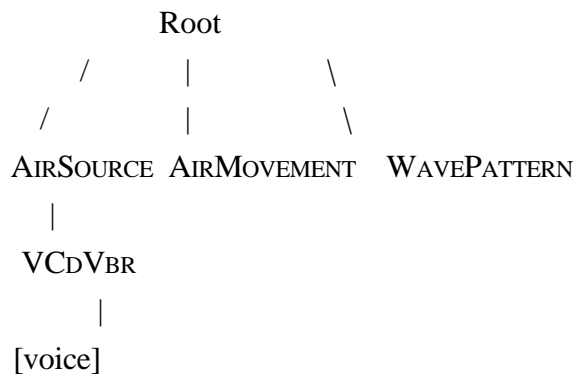
The phonetic/phonological features [voiceless], [voiced] and [nasal] are by definition default values of the three nodes, AIRSOURCE, VOCALCORDSVIBRATING and NASALBYPASSOPEN, respectively.

All feature trees for phonological segments are, so to speak, embedded in this tree diagram in (16). We can see by inspection that three trees (17a-c) are embedded in (16). They are the relevant part of the feature trees for the segments /t/, /d/ and /n/.

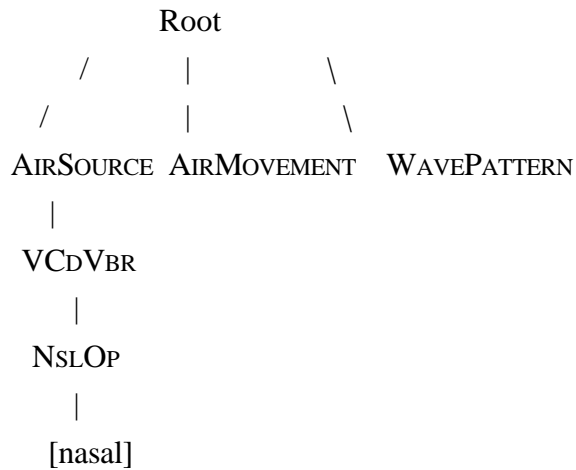
(17)a Feature tree for /t/



b Feature tree for /d/



c Feature tree for /n/



### 3.2. Redundancy and Underspecification

In this geometry the phonetic dependency of nasality on voicing (that is, the fact that nasal sounds are acoustically voiced) is NOT captured by making [voiced] a redundant feature of nasal sounds.

Rather, the significance of the dependency of nasality on voicing is incorporated in the design of the geometry. The node VCDVBR signifies the vibrating vocal cords, an articulatory characteristic shared by non-nasal voiced sounds and nasal sounds. In this geometry, feature called [voiced] signifies "vibrating vocal cords without the nasal bypass open". This is a characteristic of non-nasal voiced sounds.<sup>9</sup> The phonetic substance of the feature commonly called [voiced] is assigned to the node VCDVBR, rather than to the phonological/phonetic feature here labeled [voiced].

I introduce a familiar type of convention for the application of feature geometry.

- (18) Underspecification convention: Default values are left unspecified in the underlying phonological representations.

Under this Convention, the relevant part of the feature trees for /t/, /d/, /n/ are given in (19):

- (19)a /t/ = /...[AIRS] .../  
 b /d/ = /...[AIRS] .../  
     |  
     [VCDVBR]  
 c /n/ = /...[AIRS] .../  
     |  
     [VCDVBR]  
     |  
     [NSLOP]

## 4. Feature geometry and Progressive Voicing Assimilation

### 4.1. Preliminary observation: A linear account

Given this feature geometry and the above conventions, let us consider how the process of Progressive Voicing Assimilation in the verb paradigm can be accounted for. Observe that voicing and nasalization are phonologically redundant predictable features for the liquid /r/ and glide /w/ (as

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<sup>9</sup> As a matter of fact, the idea to group non-nasal voiced sounds and nasal sounds under one category has already been explored by Nasukawa (1998) in the framework of Element Theory. We see here how a particular design of feature geometry can implement the same idea as Nasukawa's.

well as /y/) and for the vowels. For these sounds no contrast is relevant under the node AirS, and hence nodes under AirS must be left unspecified. On the other hand, the nasals /n/ and /m/ contrast with the non-nasals /d/ and /b/ under the node VCdVbr; hence, the nasals, in opposition to /r/, /w/ and vowels, share the feature VCdVBR with voiced obstruents in the underlying representations. Then, if we formulate PROGRESSIVE VOICING ASSIMILATION in terms of VCdVBR, the specified environment of the rule includes voiced obstruents and nasals but excludes /r/ and /w/ as well as the vowels. The initial segment for the suffix /ta~da/ is underlyingly unspecified under AirS. In linear phonology, we can formulate the rule as in (20)

- (20) Progressive VOICING ASSIMILATION in linear phonology  
 [ ] -> VCdVBR / [VCdVBR]\_\_\_

By rule (20), the blank segment [ ] gets the node VCdVBR inserted and eventually gets its default value [voiced]. The segment /t/ is converted to /d/.

#### 4.2. A non-linear account with ADG: Horizontal copying

It might seem that we can put (20) directly in the autosegmental formulation as in (21): VCdVBR spreads to the right.

- (21) \*Progressive Voicing Assimilation in autosegmental phonology (incorrect form)



However, this rule gives the right result only when the stem-final consonant is a voiced obstruent and not when it is a nasal, because in the latter case the suffix initial /t/ would be nasalized. The

following examples illustrate this situation.

