Feature Geometry and Phonetic Features: A Case Study in Voicing and Coda Nasalization in Japanese*

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1. Introduction

The objective of this paper may be understood at three levels. At the descriptive level, I propose a revision to my earlier description of voicing in Japanese and coda nasalization. At the level of phonological theory I propose an innovation to the feature geometry I have presented in my earlier work and wish to add a new perspective to the conception of feature geometry. Finally, at a general level of linguistic theory on the phonetic side, I wish to raise a general question on the role of phonetic features in phonology and phonetics.

In a talk I gave at the Second International Conference on Contrast in Phonology in Toronto in 2002, I proposed a new conception of feature geometry, aerodynamic feature geometry (ADFG), which is claimed to reflect the aerodynamic and articulatory reality of speech sounds. I pre-

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sented a description of the voicing phenomenon in Japanese by applying this geometry. In a later work, I applied it to Korean sonorant assimilation, and I called the geometry projective feature geometry, since the contextualization of markedness by PROJECTION REVERSAL plays a prominent role in this application. These two applications are claimed to provide insightful descriptions of these two phonological phenomena and thus contribute to justifying the idea of ADFG. See Kuroda (2002, 2003) for details.

In the description of voicing in Japanese in terms of ADFG, however, I had to have recourse to an operation, called COPYING, which may be thought of as a process of partial assimilation. This operation had been introduced before in the literature by Rice and Avery (1991). Nonetheless, for a test-case application intended to motivate and justify an introduction of a new conception of feature geometry, it might appear to be a serious drawback if an extra operation is necessary in addition to the two basic operations in feature geometry, SPREAD and DELINK. But I have now realized that a much improved description of voicing in Japanese is possible and that this improved description does not require the introduction of COPYING. (This innovation also simplifies the description of Korean phonology given in my earlier work, though rather in a trivial way.) As a consequence, the argument for ADFG is strengthened.

The innovation of the geometry concerns how the abstract phonological structure relates to phonetic reality. I propose that nodes whose structural relations the geometry accounts for are *in principle* not to be taken as *class nodes* that are interpreted as representing categories or classes of features as in Clements (1985: 228) and Sagey (1986: 25ff). They are taken to be abstract entities. A class node N is like a non-terminal of a context-free grammar, and can be replaced by a feature f, analogous to using a context free rule $N \rightarrow f$. In our geometry, we will introduce a node that cannot be rewritten by a feature in such a context-free way; such a node can be replaced by a feature only under a condition that is sensitive to a context determined by the entire segment that contains the node.

However, to say this does not prevent that some nodes happen to be just like class nodes. In fact, I have to add quickly that as far as the present study of Japanese phonology is concerned, there are only two nodes (CLEAR and DARK) that resist the reinterpretation of them as class nodes. But the crucial point is to accept that feature geometry is not about a structure of class nodes, even though some of them (and, in the present study, most of them) can be reinterpreted as class nodes. Note that a grammar is context-sensitive, even if just one rule is context-sensitive.

From the proposition that the rewriting of nodes by features cannot (necessarily) be context-free, I also claim that this process is outside of the realm of feature geometry. Feature geometry is assumed to be concerned only with the context-free structure formed by abstract nodes[1)]. Phonetic features may now be considered outside of phonology and only as part of interface conditions that materialize abstract phonological structures in phonetic reality[2)].

The fundamental idea that initiated ADFG is to explore the possibility of feature geometry which is in some sense grounded in the physical reality of speech sounds. By stating this I do not mean to depart from the basic understanding regarding feature geometry that "the ultimate justification for a model of phonological features must be drawn from the study of phonological and phonetic processes, and not from *a priori* considerations of vocal tract anatomy or the like." (Clements 1985: 230) The idea is that the formal structure that relates elements that constitute underlying phonological structures is *in some way* grounded on the physical reality of speech sounds. In this perspective, nodes in feature geometry and their formal relation to each other should not be justified solely on

1) In accordance with this new conception of feature geometry, the innovated version of ADFG might better be called *Aerodynamic Phonological Geometry* (ADPG), but for now I keep the old name.

2) This approach may even open the possibility that interface conditions are more globally context-sensitive and not segment-bound; perhaps syllables are natural domains for them, as Osamu Fujimura contends with his C/D model. For the C/D model, see Fujimura (1992, 1996, 2002).

functional and classificatory grounds. But by subjecting ourselves to this constraint, we must realize that the task of feature geometry is as much for accounting for the functions and contrasts that those elements show in phonological processes as for revealing the ways in which the structure they form relates to physical reality.

In the course of human evolution, the language faculty became connected to the human vocal and auditory capacity and created the discrete structure of the phonological code out of continuous patterns of air waves produced and perceived by the vocal and the auditory organs. The fundamental thesis underlying our approach to feature geometry is that the way discrete phonological elements are structurally organized is not totally independent of physical reality, but is rooted in it.

By physical reality I mean in this paper what physics in a classical and naive sense is concerned with, excluding neuro-cognitive aspects, though feature geometry would ultimately have to be related to brain sciences. Following Catford, we can distinguish three phases in the physical aspects of human speech: the *articulatory*[3)], the *aerodynamic* and the *acoustic*. Among these, "the aerodynamic phase is a particularly important one, since it is precisely at this stage that the sounds of speech are generated". (Catford 1977: 24) The auditory organ processes sounds as air waves that serve the human as a general (not necessarily linguistic) medium of information. The vocal organs produce air flows that generate sounds as general (again, not necessarily linguistic) means of emitting information. Articulatory phonetics is a study of the vocal organs as they function as tools to produce particular air flows that serve as means of producing the *linguistic* code; acoustic phonetics is a study of particular patterns of air waves generated by such air flows and perceived by the auditory organ as means of the *linguistic* code. Acoustics is relevant to grammar insomuch as it can identify air waves produced by aerodynamic characteristics of air flows that produce the sounds of speech.

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3) Strictly speaking, Catford has *organic* instead of *articulatory*, but here I ignore this distinction.

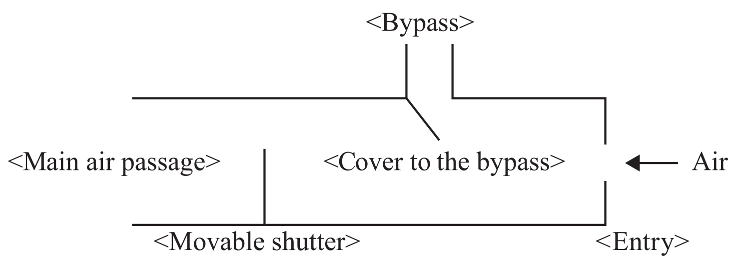
Our feature geometry as it is presented in this paper does not make direct reference to aerodynamic phonetics in any technical sense. But the aerodynamics of speech must relate to the structure of the vocal organs to an significant extent, if not isomorphically. Our feature geometry is based on a simplified schema of the articulatory organ presented in (1) below that is supposed to depict its aerodynamic function in speech, to the extent relevant to our limited aims in this paper. The fundamental thesis of ADFG is that the formal structure that relates nodes to each other mirrors the formal structure of the vocal organs as the aerodynamic source of speech.

In sections 2 and 3, I will describe ADFG as it was formulated in my earlier works. In section 4, I will introduce the main idea that leads to an innovation of ADFG. In sections 5–6, a new conception of feature geometry will be developed along with an improved account of voicing in Japanese. A summary and conclusions are given in section 7.

2. Aerodynamic feature geometry 1: Introduction

ADFG is intended to be a feature geometry that is faithful to the aerodynamic design of the articulatory organ. The articulatory organ is schematized in the figure below. The schema consists of a main air passage (the oral cavity), a bypass (the nasal cavity) and a movable shutter (the lips and the tongue).

(1) The schema of the articulatory organ



There are three parameters in this design that are relevant:

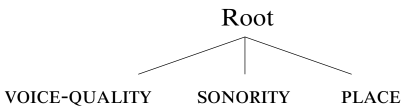
- The states of the entry to the main air passage and of the cover to the bypass. This parameter determines the quality of the Air Source aerodynamically and the VOICE-QUALITY phonetically.
- The degree and manner in which the shutter is opened/closed. This parameter determines the quality of Air Movement aerodynamically and the degree of SONORITY phonetically.
- The positioning of the shutter. This last parameter determines the quality of the Wave Pattern aerodynamically and the PLACE of articulation phonetically.