(22) Inputs to (21):

tob-ta 'flew'	yom-ta 'read' (past)
/b/    /t/	/m/    /d/
AIRS   AIRS	AIRS    AIRS
VCdVBR	VCdVBR
	NSLOP

(23) Outputs by (21)

OK	Undesired
tob-da (> tonda)	*yom-na (>*yonna)
/b/    /t/	/m/    /n/
AIRS   AIRS	AIRS    AIRS
^	^
/	/
/	/
VCdVBR	VCdVBR
	NSLOP

The operation we need here is not spreading. Rather, only the symbol VCdVBR must be copied to the right after any nodes dominated by it are delinked. This is the operation called COPYING introduced in Rice & Avery (1991: 106). Let us then represent this horizontal operation as follows:

(24) PROGRESSIVE VOICING ASSIMILATION

x	y
AIRS	AIRS
VCdVBR	->VCdVBR

The application of this rule can be illustrated as follows. We have the underlying representations for *tonda* 'flew' and *yonda* 'read':

(25)	Inputs to ( 24):		
	tob-ta		yom-ta
	/b/.	/t/	/m/    /t/
	AIRS	AIRS	AIRS    AIRS
	VCdVBR		VCdVBR
			NSLOP

(24) applied to these forms yields

(26)	Outputs by (24)		
	tob-da (> tonda)		yom-da (>yonda)
	/b/.	/d/	/m/    /d/
	AIRS	AIRS	AIRS    AIRS
	VCdVBR ->	VCdVBR	VCdVBR ->VCdVBR
			NSLOP

## 5. Regressive voicing assimilation

I will now discuss a regressive process. A principal data for this process comes from a particular form of mimetic adverbs, which I call *ri*-extended mimetic adverbs. We can assume that the *ri*-extended forms are derived from two mora mimetic stems  $C_1V_1C_2V_2$ . These stems form mimetic adverbs either by reduplication, as shown in the first column of (28), or by the following morphological rule that inserts an underspecified consonantal segment C between the two stem moras.:

(27) Morphological rule for *ri*-extended mimetic adverbs

$C_1V_1C_2V_2 \rightarrow C_1V_1CC_2V_2ri$

where C is an unspecified consonantal segment

The phonetic forms of *ri*-extended mimetic adverbs are given in the second column of the table in

(28).

(28) The *ri*-extended mimetic adverbs:

Reduplicated forms	<i>ri</i> -extended intensive forms		
$C_1V_1C_2V_2-C_1V_1C_2V_2$	$C_1V_1CC_2V_2-ri$		
hakahaki	hakkiri		'clearly'
yutayuta	yuttari		'leisurely'
boyaboya	boŷyari	(*boyyari)	'absent-mindedly'
yawayawa	yaŷwari	(*yawwari)	'softly'
syoboshobo	syombori	(*syobbori)	'discouragedly'
sugasuga	sungari	(*suggari)	'nicely slender'

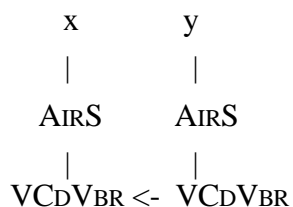
The point of interest regarding the data given in (28) is this: if  $C_2$  is voiced (including glides /y/ and /w/) the inserted unspecified consonantal segment /C/ gets nasalized. It appears that there is a regressive nasalization triggered by voicing, but such a process cannot be understood as a process of assimilation, and cannot be easily formalized in terms of feature geometry. However, as a matter of fact, this process of nasalization can be factored out into two processes, a regressive voicing assimilation and coda nasalization. In Japanese, voiced codas are necessarily nasalized, that is, we have a rule:

(29) CODA NASALIZATION

$VCdVbr)_\sigma \rightarrow [nasal]$

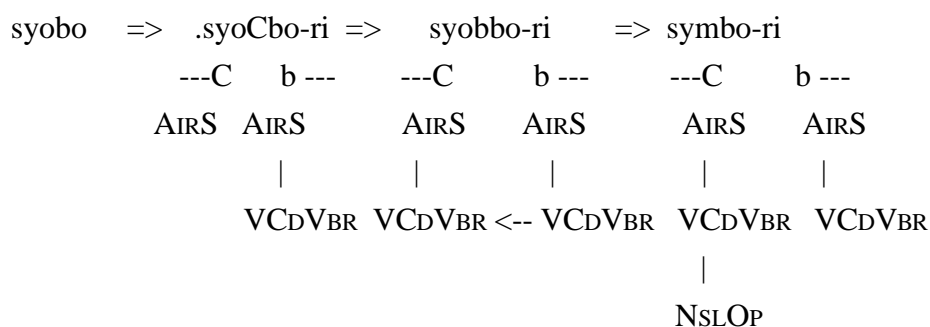
Hence, in order to get the inserted C in (27) nasalized, it suffices to have C become voiced.<sup>10</sup> So, we have the following regressive voicing assimilation:

(30) REGRESSIVE VOICING ASSIMILATION<sup>11</sup>



The derivation of *syombori* is given in (31):

(31) syombori



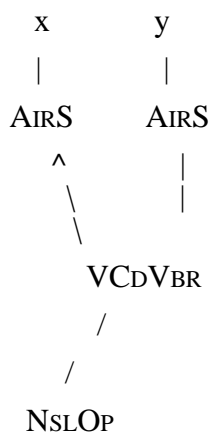
We again have Copying, not Spreading. For, if VCDVBR were spread and became a multi-linked node, Coda Nasalization would not be able to nasalize only the left half of this node.

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<sup>10</sup>This analysis is essentially equivalent to that given by McCawley (1968:97) and Itô & Mester (1986:59, n.14).

<sup>11</sup>Regressive Voicing Assimilation is formally a mirror image of Progressive Voicing Assimilation. However, the former is a general rule while the latter, to recall, is restricted to cross-morphemic context; see notes 4 and 7.