Aerodynamic Feature Geometry (ADFG) is intended to be structurally homomorphic to this aerodynamic schema of the articulatory organ.

It is in order here to insert some terminological remarks. I used different systems of labels for nodes in the geometry in the previous two works. In the earlier Kuroda (2002) I adopted a system according to which labels of nodes suggest aerodynamic characters of aspects of speech sounds intended to be captured by the nodes, such as AirSource, NasalBypassOpen, AirMovement, SmoothCurrent etc. This system has the advantage that the fundamental principles underlying the architecture of ADFG are reflected in the names of nodes. However, it has a disadvantage in that it exposes the reader to unfamiliar names and as a consequence much decreases the readability of descriptions framed in the geometry. In Kuroda (2003) I adopted the policy of labeling nodes by terms more or less familiar in phonology that are assumed to characterize the aspects of sounds captured by the nodes, such as VOICE-QUALITY, VOICED, NASAL, SONORANT etc. This policy has an advantage of increasing the readability for the general audience, though to some extent at the risk of inviting unwarranted inferences falsely based on the usual connotation associated with familiar terms. For this paper I have opted for the latter policy, for the sake of readability. The description of Japanese given in Kuroda (2002), which is a main concern of this paper, will be reformulated in this paper in the new terminology.

The root node dominates three branches that correspond to the three parameters of the schema of the articulatory organ given above. I name the three branches VOICE-QUALITY, SONORITY and PLACE. Let us agree to understand that these are strictly speaking names of the branches and are not names of nodes. (But by the force of metonymy they could be (mis)used as the names of the top nodes of the branches, as in (2), but only in (2) in this paper.)

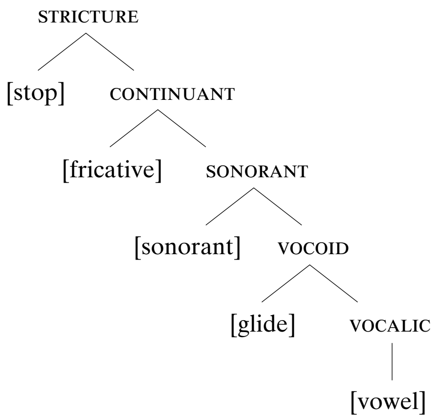
(2) A node tree for ADFG 1: the top level.



VOICE-QUALITY concerns voicing and nasalization. SONORITY relates to manners of articulation and PLACE to places of articulation.

In my earlier works I did not specify the structure of the branch PLACE, as it was irrelevant to the empirical issues in Japanese and Korean I was concerned with. I will return to the branch PLACE later. Let me give here first the structures under SONORITY and VOICE-QUALITY as they were presented in the earlier works.

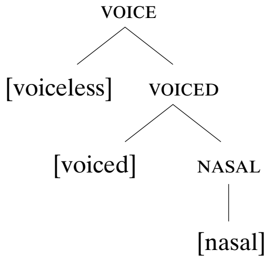
(3) A node tree for ADFG 2: the SONORITY branch (An old version)



STRICTURE is the topmost node of the branch and thus the most unmarked, hence default specification of the SONORITY branch. It is phonetically actualized by the feature [stop]. The markedness levels under STRICTURE may be considered to correspond to sonority degrees, the higher in the tree less sonorous. Hence the name SONORITY for the branch. The most marked option under SONORITY is VOCALIC, which actualizes phonetically as the feature [vowel].

I assumed that the VOICE-QUALITY branch has the structure represented by the following tree[4]:

(4) A node tree for ADFG 3: the VOICE-QUALITY branch (An old version)



This diagram specified that [nasal] is the most marked value of VOICE-QUALITY and [voiceless] is the least marked and default value for VOICE-QUALITY. Note that in this geometry the fact that nasal sounds are acoustically voiced was not captured by making [voiced] a redundant feature of nasal sounds. The dependency of nasality on voicing was incorporated in the design of the geometry. We agreed, and continue to agree in this paper, too, to understand that the phonetic feature called [voiced] signifies "vibrating vocal cords without the nasal bypass open", a characteristic of non-nasal voiced sounds. The phonetic substance of the feature commonly called [voiced] was assigned to the node VOICED, rather than to the

4) In Kuroda (2003) I called the top node of the voice-quality branch VOICE-QUALITY. In order to distinguish the name of the branch and that of the node, I use VOICE for the name of the node in this paper.

phonetic feature here labeled [voiced][5].

3. Aerodynamic feature geometry 2: Projection reversal

Usually feature geometry distinguishes consonants and vowels by introducing [consonantal]/[vocalic] as features attached to the Root node. Similarly for the feature [sonorant]. (Clements and Hume 1995: 292; Halle 1995: 2) Such features, however, are not justified in terms of the aerodynamic design of feature geometry. The distinction between consonants and vowels is a matter of sonority degrees, which is structurally mirrored in the SONORITY branch. Sounds with a lesser degree of sonority are consonantal, and those with a greater degree vocalic. Thus, in (3) consonants branch off at a higher position in the tree, and vowels at a lower position.

According to this conception, stops are default consonants, and fricatives more consonantal than liquids and glides. This fact is reflected in (3). This structure also implies that a general rule that affects stops as consonants can be formulated in terms of the node STRICTURE and affects fricatives and liquids as well. Thus, it looks as though we can dispense with the feature [consonantal]. However, a problem with this line of thought, of course, is that vowels are located down at the bottom of the SONORITY tree and would count as the least consonantal consonants and would be affected by rules that apply to consonants in general.

We face this difficulty because we have made an arbitrary decision when we decided to represent sonority degrees by tree (3). The sonority is a scalar measure. When we combine this measure with an entailment relation encoded in the form of a tree, there is no intrinsic reason to choose which way the directionality of entailment should take. Let x and y be sonority degrees 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

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5) Thus, in this paper the word *voiced* is to be understood in two different senses. In the text of the paper it is usually used with the customary sense in phonetics: a sound can be said to be voiced, either nasal or non-nasal. Only as a technical term in our geometry as a name of phonetic feature [voiced], is the word meant to imply non-nasal.

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 (3). We can envision the geometric structure for the latter perspective if we imagine the tree in (3) as if it were a mobile and if we imagine holding it at the other end. Then we would get the tree (5). The entailment relation encoded in this tree in terms of the dominate relation among nodes is "at most as sonorous as".

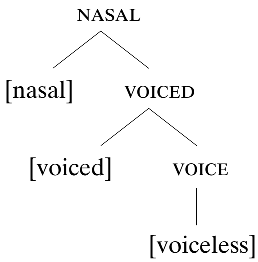
(5) Projection reversal: SONORITY in the vocalic projection
(An old version)

- VOCALIC
  - [vowel]
  - VOCOID
    - [glide]
    - SONORANT
      - [sonorant]
      - CONTINUANT
        - [fricative]
        - STRICTURE
          - [stop]

To summarize, we have the geometry of the sonority structure projected in two different perspectives: the consonantal perspective, (3), and the vocalic perspective, (5). I claim that the opposition consonantal/vocalic is not one that is determined by properties of segments formalized in terms of features like [consonantal]/[vocalic]; rather, it is one that inheres in positions (sites) that segments occupy. Each site is consonantal or vocalic. At consonantal positions, i.e., at syllable peripheries (onsets or codas), the SONORITY branch is projected in the consonantal perspective as given in (3), while at vocalic positions, i.e., at syllable nuclei, it is projected in the vocalic perspective as given in (5). The entailment relation determined in one projection does not apply in the other projection; a general rule that applies to consonants does not apply to vowels, since vowels are represented by trees planted upside down from the consonantal perspective. See Kuroda (2002), section 8 for more discussion and examples of the consonantal/vocalic perspectives.

In the earlier work (Kuroda 2003), I also introduced the notion of SONORANT SITE, where the VOICE-QUALITY branch reverses projections.

(6) Projection reversal: VOICE-QUALITY at a sonorant site
(An old version)



This reversal allows us to account for the situation where nasals behave as unmarked sonorants. I leave this issue aside for the moment and will return to it below, as the innovation of the geometry I propose in this paper concerns the treatment of the VOICE-QUALITY branch in particular.