## (32) Impossible Coda nasalization

**6. The problem of sonorants**

Recall, however, that this regressive voicing assimilation must apply to liquids and glides.

Previously, we saw that Progressive Voicing Assimilation (24) is not triggered by the liquid /r/ or the glide /w/. This condition is satisfied because liquids and glides are underlyingly underspecified and not marked for VCdVBR. In contrast, the glides /y/ and /w/ must trigger Regressive Voicing Assimilation in order for coda to be nasalized, as *bonyari* and *yanwari* in (28) show, which I repeat in (33):

## (33) Part of (28) repeated

boyaboya	boỹyari	(*boyyari)	'absent-mindedly'
yawayawa	yañwari	(*yawwari)	'softly'

For this reason, we need a special default rule for sonorants:

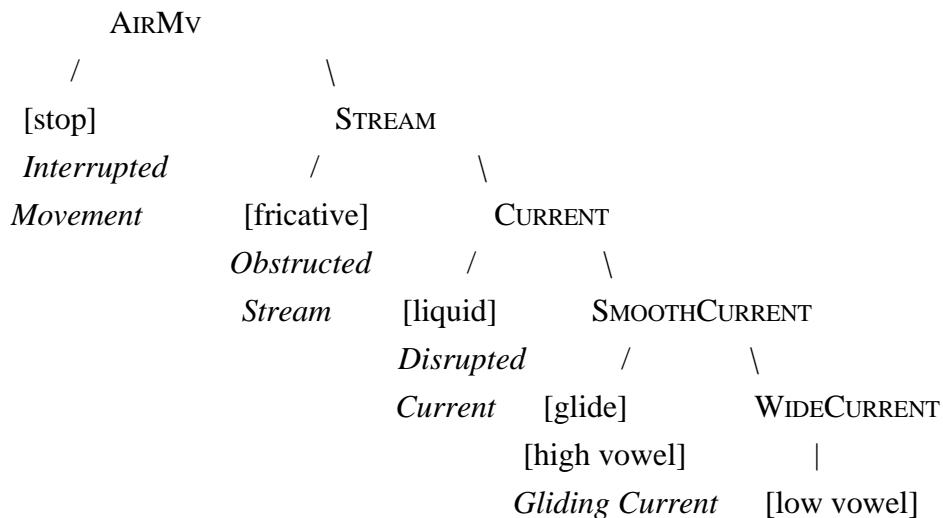
## (34) Sonorant Default Voicing Rule

[SONORANT] => [VCdVBR] (sonorant = liquid/glide)

Now, how to deal with the problem of sonorants is another innovation I have in mind for the new design of feature geometry. I do not introduce [sonorant] as a feature, either as a root feature or as an organizing node. Instead, I design the structure under the node AIRMOVEMENT as one that

mirrors the sonority hierarchy of segments. This is shown in the tree diagram in (35).

(35)



The terms in square brackets represent features obtained as default values of the immediately dominating nodes. The terms in italics given under square brackets are "nicknames" for these features suggesting their aerodynamic characteristics in conformity with the design of the geometry.

I assume that the following rule in (36) replaces the informally stated rule (34) in our feature geometry:

(36) Sonorant Default Voicing Rule

CURRENT => VCdVBR

This rule in effect interprets segments dominated by node CURRENT as sonorant and specifies that sonorant segments are voiced. In the next three sections, I will discuss two general issues that arise in the design of feature geometry exhibited in the diagram (35).

## 7. Nasals as sonorants

The first issue concerns the generally held view that nasals are sonorants. The intent of Sonorant Default Voicing Rule (36) is to formally characterize the informal concept of sonorants in our

feature geometry by node CURRENT. Then, the following redundancy rule can be taken as expressing this general view:

(37) **Nasal Sonority Rule**

NSLOP -> CURRENT

Nasals are usually grouped with oral stops. However, according to Shirô Hattori, :

"... since air cannot flow out [either through the oral or the nasal cavity] during the retention of a stop, the air pressure at the oral cavity and the pharynx increases and the force of closure at the place of articulation is greater for obstruents than for nasals; therefore, exactly speaking, the manner of how the closure is made is not completely the same [for nasals and stops]." ( Hattori 1951: 122; translated from the Japanese by SYK.)<sup>12</sup>

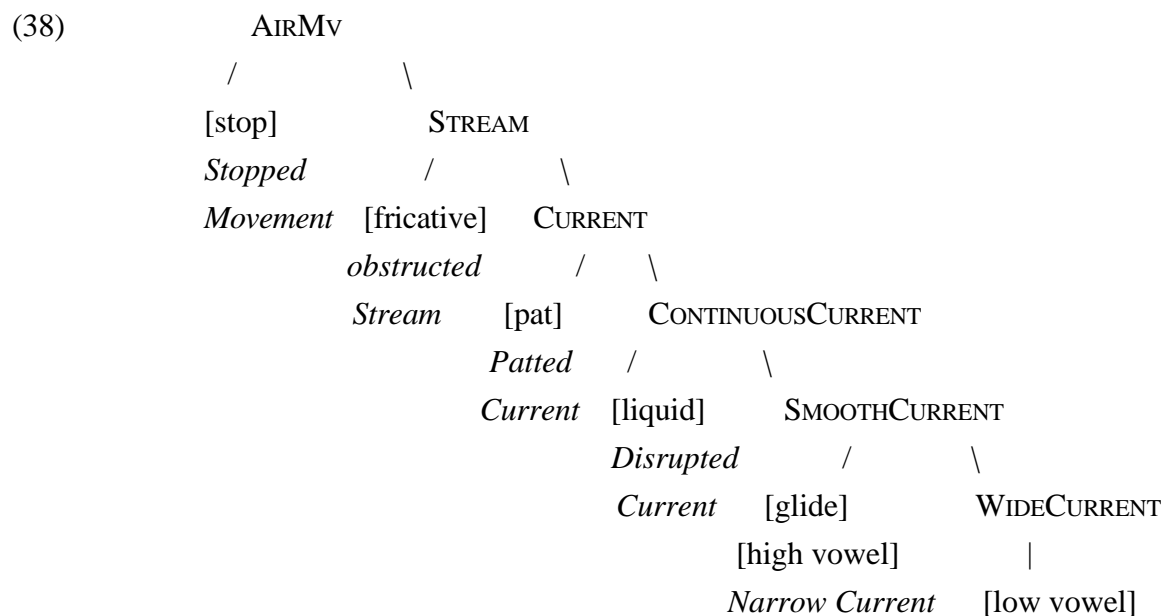
Hattori (1951: 124; tr. by SYK) then notes that while nasalized liquids and glides are easy to articulate, fricatives (as well as trills) are difficult or impossible to fully nasalize, since "to articulate usual fricatives, it is necessary for fairly strong breath to flow through the oral cavity." Thus, the sonority of nasals must be greater than STREAM in terms of the tree structure of AIRMOVEMENT (35). The Nasal Sonority Rule (37) conforms to this requirement. Rule (37) together with the structure given in (35) puts nasals like /m/ and /n/ at the same level of sonority as lateral liquids like /l/. This stipulation represents a minimally required condition and suffices for accounting Japanese phonology.<sup>13</sup>