4. An innovated conception of feature geometry

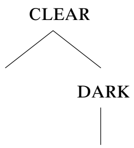
Let me start with describing a problem we would face if we operate in the conventional conception of feature geometry and set our task as resolving this problem. Feature geometry, according to this conception, determines the structure of a phonologically relevant space of sounds with phonetic features as coordinate values of sound elements in this space. In ADFG as defined by the above two trees, (3) and (4), the two subtrees VOICE-QUALITY and SONORITY cannot constitute a subspace with two mutually orthogonal coordinates: we have no sounds with specification [stop, nasal] or with [fricative, nasal]. This type of skewed distribution is usually accounted for by redundancy rules. For the present case, one could account for it by the following redundancy rule:

(7) [nasal] $\Rightarrow$ sonorant.

I wish now to propose that we remove this redundancy by making voice-quality and sonority mutually orthogonal subspaces. I claim that we can achieve this by reducing the number of markedness levels for voice-quality from three to two. This reduction in turn is achieved by severing direct links between nodes and phonetic features. Nodes, without direct links to phonetic features, are to be taken as abstract entities, on the one hand, and phonetic features, on the other hand, must be considered as contextualized conditions for the phonetic implementation of such abstract entities.

I assume that the voice-quality branch distinguishes two levels, which I will call clear and dark.

(8) A node tree for ADFG 4: The voice-quality branch
(A new version)



In contrast to (4), in our innovated framework of feature geometry, we do not enter phonetic features as default values of clear or dark in (8). Terminating branches are left "dangling" as seen (8). Phonetic features are supplied by interface conditions, as we will see below.

Sonority and voice-quality can now be taken mutually orthogonal: at each value of the sonority branch we have a binary opposition for the value of voice-quality, clear and dark. The phonetic implementation of clear and dark is dependent on the values that a segment takes at the sonority branch. At the least sonorous end of the sonority scale, the unmarked default phonetic realization of voice-quality is [voiceless] and the marked one is [voiced]. But [voiceless] cannot implement sonorants or any sounds of a greater degree of sonority[6]. The default realization of such a sound is [voiced] and the marked realization [nasal]. In tree (3), a downward limit point for a natural implementation of [voiceless] is located to the left of SONORANT, on the one hand, and SONORANT, on the other hand, is an upper limit for a natural implementation of [nasal].

"Dangling" branches without terminal nodes in (8) indicate that they are input routes to the interface between the phonology described by feature geometry on the one hand and phonetics on the other. We might summarize the interface conditions for (8) by the following interface rules:

(9)-1 The interface conditions for DARK

$$\text{DARK} \Rightarrow \begin{cases} [\text{nasal}] & \text{in env.} \quad \begin{array}{l}\text{STRICTURE}\\ \quad | \\ \text{CONTINUANT} \\ \quad | \\ \text{SONORANT}\end{array} \\ [\text{voiced}] & \text{otherwise}\end{cases}$$

(9)-2 The interface conditions for CLEAR

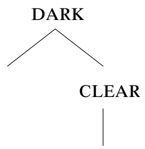
$$\text{CLEAR} \Rightarrow \begin{cases} [\text{voiced}] & \text{in env.} \quad \begin{array}{l}\text{STRICTURE}\\ \quad | \\ \text{CONTINUANT} \\ \quad | \\ \text{SONORANT}\end{array} \\ [\text{voiceless}] & \text{otherwise}\end{cases}$$

6) I assume that voiceless vowels are phonetic variants and do not appear as phonologically significant segments, at least for standard cases.

Two remarks are in order here. First, the specification of the environment is meant to be satisfied not only by SONORANT segments (i.e., /r, n, m/) but also by VOCOID segments (i.e., /w, y/); the structure assigned to a VOCOID segment contains the structure that specifies the environment as a substructure. Secondly, recall that the SONORITY branch are projected "upside down" at vocalic sites. The above interface rules work only in the consonantal projection. For the vocalic projection, we need another set of conditions but I leave this problem aside for now.

At a sonorant site the projection of VOICE-QUALITY reverses and we have the following tree:

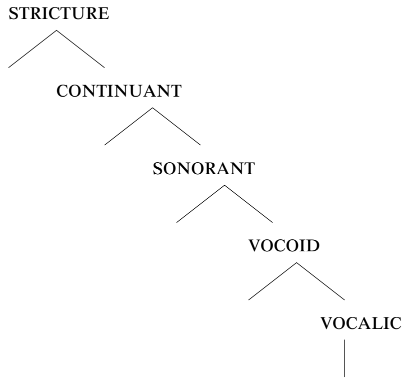
(10) Projection reversal: VOICE-QUALITY at a sonorant site
(A new version)



The idea of sonorant site was introduced for the account of Korean assimilation in Kuroda (2003). I will show later that this idea is also useful for the account of coda nasalization in Japanese.

In conformity with the idea that the geometry is freed of phonetic features, the description of the SONORITY branch can also be divided into two parts, the phonological geometry and the interface conditions. However, for this work we assume that we have a trivial type of interface conditions as indicated below.

(11) A node tree for ADFG 5: The SONORITY branch (A new version)



(12) The interface conditions for SONORITY

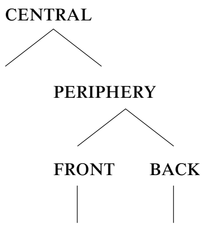
STRICTURE	⇒	[stop]
CONTINUANT	⇒	[fricative]
SONORANT	⇒	[sonorant]
VOCOID	⇒	[glide]
VOCALIC	⇒	[vowel]

Crucially, the liquid /r/, the glides /w/ and /y/ and the vowels /a, i, u, e, o/ are CLEAR SONORANT, VOCOID and VOWEL, respectively, and they are unmarked at normal (i.e., non-sonorant) sites. The nasals /n, m/ are DARK SONORANT, and marked at normal sites. The markedness reverses at sonorant sites.

Since the interface conditions (12) are context-free, the nodes of the sonority branch can be interpreted as usual class nodes, and in fact I have named them with traditional terms that would invite this interpretation. But in accordance with the thesis that nodes are in principle abstract, we might as well name them SONORITY#1, SONIRITY#2, ..., SONORITY#5. This renaming would preempt the misunderstanding that these nodes are inherently bound with the traditional phonetic features that the names I gave suggest. Consider, for example, certain types of /r/ as in Czech and Scots that pattern with either liquids or with voiced fricatives; they might be assigned to SONORITY#2 or SONORITY#3, as the case may be. Then, these nodes cannot be interpreted as class nodes defined by features [fricative] and [sonorant], respectively[7].

I will now give the structure for the tree PLACE, which I have put aside before.

(13) A node tree for ADFG 6: The PLACE branch



This configuration means first of all that the unmarked (default) realization of PLACE is as in (14):

(14) The unmarked (default) realization of PLACE

Secondly, FRONT and BACK are sisters. In this paper I do not commit myself to any claim as to which of them, if any, is the less marked, default choice for PERIPHERY. FRONT and BACK are assumed to be more marked than CENTRAL but neither FRONT nor BACK is assumed to be more marked than the other.

In conformity with the common practice, let me introduce two different sets of phonetic features for the interface conditions for PLACE in the consonantal and in the vocalic perspective. But these rules must be taken here merely as expository guides. In reality, interface conditions could be highly context sensitive. For consonants, we have

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7) Cf. Anderson and Ewen (1987: 159). I thank a referee of the journal for bringing this reference to my attention.