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<sup>12</sup>For experimental evidence for this statement, I quote from Fujimura (1961: 246): "There is a significant difference in the physical mechanism of the motion of the nasal bilabial, compared to that for the stops, because of the overpressure built up behind the closure in the case of stops."

<sup>13</sup>(35) and (37) together would mark nasals as [liquid], perhaps a bad choice of term, but substantive confusion should not arise from it.

However, it has been argued that nasals are to a less degree, or less marked, as sonorant than liquids and that feature geometry must be structured to incorporate this assumption. (McCarthy 1988, Rice & Avery 1991, Rice 1993, Iverson & Sohn 1994.) We can accommodate this position by refining the structure given in (35). For the purpose of separating nasals and liquids for sonority degrees, we insert a new node *CONTINUOUSCURRENT* between *CURRENT* and *SMOOTHCURRENT*. The feature [liquid] is now taken as the default of *CONTINUOUSCURRENT*. I label [pat] the default feature of *CURRENT* in this refined structure to suggest a light closure characteristic of nasals:



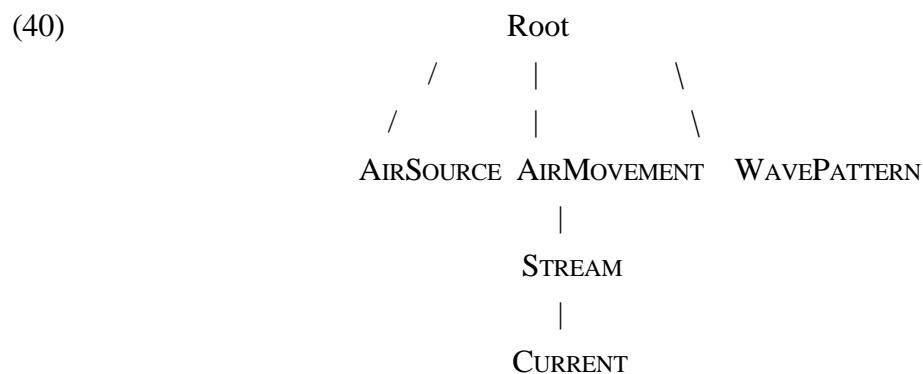
### 8. Sonorant assimilation in English

As an example, let us consider the phenomenon of sonorant assimilation in English. I reproduce relevant data from Rice and Avery (1991: 107):

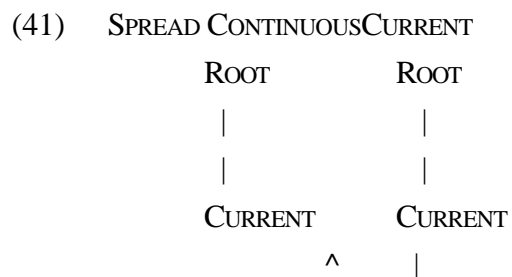
- (39)a i[m]balance i[n]dentured i[ŋ]grown  
       i[m]possible i[n]tangible i[ŋ]credible  
       b i[r]rational i[l]legible i[n]numerable i[m]measurable

The prefix-final segment fully assimilates to a following sonorant, as shown in (b), but not to a following obstruent as seen in (a); in the latter case, the prefix-final segment is realized as a nasal, the assimilation being restricted to the place of articulation. These facts suggest, on the one hand, that the prefix-final segment is a "generic" sonorant, i.e., an unspecified sonorant segment, rather than an unspecified consonantal segment, and, on the other, that the default sonorant in English is an unspecified nasal.

As CURRENT formally characterizes the informal concept of sonorant, the "unspecified" sonorant segment has the following representation in our feature geometry:



This segment is the final segment of the prefix in question in its underlying representation. We assume that between this prefix-final segment and the initial segment of the stem that follows the prefix, leftward sonorant assimilation applies. Formally, it takes the form of SPREAD CONTINUOUSCURRENT:





$$\begin{array}{r}
 (44) \quad / \dots \text{AirS} \quad \text{AIRMv} \dots / + / \dots \text{AIRS} \quad \text{AIRMv} \dots / \\
 \quad \quad | \quad \quad \quad : \quad \quad \quad | \quad \quad \quad | \\
 \quad \quad \text{VCdVBR} \quad \text{CURRENT} \quad [\text{voiceless}] \quad \text{STREAM} \\
 \quad \quad | \quad \quad | \quad \quad \quad \quad \quad \quad | \\
 \quad \quad \text{NSLOP} \quad [\text{pat}] \quad \quad \quad \quad \quad \quad [\text{fricative}] \\
 \quad \quad | \\
 \quad \quad [\text{nasal}]
 \end{array}$$

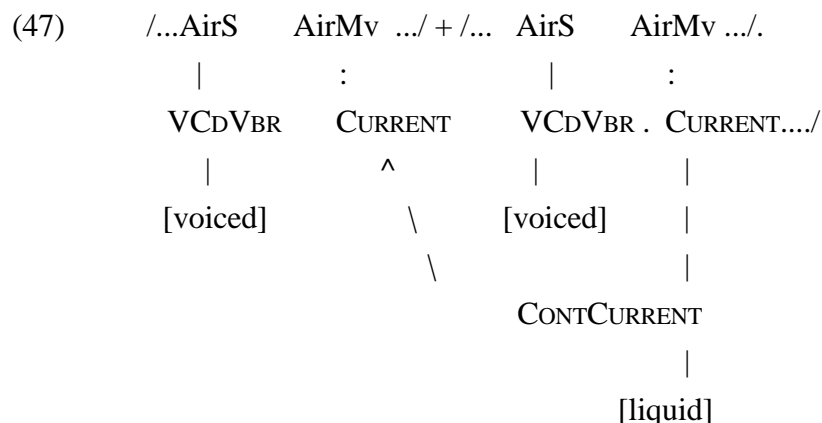
Next, consider the case where the stem-initial segment is a liquid, as in *irrational*. We have the following underlying representation:

$$\begin{array}{r}
 (45) \quad / \dots \text{AIRS} \quad \dots \text{AIRMv} \dots / + / \dots \quad \text{AIRS} \quad \text{AIRMv} \dots / \\
 \quad \quad \quad \quad \quad \quad | \quad \quad \quad \quad \quad \quad : \\
 \quad \quad \quad \quad \quad \quad \text{CURRENT} \quad \quad \quad \quad \quad \quad \text{CURRENT} \dots \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad | \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \text{CONTCURRENT}
 \end{array}$$

The structural description of Spread CONTCURRENT is met, and it yields the following representation:

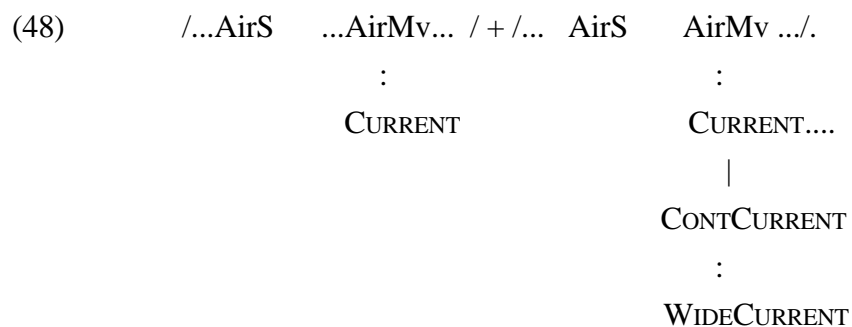
$$\begin{array}{r}
 (46) \quad / \dots \text{AIRS} \quad \text{AIRMv} \dots / + / \dots \quad \text{AIRS} \quad \text{AIRMv} \dots / \\
 \quad \quad \quad \quad \quad \quad : \quad \quad \quad \quad \quad \quad : \\
 \quad \quad \quad \quad \quad \quad \text{CURRENT} \quad \quad \quad \quad \quad \quad \cdot \quad \text{CURRENT} \dots / \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad | \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad | \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad | \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \text{CONTCURRENT}
 \end{array}$$

The Sonorant Default Voicing Rule (36) and the default conventions derive the following representation of a liquid geminate.:

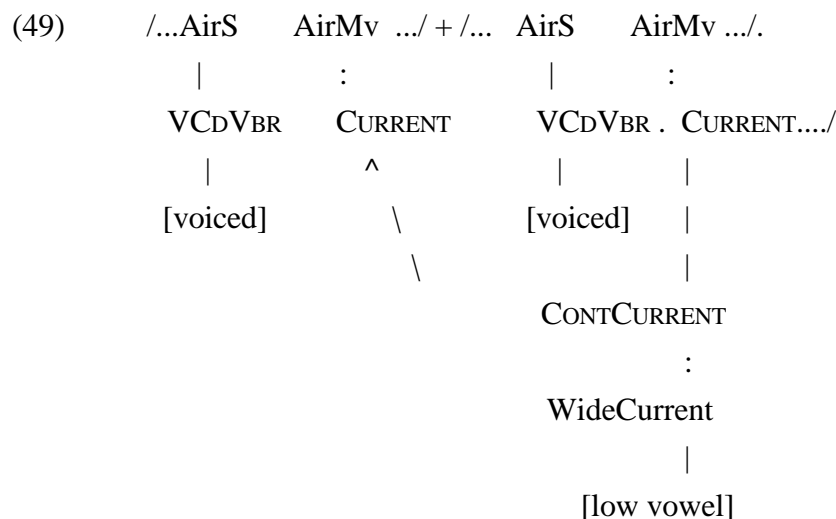


We have thus accounted for the alternation of the prefix *in-* discussed by Rice and Avery.