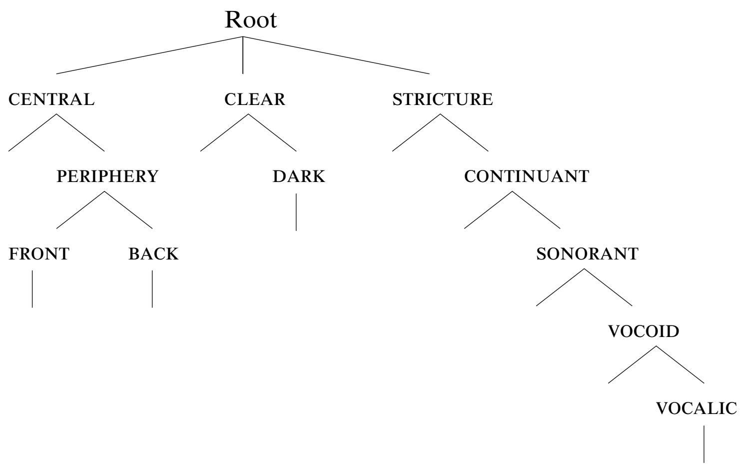
(15)	CENTRAL	$\Rightarrow$	[coronal]
	FRONT	$\Rightarrow$	[labial]
	BACK	$\Rightarrow$	[dorsal]

For vowels, we have

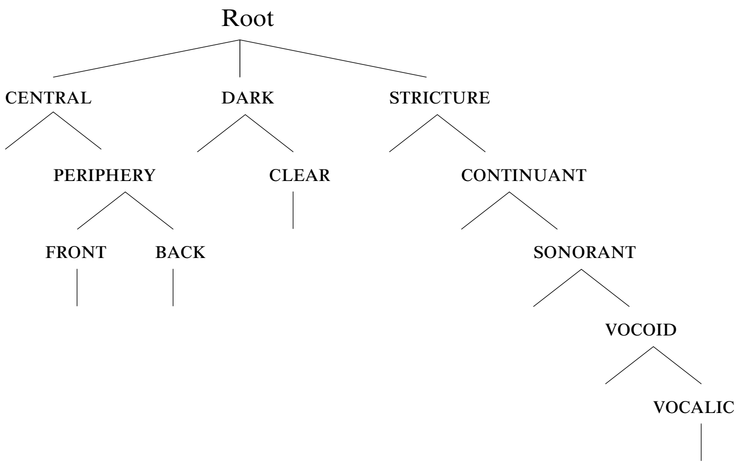
(16)	CENTRAL	$\Rightarrow$	[mid]
	FRONT	$\Rightarrow$	[front]
	BACK	$\Rightarrow$	[back]

To sum up, a complete structural tree of our geometry is a tree with three main branches where terminal branches are all "dangling". There are three configurations of a structural tree depending on how the VOICE-QUALITY and the SONORITY branches are projected:

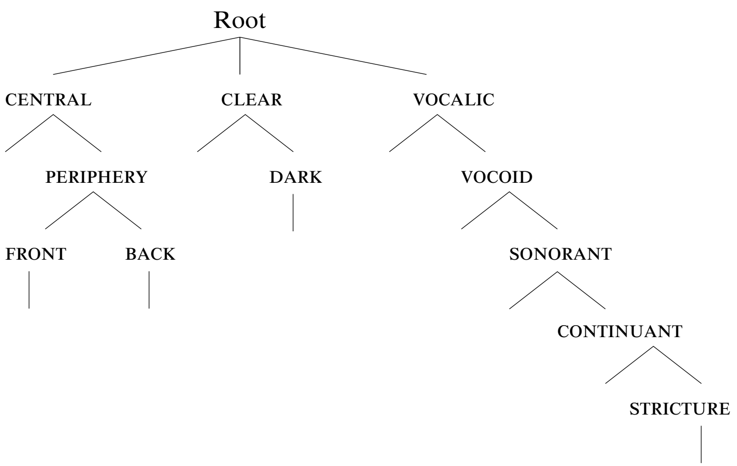
(17) The structure tree at a consonantal site



(18) The structure tree at a sonorant site



(19) The structure tree at a vocalic site



Let us agree to call a node in a structural tree that dominates another node *open*, and one that does not *closed*. So, PERIPHERY and CENTRAL are open but FRONT and BACK are closed in each of the three trees above. In (17), CLEAR is open but DARK is closed, while in (18) DARK is open and CLEAR closed. A subtree of a structure tree is by definition a PHONOLOGICAL

SEGMENT (or, simply SEGMENT) if it satisfies the following conditions:

(20) (i) Root has all the three main branches, PLACE, VOICE-QULITY and SONORITY;
(ii) each main branch does not branch;
(iii) each main branch terminates in a dangling branch or an open node.

Hence no branch of a segment terminates in a closed node. Those segments of which the main branches all terminate in a dangling branch are by definition *closed*, and those of which there is a branch that terminates in an open node are *open*. The phonological representation of a lexical entry in the lexicon is a sequence of segments. Given a language, a closed (open) segment is called a phoneme (archiphoneme) of the language if there is a lexical item in the lexicon in which the segment is a component of its phonological representation.

5. Progressive voicing assimilation

A main empirical data we will be concerned with in this paper is provided by the progressive voicing assimilation that takes place between verb stems and three suffixes each of which has two allomorphs: /-ta~da/ 'PAST/PERFECT', /-te~de/ 'GERUND' and /-tari~dari/ 'REPRESENTATIVE'. In what follows, I refer only to /-ta~da/ 'PAST/PERFECT' as a model example. I present the data as if the voiceless *t*-allomorph is basic form, but this presentation is only for the expository purposes of describing the phenomenon in question, not meant to give the representation in the lexicon. The process of assimilation we are concerned with is apparent in the minimal pair given in (21), although a later process of lenition affects the velars, /k/ and /g/, and makes the effect of the voicing assimilation opaque.

(21)	kak-u 'write'	kak-ta	(> kai-ta)	'wrote'
	kag-u 'smell'	kag-ta > kag-da	(> kai-da)	'smelled'

In (22), the effect of the voicing assimilation is seen again opaquely since the stem-final /b/ voices the following /t/ and then gets nasalized due to the phenomenon of coda nasalization, to which I will return later.

(22)	tat-u	'stand'	tat-ta	'stood'
	tob-u	'fly, jump'	tob-ta > tob-da (> ton-da)	'flew, jumped'

In this process, stem final nasals also voice the following suffix:

(23)	yom-u	'read'	yom-ta > yom-da	(> yon-da)	'read' (past)
	sin-u	'die'	sin-ta > sin-da		'died'

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

(24)	kar-u	'trim'	kar-ta (>kat-ta)	'trimmed'
	kaw-u > ka-u	'buy'	kaw-ta (>kat-ta)	'bought'

Stem-final vowels do not cause voicing:

(25)	tabe-ru	'eat'	tabe-ta	'ate'
	oki-ru	'wake up'	oki-ta	'woke up'

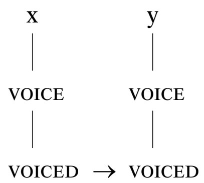
The *s*-stem verb takes an epenthetic /i/ and behaves as if it is a vowel stem verb in this particular morphological context.

(26) kas-u 'lend' kasi-ta 'lent'

(21)–(26) exhaustively list all the patterns of the past/perfect forms; there are no verb stems that end in /p/, /z/ or /d/. Thus, evidence for Progressive Voicing assimilation is scarce and opaque, but, nonetheless, I claim, decisive.

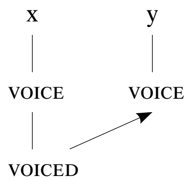
Kuroda (2002) assumed tree structure (4) and accounted for this progressive assimilation by the following rule:

(27) Progressive Voicing Assimilation (Old account)



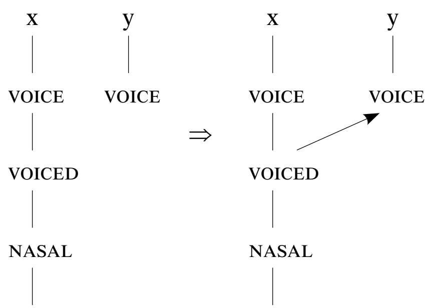
The horizontal arrow → indicates the operation of COPYING mentioned above in section 1. COPYING instead of SPREAD was required. In order to see this point, assume instead that we have Progressive Voicing Assimilation formulated in terms of SPREAD:

(28) Progressive Voicing Assimilation
(A wrong version for the old account)



Consider the case where a nasal segment occupies the position x; (28) applies and we get the following derivation[8]:

(29)

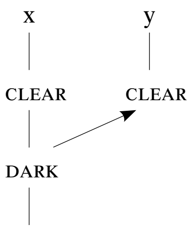


8) Spread is a unification with the condition that the source ≥ the target, that is, the source is equal to or more specified than the target. See Iverson and Sohn (1994), Kuroda (2003: 97/2004: 91).

(29) means that we have, for example, the undesired derivation /yom-ta/ > */yom-ma/ instead of /yom-ta/ > /yom-da/ (> /yon-da/ by Regressive Assimilation). Hence we had to have COPYING (27), not SPREAD (28).

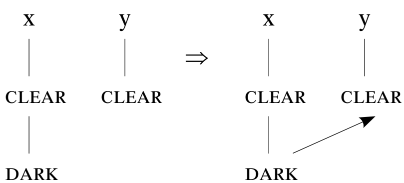
In contrast, with the structure (8) and the interface conditions (9), which I am proposing in this paper, we can replace (27) by the following account by means of SPREAD:

(30) Progressive Voicing Assimilation (New account)



(30) assumes that the initial consonant of the suffix is unmarked, i.e., specified as CLEAR, at the VOICE branch. This assimilation rule derives a sequence of consonants C_1C_2 co-specified for VOICE-QUALITY. The VOICE-QUALITY branch of *kag+ta* before and after the application of (30) are given below:

(31)



Let us pay a special attention at this point to the fact that the suffix initial segment *y* does not get voiced after a stem ending in the glide /w/ or the sonorant /r/, as desired, because both /w/ and /r/ are entered as CLEAR, not as DARK. Thus, we get the voiced alternant of the suffix *da* after *kag-, tob-, yom-, sin-* and the voiceless alternant *-ta* after *kak-, tat-, kar-, and kaw-* as well as after *tabe-* and *sasi-*.

We must now be concerned with the fate of the stem final consonants of consonantal stems. Of these we will leave aside the velars /-k/ and /-g/; they are replaced by the vowel /i/ and we are not concerned with this process in this paper. We are not concerned with the -s stem, either; an epenthetic /i/ is inserted between the stem and the suffix. In the rest we get the geminate /-tt-/ for the case where the suffix is voiceless *-ta* and a nasal coda for the case where the suffix is voiced *-da*. We will deal with codas in general in the next section.

6. Codas

The pattern of coda-onset pairs we saw in verb morphology (22)–(24) conforms to the following well-known generalization illustrated by examples that follow:

(32) The Coda-Onset Patterns.
A coda-onset pair is
(i) a voiceless obstruent geminate,
(ii) a nasal coda followed by a voiceless or voiced obstruent, or
(iii) a nasal coda followed by a sonorant or glide.
Missing pairs are
(iv) voiced obstruent geminates[9] and (v) sonorant or glide geminates.

(33) Examples of coda-onset pairs
(i) *motto* 'more', *sippo* 'tail' *tekka-maki* 'tuna-roll sushi', *messoo (mo nai)* '(cannot be more) absurd';
(ii) *tampopo* 'dandelion', *tambo* 'rice paddy', *karinto* 'fried cookies', *sindoi* 'tired', *kenka* [keŋka] 'fight', *kangae* [kaŋgae] 'thought', *tansu* 'chest', *kanzi* 'feeling';
(iii) *tomma* 'silly fellow', *minna* 'all', *konro* 'stove', *tenya-wanya* 'in utter confusion', *wanwan* 'bowwow'.

9) The foreign loan stratum is exempt of this constraint. Thus, we may have voiced-geminates as in *hottodoggu* 'hotdog'.

The generalization (32) can be factored out into the following two generalizations:

(34) Regressive Assimilation: Codas assimilate to the onsets that follow them.

(35) Coda Nasalization: Voiced codas are nasalized.

In Kuroda (2002) I introduced the following rule to account for the coda nasalization:

(36) Coda Nasalization (Old version)

VOICED$)_\sigma$ $\Rightarrow$ [nasal]

The subscript sigma indicates a syllable boundary. One might think that this rule can be directly transferred to our present system as an interface rule:

(37) Coda Nasalization (A wrong new version)

DARK$)_\sigma$ $\Rightarrow$ [nasal]

But this will not do. For, according to our assumption, the glides /y, w/ as well as the liquid /r/ are unmarked for VOICE-QUALITY: that is, their VOICE-QUALITY branch is specified as CLEAR. Only by the interface rule (9)-2 do they get specified as [voiced].

We could take Coda Nasalization as an interface condition of the form given below and assume that (9)-2 feeds (38).

(38) Coda Nasalization (New version, a trial)

[voiced]$)_\sigma$ $\Rightarrow$ [nasal]$)_\sigma$

The above account suffices to provide us with a straightforward and accurate description of the coda nasalization phenomenon. But we may wonder if there might be anything formally remarkable behind this phenomenon and if there is, this straightforward description might not capture it and we might fail to understand the significance of this phenomenon. Note that Coda Nasalization is formulated in (38) in terms of phonetic features. According to the conception of feature geometry I am exploring in this paper, phonetic features are not constitutive of feature geometry; they serve only as guides to the understanding of interface conditions. Accounting for the coda nasalization phenomenon by (38) implies that it is understood as an interface phenomenon. (38) does not reveal any significance feature geometry might have in the coda nasalization phenomenon. We must broaden our empirical perspective at this point and first consider codas at word-final position.

6.1. Terminal codas

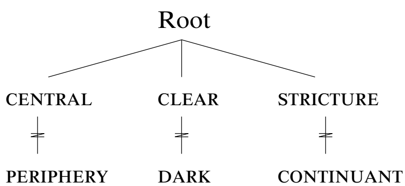
We consider those codas that are followed by a pause; let us call such codas TERMINAL CODAS. There are two, and only two, types of terminal codas, unvoiced and nasal. Words that exemplify the nasal terminal coda are legion: *mikan* 'mandarin orange', *takusan* 'many', *san* 'three', *san-nin* 'three persons' etc. In contrast, unvoiced terminal codas can be found only in a small number of interjections such as *a!* 'ah' and *si!* 'hash', words uttered with exclamatory intonation. Phonetically, the terminal coda of such a word as *a!* or *si!* actualizes as a varied degree of tension of the glottis but its presence may not necessarily be obvious. Phonologically, however, its presence can be confirmed by putting such a word in contexts where the coda in question is made non-terminal. If we put *a!* or *si!* before the quotation particle *-to*, the voiceless terminal coda turns into a voiceless non-terminal coda, an initial part of the geminate *-tt-*. We observe an obligatory geminate as in *a! to sakenda* [attosakenda] 'cried out "ah"' (*[atosakenda]) or *si! si! to sasayaita* [ʃi'ʃittosasayaita] 'whispered "hash!"' (*[ʃiʃitosasayaita]).

In addition, any word may be uttered with an intonation of exclamation, and can be followed by the quotative *to* with gemination, as in *kuma! to sakenda* [kumattosakenda] 'cried out "bear!"'. But in this case a plain quotation without gemination is also possible: *kuma-to sakenda* [kumato-sakenda]. The difference in the observed obligatory vs. optional gemination in the *to* quoted form provides evidence for the lexical presence of a voiceless terminal coda in an interjection that requires gemination in the *to*-quotation form. By this criterion, we can test whether an interjection lexically ends in a voiceless coda or not; the interjection *kora* does not have a voiceless coda in the lexicon and may be quoted without a coda: *kora to itta* ‘uttered *kora*’ [koratoitta].

Now the question is how we account for terminal codas. At this position all the phonological oppositions are reduced except for voicelessness vs. nasality. Such a radical reduction is a characteristic of neutralization. Feature geometry formally captures neutralization in terms of DELINK. We might wonder if we can find an account of coda neutralization in terms of DELINK.

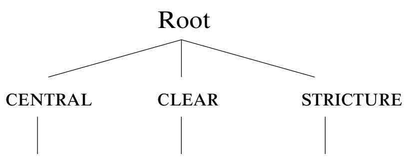
Indeed, if all terminal codas were voiceless, it would be easy to account for them in terms of DELINK. We can introduce the following rule of DELINK as a constraint at terminal coda position.

(39)



This rule has the effect of constraining terminal codas to the following form with dangling branches:

(40)

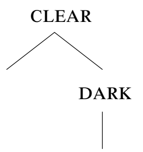


This structure is a reasonable representation for the voiceless terminal coda. The interface condition given in (15) returns /t/ for (40) and is obviously inadequate, but we are not concerned with detailed interface conditions in this paper, which could be highly context-sensitive. Suffice it to note that (40) taken together with (39) indicates that there is no phonological contrast at terminal coda position.