The attentive reader will, however, have noticed that there is a potential serious flaw in this account in terms of our feature geometry. As it stands now, Spread CONTCURRENT does not distinguish between liquids and vowels. Take, for example, *inactive*. The relevant part of the underlying representation for this form is:



The structural description of Spread CONTCURRENT is met; together with default conventions, it yields the following representation:



The result would be *iaactive* /iææktiv/ a form with a "geminate" vowel. This undesired consequence leads us to the second general issue I would like to discuss.<sup>15</sup>

## 9. The problem of consonants vs. vowels

It is common in feature geometry to introduce [consonantal]/[vocalic] as well as [sonorant] as features of the Root node. (Clements & Hume 1995: 292; Halle 1995: 2). Such features, however, are deemed arbitrary in the aerodynamic conception of feature geometry. As shown above, the feature [sonorant] is dispensed with in our feature geometry as incongruent with the basic idea of

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<sup>15</sup> Sonorant/nasal assimilation in Korean also provides support for the refined structure (38). Indeed, our feature geometry in (38) not only can accommodate the account of the sonorant/nasal assimilation given by Iverson and Sohn (1994) but also can account for the spirantization phenomenon as well by one and the same rule: sonorant, nasal and fricative assimilation in Korean can be understood as manifestations of Spread Stream; see Kuroda (in preparation).

I am fairly confident that with the refined structure (37) our geometry can deal with the kinds of issues involving voicing and sonorant that Avery and Rice (1989) and Rice (1992) tackled with their node SV (Sonorant Voice or Spontaneous Voice). But there is also a problem with (37). The system would impose on us an arbitrary decision: except for the unlikely case where there is an underlying contrast between nasal and nonnasal stops, we can characterize nasal sounds underlyingly either as [nasal] or as [pat], the other being introduced by a redundancy rule. It would thus seem preferable if we could somehow take (35) as an unmarked situation and devise a separate means for making nasals less marked sonorant than liquids. I leave this issue for future study.

our geometry. It is resolved in the sonority hierarchy, which is structurally mirrored in the node organization under AIRMOVEMENT. Features [consonantal] and [vocalic] are also matters of sonority and must be dispensed with in our feature geometry.

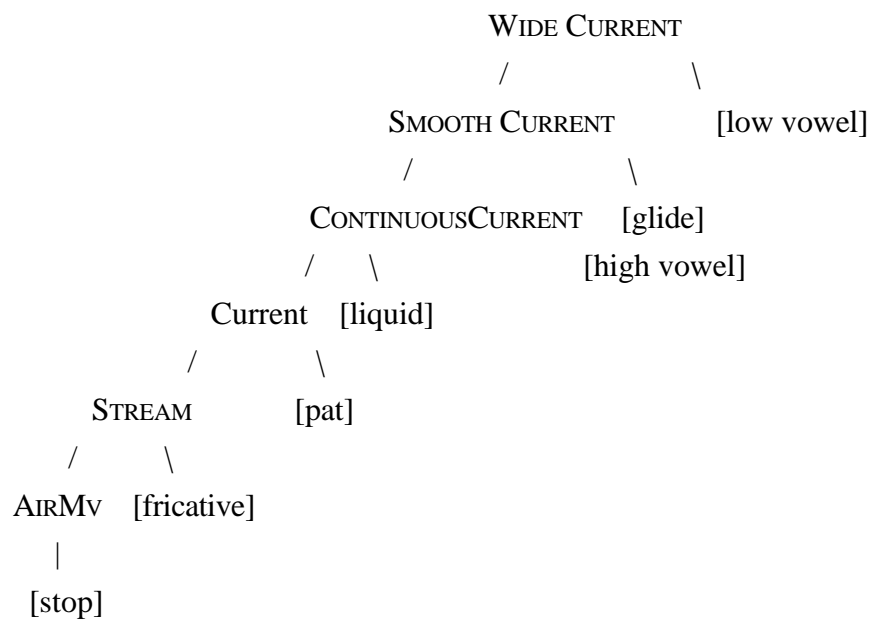
Sounds with a lesser degree of sonority are deemed consonantal, and those with a greater degree are deemed vocalic. Thus, consonants, so to speak, branch off at a higher position in the tree structure, and vowels at a lower position (35). Stops may well be considered as default consonants, and fricatives AS more consonantal than liquids. This fact is reflected by the tree structure under AIRMv, where AIRMv, whose default value is [stop], dominates STREAM, whose default value in turn is [fricative], and STREAM dominates CURRENT, whose default value is [liquid]. This structure also implies that a general rule that affects stops as consonants can be formulated in terms of the node AIRMv and must also affect fricatives and liquids, as desired. Thus, it looks as though node AIRMv dispenses with the feature [consonantal], taking over its function.

However, the problem with this line of thought, of course, is that vowels are located down at the bottom of the AIRMv tree and would count, so to speak, as the least consonantal segments. Vowels would then be affected by a rule affecting consonants in general. Likewise, they would also be affected by a rule that affects sonorants, as we have seen at the end of the last section.