But DELINK would not seem to give us an adequate means to represent the nasal terminal coda in terms of neutralization. The key to get out of this impasse, I propose, is to attribute the voiceless/nasal contrast to the difference in the types of sites rather than in the forms of segments. To elaborate on this idea we need to recall, first of all, that I have introduced the notion of sonorant site in an earlier work: a SONORANT SITE is a site where the projection of the VOICE-QUALITY branch reverses. Commonly sounds are divided into consonants and vowels, and sonorants and glides count as consonants. But I assume that sonorants and glides function like consonants together with obstruents at some sites, but at some other sites they function characteristically as sonorants or glides proper and in a different way than obstruents; such sites are by definition SONORANT SITES. The reversed projection at sonorant sites captures the generalization that unmarked sonorants are nasals. I exploited this idea in Kuroda (2003) for the account of the assimilation among sonorants in Korean.

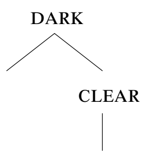
In the geometry I am proposing in this paper the VOICE-QUALITY branch is given as in (8), which I repeat here:

(41) The VOICE-QUALITY branch



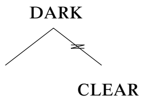
At a sonorant site, this tree is projected upside down:

(42) The VOICE-QUALITY branch projected upside down



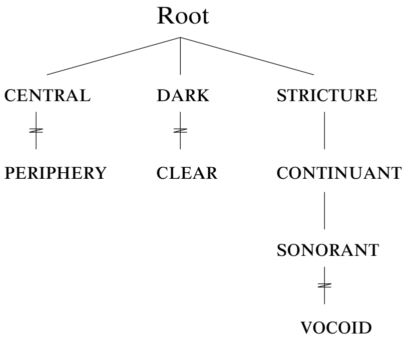
Given this tree assume that we delink CLEAR in (42):

(43)



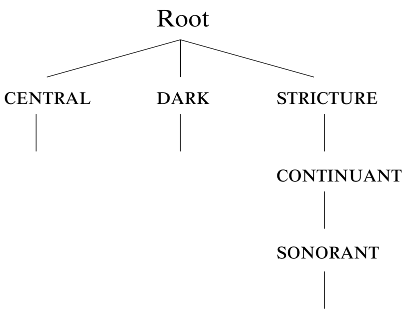
We have then the neutralization in favor of nasality over voicing for SONORANT segments. We can introduce the following DELINK rule parallel to (39) at a sonorant coda site:

(44)



This rule constrains the nasal terminal coda to the form represented by the following tree:

(45)



In sum, I propose the following account of terminal codas:

(46) Coda Condition

There are two types of codas, one at a consonantal site and the other at a sonorant site; segments that occupy these coda sites are constrained by DELINK rules (39) and (44).

As a consequence of (46), a terminal coda is a form represented either by (40) or (45).

6.2. Word-internal codas

We now consider word-internal codas. A null hypothesis would be to maintain (46) for word-internal codas as well. I wish to claim that that is in fact the case. There are three cases to consider:

[1] Lexically determined codas. Lexically determined codas arise either morpheme-internally, as given in (33), or at a morpheme-boundary inside a word, as illustrated below. We observe the same patterns of the coda-onset pairs for these two subcases.

(47) (i) *set-toku* ‘persuade’, *hip-paru* ‘pull, tug’, *gak-koo* ‘school’, *zas-si* ‘magazine’;
(ii) *bum-poo* ‘grammar’, *kom-ban* ‘this evening’, *bun-too* ‘sentence-head’, *mon-dai* ‘problem’, *san-kaku* ‘triangle’, *bun-gaku* ‘literature’, *sin-situ* ‘bedroom’, *sin-zitu* ‘truth’.
(iii) *him-mageru* ‘twist’, *bun-naguru* ‘wallop’, *han-ran* ‘revolt’, *kon-ya* ‘tonight’, *sin-wa* ‘mythology’.

[2] The well-known *ri*-extended mimetic adverbs to be discussed below.
[3] The verb morphology illustrated in (21)–(24).

A crucial difference between word-final and word-internal codas is that word-internal codas are liable to the assimilation from the onsets that follow them. This assimilation is total, as it is responsible for producing geminates. I hence assume that the initial (the most unmarked) node of each main branch spreads from the onset leftwards to the coda:

(48) Regressive Assimilation

x y

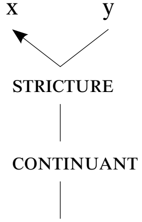
[CENTRAL, VOICE, STRICTURE]

The brackets indicate that the three branches spread.

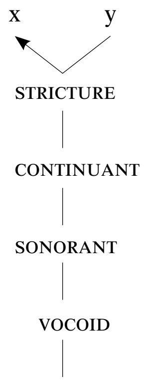
Next, what about the effects of the neutralization at coda position, which for terminal codas is embodied in rules (39) and (44)? We observe in (33) and (47) that the PLACE of articulation is not neutralized at word-internal coda position. In contrast, VOICE QUALITY, I assume, is constrained for word-internal codas in the same way as for terminal codas: they are voiceless at consonantal sites and nasal at sonorant sites. Since the coda may be either voiceless or nasal if the onset is a voiceless obstruent, but must be nasal otherwise, we have the following rule that determines the type of coda site:

(49) Coda site rule:
If the onset that follows it is not a voiceless obstruent, the coda is a sonorant site.

As for SONORITY the opposition between STRICTURE and CONTINUANT is preserved at consonantal sites (cf: *sattoo* 'rush to' vs. *sassoo* 'dashing') and that between SONORANT and VOCOID at sonorant sites (*konro* 'stove' vs. *konya* 'tonight'). These contrasts, however, can be accounted for by Regressive Assimilation by assuming that it is a late rule ordered after DELINK rules (39) and (44). The relevant parts of *sassoo* and *konya* after Regressive Assimilation has applied are shown below:

(50)


(51)



We now have to turn our attention to the differences among [1]–[3]. For [1], codas are given in the lexicon. For [2], codas are inserted into underlying representations by a morphological rule that generates *ri*-extended mimetic adverbs. Finally, in the case of [3] a stem-final consonant is given in the lexicon, which is made a coda as a result of a morphological process of suffixation. For example, the coda position occupied by /n/ in the surface form *tonda* 'flew' is derived as a result of the suffixation: /tob/+/ta/. In the following subsections, I am going to show case by case that the rules stated above account for the facts.

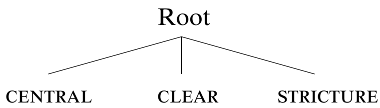
6.2.1. Lexically determined codas

We need to distinguish morpheme-internal codas as exemplified in (33) and codas at a morpheme boundary, that is, morpheme-final codas as shown in (47). In either case the surface forms of codas are determined by the onsets that follow them due to Regressive Assimilation, but different situations prevail for the underlying representations of codas.

6.2.1.1. Morpheme-internal codas

If the coda is a consonantal site, we assume that the coda is given in the form of the following archiphoneme:

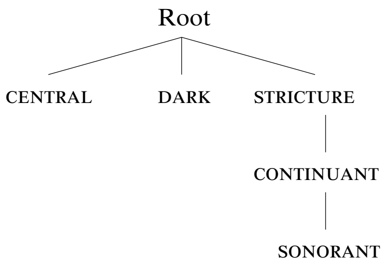
(52)



The PLACE and the SONORITY branches are filled in by Regressive Assimilation.

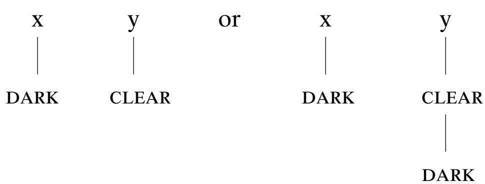
If the coda is a sonorant site, we assume that the coda is the following archiphoneme:

(53)



The onset can be either an obstruent, sonorant or glide. If the onset is a glide, the coda also becomes a glide by Regressive Assimilation; otherwise it remains as a sonorant. VOICE-QUALITY of the coda can never be affected by the onset; for, this branch is projected "upside down" at the coda site, but it is not at the onset site, and hence Regressive Assimilation cannot apply. To see this, observe the following figure where x is a coda at a sonorant site and y is an onset:

(54)



Regressive Assimilation cannot *unify* these two trees by SPREAD. This accounts for the fact that we have *konro* and *konya* [kõj̃ja] but not **korro* or **koyya*. In all, we can get a nasal followed by an obstruent, sonorant or glide, either CLEAR (a voiceless obstruent, a liquid or a glide) or DARK (a voiced obstruent or a nasal).

6.2.1.2. Morpheme-final and word-internal codas

Morpheme-final codas are determined in a fully specified form (or, at least, a more fully specified form) underlyingly in the lexicon and are transformed into surface forms by Regressive Assimilation. There are two major sources for morpheme-final codas, Sino-Japanese compounding and Yamato verbal root compounding: For Sino-Japanese morphemes, their underlying representations can be determined from their free or word-final occurrences. For example, the word-final form of the first morpheme in the compound *zas-si* 'magazine' given above in (47) is phonologically /zatu/ and phonetically [dzatsu], as in *huku-zatu* 'complex'; assuming that the final vowel is epenthetic, the underlying representation is /zat/ and Regressive Assimilation transforms it to /zas-/ in the compound *zas-si* 'magazine'. The derivation of the surface forms of verbal root compounds are derived from their underlying representations by Regressive Assimilation possibly together with some other (morpho-)phonological processes. For example, *hip-paru* 'pull, tug' given above in (47) is derived from the underlying /hik-har-u/, where /h/ alternates with /p/, showing the historical origin of the Modern Japanese /h/.

A complete treatment of these compounding phenomena is outside the scope of this paper[10]. It suffices to note that the morpheme-final codas that result from the compounding processes conform to the conditions set by (39), (44) and (49) and by Regressive Assimilation.

6.2.2. Codas in *ri*-extended mimetic adverbs

We can assume that *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 the table below, or by the

10) For the recent treatment of these much discussed topics, see Ito and Mester (1996) and Kurisu (2000).

following morphological rule that inserts a segment C_0 between the two stem moras:

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

$C_1V_1C_2V_2 \rightarrow C_1V_1C_0C_2V_2$ ri

The phonetic forms of *ri*-extended mimetic adverbs are given in the second column of (56). There are also mimetic adverbs that lack the corresponding reduplicate forms. I will apply the term *ri*-extended mimetic adverbs to such forms, too.

(56)

Reduplicated forms	*ri*-extended forms		
$C_1V_1C_2V_2$-$C_1V_1C_2V_2$	$C_1V_1C_0C_2V_2$ri		
hakihaki	hakkiri		‘clearly’
yutayuta	yuttari		‘leisurely’
tyopityopi	tyoppiri		‘slightly’
kosokoso	kossori		‘stealthily’
*kogakoga	koŋgari	(*koggari)	‘(toasted) brown’
sugasuga(-sii)	suŋgari	(*suggari)	‘nicely, slender’
*nodonodo	nondori	(*noddori)	‘balmy’
syobosyobo	syombori	(*syobbori)	‘discouraged’
*mazimazi	manziri	(*mazziri)	‘[can’t sleep] a wink’
boyaboya	boỹyari	(*boyyari)	‘absent-mindedly’
yawayawa	yaw̃wari	(*yawwari)	‘softly’
korokoro	??konrori	(*korrori)	‘[roll] over and over’

I cannot find good examples for C_2=/r/; the form ??*konrori* is somewhat dubious, but **korrori* is certainly impossible[11)]. The coda C_0 in the *ri*-extended mimetic adverb is subject to a condition more strict than (46). For, in this case, we cannot have a nasal coda before a voiceless obstruent; we do not have forms like **mansiri*. We need a special coda site rule:

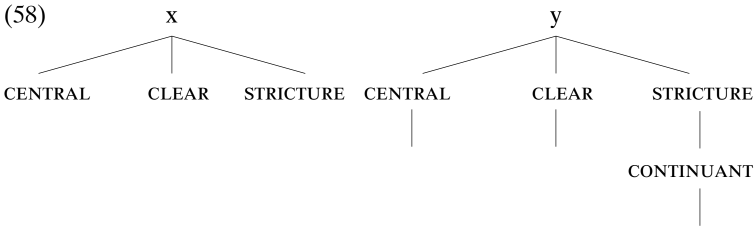
11) In (56), ỹ and w̃ represent nasalized glides. *Sungari* and *nondori* are not common words but are found in Shinmura (1997). I cannot come up with another example with C_0=/d/, but *gundari* or *gunderi* is certainly a possiblility.

(57) Coda site rule for the ri-extended mimetic adverb:
The coda is a sonorant site if and only if the onset that follows it is not a voiceless obstruent.

We assume naturally that C_0 is underlyingly given as the archiphonemes (52) at a consonantal coda site and (53) at a sonorant coda site, respectively.

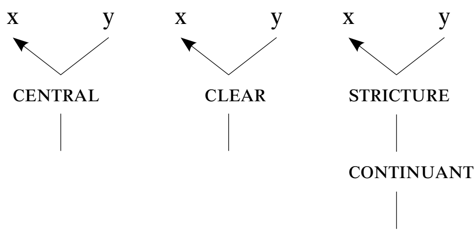
Consider, for example, *kossori*. C_0 must be a consonantal site by (57). We have the underlying representation /koC_0sori/ where x=C_0 and y=C_2 are given as follows:

(58)



Regressive Assimilation spreads the three branches of y to x and we get:

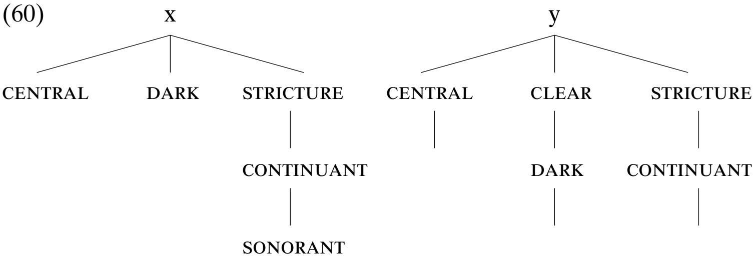
(59)



Thus, the sequence xy realizes as a voiceless geminate [ss]. There is a good reason why the morphological process of the *ri*-extended mimetic adverb requires the special form of a coda site rule (57). If x=C_0 could be a sonorant site, we would have doublets *kossori* and *konsori* corresponding to one and the same two mora stem *ko-so*.

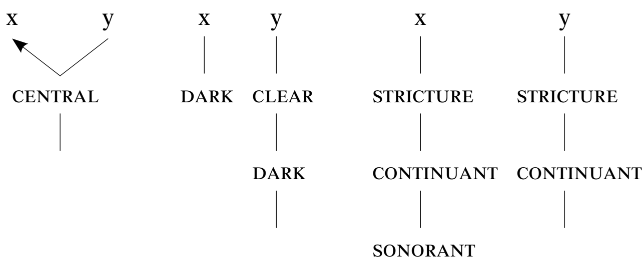
Now, take *manziri.* In the underlying representation, we have the following trees:

(60)



Regressive Assimilation fails to apply, except for the PLACE branch and we get:

(61)



At the interface, the sequence is converted to /nz/, or phonetically [ndz].

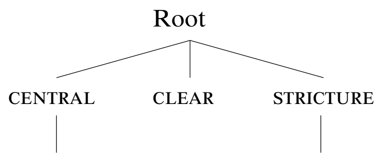
6.2.3. Codas in verb morphology

In this case a stem-final consonant is given in the lexicon and it is put in coda position as a result of a morphological process of suffixation. As we have seen above, whether a coda is a consonantal or sonorant site must be dependent on the onset that follows. But what is particular about this case of verb morphology is that the onset itself is determined in turn by the stem-final consonant that is put in coda position; the value of VOICE-QUALITY (CLEAR or DARK) is transferred from the coda to the onset by Progressive Assimilation, and then back to the coda thanks to Regressive Assimilation.

A crucial point of this transfer of VOICE-QUALITY forward and backward between the coda and the onset is that it cannot be described in terms of phonetics in the narrow and usual sense. The liquid /r/ and the glide /w/ are phonetically voiced but geometrically CLEAR; this VOICE-QUALITY, once transferred to the onset, is phonetically destined to embody voicelessness when it is transferred back to the coda by Regressive Assimilation, due to the fact that it is now accompanied by the sonority degree of an obstruent, not of a sonorant or a glide.