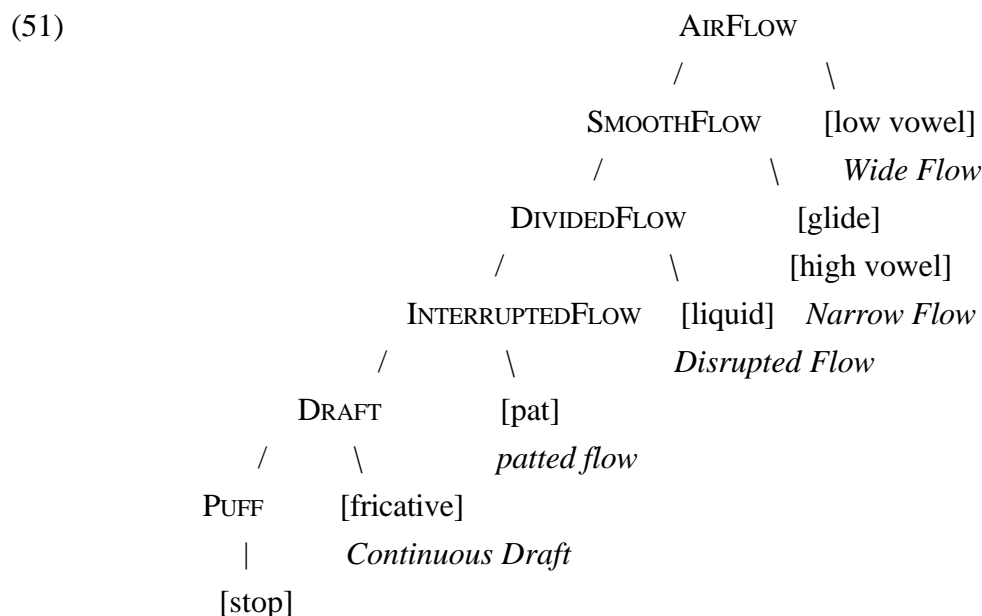
The difficulty we face arises from the fact that we have made an arbitrary choice for a value of a free parameter. The sonority is a scalar measure. When we combine this measure with an entailment relation, there is no intrinsic reason to choose which way the directionality of entailment should take. Let  $x$  and  $y$  be sonority degree and let  $x < y$ . If we gloss the sonority scale in terms of "at least as sonorous as" and define  $E_x$  as "being at least as sonorous as  $x$ ," then  $E_y$  entails  $E_x$ . In contrast, if we gloss the sonority scale in terms of "at most as sonorous as" and define  $E_x$  as "being at most as sonorous as  $x$ ," then  $E_x$  entails  $E_y$ . The former perspective gives the geometric structure given in (38). We can envision the geometric structure for the latter perspective if we imagine the tree in (38) as if it were a mobile and if we imagine holding it at the other end. Then

we get the following tree:

(50)

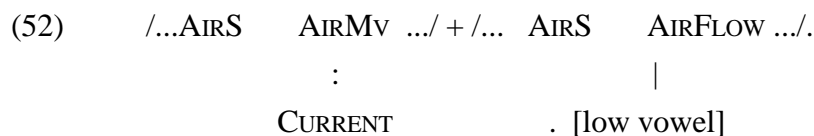


However, the connotation of a node changed from "at least as sonorous as" to "at most as sonorous as". It would be better to revise the labels so that they might conform to the reversed entailment relation as suggested below:



To summarize, we have the geometry of the sonority structure projected in two different perspectives: the consonantal perspective, (38), and the vocalic perspective, (51). What I then propose is that the opposition consonantal vs. vocalic is not one that is determined by properties of segments formalized in terms of features; rather, it is one that inheres in positions (slots) that segments occupy. At a consonantal position, i.e., at a syllable periphery, the subgeometry under AIRMV/AIRFLOW is projected in the consonantal perspective, while at a vocalic position, i.e., at a syllable nucleus, it is projected in the vocalic perspective. The entailment relation determined in one projection does not apply in another projection.

To illustrate how the mechanism of the projected geometry works, let us return to our earlier example *inactive* for the English sonorant assimilation. Since the stem-initial segment is projected in the vocalic perspective, we have the following underlying representation:



Spread CONTCURRENT does not affect this form as its structural description is not met. The relevant default conventions derive the following surface representation, /.. -n-a.. /, as desired:

(53)     /...AIRS     AIRMv .../ + /... AIRS     AIRFLOW .../.

VCdVBR	CURRENT	VCdVBR	[LOW VOWEL]
NSLOP	[pat]	[voiced]	
[nasal]			

## 10. Rendaku

Let us now return to Japanese phonology and let me add a few more remarks on rendaku. The rendaku phenomenon is commonly described in terms of the voicing of an initial obstruent of the second component of a compound word; see (3). The voicing is subject to the constraint of Lyman's Law: a non-initial voiced obstruent (but not a nasal or a sonorant), if any, in the second component of a compound word blocks the rendaku voicing.

The significance of the rendaku phenomenon, I believe, is quite different for Old Japanese and Modern Japanese. The relevant difference between the Old and the Modern Japanese mainstream dialect is that in Old Japanese no word begins with a voiced obstruent and no stem has more than one voiced obstruent.

(54) Old Japanese phonotactic constraints:

No word-initial voiced obstruent

No more than one voiced obstruent in a single stem

The rendaku phenomenon in Old Japanese, in my view, is nothing but a simple morpheme structure constraint, that is, nothing but the manifestation of the Obligatory Contour Principle on the tier

[voiced], [voiced] in the sense of the feature geometry I presented above, that is, in ordinary terms, non-nasal voiced. The voiced-unvoiced alternation of stem-initial obstruents is the manifestation of the general constraint that delinks the branch VCDVBR dominating [voiced] at word-initial position. This account explains at the same time the rendaku alternation, the absence of multiple voiced obstruents in a single stem, the absence of word-initial voiced obstruents; it also accounts for the existence of *rendaku-immune* stems, stems that never exhibit the rendaku alternation, even though the voicing would not violate Lyman's Law.

(55) Rendaku-immune stems:

saki 'tip, end'

kemuri 'smoke'

sio 'tide' (but not 'salt')

kasu 'dregs',

tuya 'gloss'

kase 'shackles' kita 'north'

tuti 'earth'

Martin (1987:114) and Vance (1987:69f)

Looked at this way, the rendaku phenomenon in Old Japanese does not involve a voicing process. Rather, it provides evidence for a devoicing process.