We assume that the suffix-initial consonant is the following archiphoneme:

(62)



Let C_1 be the above archiphoneme and C_2 be the archiphoneme (52). Then, we have the following derivation for *katta* 'bought':

(63)	/kar/+/C_1a/	>	/kar-ta/	by Progressive Assimilation
		>	/kaC_2-ta/	by (39)
		>	/kat-ta/	by Regressive Assimilation

Next, consider the derivation of *tonda* 'flew, jumped'. Let C_3 be the archiphoneme (53). The underlying representation of *tonda* is /tob-C_1a/. The coda is at a consonantal site and Progressive Assimilation applies between b and C_1:

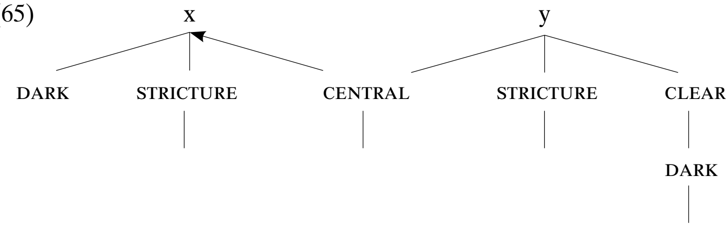
(64) /tob-C_1a/ > /tob-da/ by Progressive Assimilation

Now, the coda /b/ is followed by a voiced obstruent and hence the coda site switches from consonantal to sonorant; /b/ must be replaced by the archiphoneme C_3:

>/toC_3 -da/.

Regressive Assimilation affects only the PLACE branch and we get the following tree structure:

(65)



This tree materializes as the phone sequence /-nd-/.

6.3. Summary

Coda nasalization is captured as an effect of neutralization at sonorant coda sites, where the VOICE-QUALITY branch is projected upside down. At terminal coda position this neutralization is transparent: a sonorant coda is the unmarked nasal segment. At word-internal coda position neutralization is opaque except for the VOICE-QUALITY branch due to Regressive Assimilation. Besides, Progressive Assimilation can affect the type of coda site, switching it from consonantal to sonorant.

7. Summary and Conclusion

As I stated at the beginning, this paper makes claims at three levels and accordingly it would have to be evaluated properly at each level. At the lowest level, the paper is a empirical study of voicing in Japanese. At the second level, the paper concerns the particular feature geometry, ADFG, which I have proposed in earlier works, and it proposes a major revision for ADFG. At the third level, the paper relates to the fundamental issues in the phonological side of linguistic theory, the nature of feature geometry and in particular the role of phonetic features in linguistic theory.

I claim first of all that this work is an improved version of the account of voicing in Japanese given in Kuroda (2002) and that it provides sufficient evidence and argument for the account as an empirical study of a linguistic phenomenon. The account is framed in a particular form of feature geometry, and in fact it is claimed to serve in turn as continued empirical justification for a new conception of feature geometry proposed in the earlier works and for the further innovation formulated in this work. Nonetheless, this study should be evaluated as an empirical descriptive work independently of the claim about feature geometry made at the second level. I would like to maintain that I have provided the *right* analysis of the relevant phenomena in Japanese phonology, and hence any theoretical framework must be able to accommodate the essential features of this analysis.

The analytical improvement over the earlier version consists in two respects. For one thing what matters as a crucial phonological contrast is captured not in terms of phonetic features [+/-voiced] but in terms of abstract nodes introduced in the renovated ADFG, CLEAR vs. DARK. This renovation allows us to rid ourselves of the following redundancy rule:

(66) [+sonorant] $\Rightarrow$ [+voiced],

or its equivalent in the earlier version of ADFG:

(67) SONORANT $\Rightarrow$ VOICED.

Secondly, the phenomenon of coda nasalization is captured in this work as an instance of neutralization, formally speaking, in terms of DELINK in feature geometry. In the previous works this phenomenon was accounted for by a replacement rule such as follows:

(68) $[+\text{voiced}])_\sigma$ $\Rightarrow$ [+nasal]

or, its equivalent in the earlier version of ADFG:

(69) $\text{VOICED})_\sigma$ $\Rightarrow$ NASAL.

Such an account is descriptively adequate, but gives no insight into whatever phonologically essential that there might be behind the phenomenon.

At the second level, this study is a continuation of Kuroda (2002,

2003) and argues for a new architecture for feature geometry, ADFG. Such an enterprise cannot be completed by the accounts of two phenomena selected from two languages, voicing in Japanese and sonorant assimilation in Korean. Nonetheless, I would like to claim that providing these two *right* accounts with foundations and making them possible, ADFG must be recognized as a viable alternative approach to feature geometry. To be sure it must be expanded and detailed for dealing with a variety of phonological phenomena. To begin with, in order to describe languages with a richer inventory of sounds, ADFG must incorporate a mechanism for secondary articulation and more descriptive work has to be done in a variety of ways, but I believe that the empirical studies done so far can be taken as a good starting point for a new venture.

The present work contributes to the renovation of the theory of feature geometry in two respects, corresponding to the two analytical innovations mentioned above. First of all, I now maintain that nodes in feature geometry must be conceived of as more abstract entities than commonly assumed. A node does not correspond directly to phonetic reality as it is commonly conceived. It cannot be taken as an equivalent to, or a surrogate of, a generic term based on phonetically defined features. CLEAR and DARK certainly correlate with the opposition voiceless/voiced, but their relation is only context-sensitive; CLEAR cannot be understood extensionally as a generic or universal definable in terms of the phonetic feature [voiceless], nor can DARK in terms of [voiced]. CLEAR and DARK are an abstract opposition that SONORITY can exploit as phonological resources to enrich the phonemic inventory by actualizing them either in terms of voicing or nasality.

Second of all, the present work continues to show the significance of the concept of projection reversal. In the earlier works I have had recourse to projection reversal for the account of assimilation among sonorants in Korean. I have demonstrated in this paper that the impoverished contrast among segments at coda position in Japanese can be reduced to the contrast between different types of sites and that coda nasalization must be understood as neutralization where the projection of VOICE-QUALITY is reversed.

At the third level, I have suggested that phonetic features are not constitutive of feature geometry. Abstract away from prosody, outputs from phonology consist of sequences of segments determined by feature geometry; segments are trees composed of abstract nodes and "dangling" lines, without phonetic features attached to them.

Once rid of phonetic features, feature geometry is freed of the commitment, common among phonologists, according to which words and sentences are represented by sequences of phones, or by matrices composed of phonetic features. Thus, the content of this commitment must be taken as an empirical issue. The issue, such as it is, has been raised from the side of phoneticians, who, at least some of them, seem doubtful about the viability of phonetic features.

I have formulated *interface conditions* in terms of phonetic features. These conditions, then, transform outputs from feature geometry into matrices of phonetic features in a straightforward manner. Those interface conditions are context-free and trivial, except for those context-sensitive ones related to CLEAR and DARK, and even the latter are relatively simple. Limited to one language and to one phenomenon, the empirical content of this work is too meager to substantially contribute to big issues such as whether speech is represented by sequences of phones at any level, or what role phonetic features might have in phonology/phonetics. Nonetheless, it is significant that an improved analysis of voicing in Japanese can be achieved with the reduced role of phonetic features in feature geometry. The interface conditions formulated above, then, should be taken for now simply as expository guides, without any implication as to what role phonetic features might have in the theory of the phonology-phonetics interface and in phonetics proper.

There seem to have been two driving forces behind the development of feature geometry. One originates in functional contrasts observed in phonology, and the other in acoustic/articulatory parameters in phonetics.

In this paper I am emphasizing the abstract character of nodes and deemphasizing the role of phonetic features in feature geometry. By doing so, I might give the impression that my approach to feature geometry is functionally motivated and based on *cognitive idealism*, in the sense that it allows itself to relate to reality only in the matters of mind/brain. But an initial motivation behind Aerodynamic Feature Geometry is precisely to steer feature geometry away from such a tendency. It is meant to be founded on the physical reality of the design of the vocal organs and the aerodynamics of speech sounds produced by them.

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素性階層理論と音声素性
——日本語の有声化とコーダ鼻音化についての試み——

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日本語の有声同化及びそれに関連する有声コーダ鼻音化の現象を説明する企てを通して，空力素性階層理論の修正を提案し，それを通じて素性階層理論と音声素性との関係について注意する．まず，有声同化現象を説明するのに，素性階層理論では，有声無声の別に対応する節点をたてず，それに代えて「清濁」の別に対応する節点をたて，流音・半母音は清，鼻音は濁とする．コーダ鼻音化は，射影反転という概念のもとで，中和現象として素性階層理論的に自然に説明されることを示す．このような考察を通じて，音声素性は，音韻論と発声機構との境界条件の表現に必要であるにしても，素性階層理論本体の構成要素ではない，という提案をする．

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