(56) Rendaku in Old Japanese (Kuroda 1963, 2000b)

OCP on tier [voiced] ([voiced] in the sense defined in (16))

Delink VCDVBR in env. #\_\_\_

--|--

[voiced]

Phenomena accounted for by (56)

The rendaku voiced-unvoiced alternation

The non-existence of words with an initial voiced obstruent

The non-existence of words with more than one voiced obstruents

The existence of *rendaku-immune* words.

The matter is quite different with rendaku in later Japanese. In Modern Japanese, words *can* begin with a voiced obstruents, even discounting many such words of Sino-Japanese origin:

- (57) Modern Japanese: words with an initial voiced obstruent  
*dasu* 'bring out'; *dare* 'who'; *gama* 'toad', *gomi* 'trash' *barasu* 'expose'  
 (not to mention many Sino-Japanese words)

Also a stem in Modern Japanese can have more than one voiced obstruent:

- (58) Modern Japanese: stems with more than one voiced obstruent  
*goza* 'mat', *dobu* 'ditch'.

In Kuroda (2000b) I accounted for *rendaku* in Modern Japanese as an extension of the account given to Old Japanese, in terms of devoicing rather than voicing. The merit of this account could be questioned. Unlike the case of Old Japanese, we cannot relate the *rendaku* voiced/unvoiced alternation to other general processes or constraints in Modern Japanese phonology. In addition, the *rendaku* voiced/unvoiced alternation is irregular and arbitrary, as many scholars have noted:

- (59) "Lacking any systematic guide, one must learn for each [compound] word whether a non-initial Y[amato] morph group exhibits the alternation or not..." Martin (1952:49)  
 "I am unable to state the environment in which the 'voicing rule' applies. The relevant data are completely bewildering." McCawley (1968:87)  
 "There is little doubt that the occurrence of *rendaku* in modern standard Japanese cannot be predicted by any simple principle or set of principles." Vance (1987:57)

It might be sensible to account for *rendaku* in Modern Japanese, following traditional lines, in terms of a lexically determined voicing process, with a certain proportion of subregularities. A rule to account for it could be formulated along the lines of Itô & Mester (1986:59), where [voiced] is to be understood as the default feature of VCDVBR, i.e., "non-nasal voiced":

(60) Spread [voiced]

$$\begin{array}{c} x \quad x \\ | \quad / \\ \text{[voice]} \end{array}$$

Be that as it may, it is quite questionable to take the voicing observed in the verb paradigm as an aspect of the same process as is responsible for the rendaku voiced/unvoiced alternation at the expense of introducing \*NT with an otherwise unmotivated constraint domain"; see note 7.

## 11. Summary of voicing assimilation in Japanese

To summarize, we have the following rules to account for the phenomenon of voicing assimilation, with the given order of application:

(61) PROGRESSIVE VOICING ASSIMILATION

$$\begin{array}{c} x \quad y \\ | \quad | \\ \text{AIRS} \quad \text{AIRS} \\ | \quad | \\ \text{VCdVBR} \rightarrow \text{VCdVBR} \end{array}$$

(62) Sonorant Default Rule

$$\text{CURRENT} \Rightarrow [\text{VCdVBR}]$$

(63) Regressive Voicing Assimilation

$$\begin{array}{c} x \quad y \\ | \quad | \\ \text{AIRS} \quad \text{AIRS} \\ | \quad | \\ \text{VCdVBR} \leftarrow \text{VCdVBR} \end{array}$$

- (64) Coda Default  
 $VCDVBR)_\sigma \rightarrow [nasal]$

Rendaku is a separate lexical mechanism which, regardless of whether it is formulated in terms of voicing or devoicing, affects the tier of feature [voiced].

To return to the opening theme of this paper, the contrast between voiced obstruents and sonorants in Japanese phonology, we have the following three way taxonomy shown in (2). The first type, manifested in rendaku, is an opposition characterized by feature [voiced] in the sense of our feature geometry in underlying representation; the second type, manifested by the verb paradigm, is characterized by node  $VCDVBR$  in underlying representation, and the third by the node  $VCDVBR$  in phonetic representation:

- (65) [Cf: (2)]
- |                      |                       |
|----------------------|-----------------------|
| Rendaku/Lyman's Law: | [voiced] (underlying) |
| The verb paradigm:   | $VCDVBR$ (underlying) |
| Mimetic adverbs      | $VCDVBR$ (surface)    |

## 12. Conclusion

In this paper, I have defended the earlier view of Japanese generative phonology concerning the phenomena of voicing assimilation. For this purpose, it is necessary to have a means to group together nasals with voiced obstruents to the exclusion of liquids and glides. I have justified this grouping on the basis of the idea of a feature geometry homomorphic to the aerodynamic design of the articulatory organS. But the part of the feature geometry to be referred to for this purpose constitutes a small branch of the geometry. Hence, this paper might, from one perspective, be equivalent to using a sledgehammer to crack a nut, and, from another, to building a castle in the air.

from the perspective of Japanese phonology, what concerns us first and foremost is the matter of descriptive adequacy of the competing descriptions, which in particular, hinges on whether Itô & Mester's \*NT is viable or not. \*NT, in my view, is untenable. We are thus turned back to the

classical view of voicing assimilation. But from the perspective of linguistic theory, the issue of descriptive adequacy is not left alone; the claim for a descriptively adequate account is in the end judged by the adequacy of the theory that frames the description or its contribution to the development of explanatory adequacy. In this paper, I wish to claim that a crucial step for an adequate account of Japanese phonology justifies, and is justified by, an aerodynamically motivated feature geometry. Plainly, the issue in Japanese phonology addressed here by itself hardly justifies this geometry. From a theoretical perspective, this paper is mostly conceptually driven, in the hope of suggesting the viability of aerodynamically motivated feature geometry, and is just a small step toward empirical substantiation of this conceptual possibility.

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