A Phonological Analysis of Numeral-Counter Compounds in Japanese Within the Framework of Generative Phonology

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I. Introduction

There are a class of formatives called counters in Japanese. Each counter is used to count or modify some specific class of nouns which have some semantic feature in common such as shape or appearance. Counters are usually combined with numerals to construct numeral-counter compounds and the relevant numerals for the discussion of these compounds are numerals from one to ten, because in Japanese numerals from eleven on are composed of 'ten' and 'one', 'ten' and 'two' and so on. The numerals from one to ten are as follows :

?iči(one),[(1)] ni(two), san(three), yon(four), go(five), roku(six), hiči(seven), hači(eight), kyuu(nine), juu(ten)

Numeral-counter compounds show some irregular alternations in their phonetic shapes, for example, 'sam*by*aku(300)' vs. 'yon*hy*aku(400)', not *'yom*by*aku', 'sannin(3 persons)' vs. '*yo*nin(4 persons)', not *'*yon*nin', 'kyuukai(9 times)' vs. '*juk*kai(10 times)', not *'*juu*kai' though we say 'kyuumai(9 sheets)' and 'juumai(10 sheets)', and 'hičiten(7 points)' vs.

'*hat*ten (8 points)' but 'hičijikan (7 hours)' and 'hačijikan (8 hours)'.
The list of these examples may be easily extended but they are suffi-
cient to show the irregularities of the phonetic alternations.

The aim of this paper is to set up the underlying forms for the numerals
in question and formulate several phonological rules which convert the
underlying forms into the actual phonetic forms and account for those
irregularities on the phonetic level. These phonological rules should
be general and independently motivated in that they are in any case
necessary to account for other phonetic facts in Japanese phonology.
Therefore, in discussing numeral-counter compounds we will often refer
to other phonetic facts observed in Japanese.

II. Underlying Forms for Numerals

The underlying forms for numerals from one to ten may be set up
as follows :

underlying forms	phonetic forms
it	?iči/?it
ni	ni
san	san
.yo-	yon/yo
go	go
roku	roku/rok
hiti	hiči
hat	hači/hat
kyuu	kyuu
jupu	juu/jup.

To begin with, let us take up those underlying forms which are different
from the corresponding phonetic forms in an essential way, that is,

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/it/, /hat/, /yo-/ and /jupu/.

(1) /it/ and /hat/ : I set up these forms to account for the alternation
?iči/?it and hači/hat, considering also that /hiti/ shows no such
alternation. Compare the following examples :

$?it$/*hat*-ten (1/8 points)   vs.   *hiči*ten (7 points)

$?ip$/*hap*-pai (1/8 glassfuls etc.)   vs.   *hiči*hai (7 glassfuls etc.)

$?ik$/*hak*-ken (1/8 houses)   vs.   *hiči*ken (7 houses)

$?is$/*has*-sai (1/8 of age)   vs.   *hiči*sai (7 of age)

$?iš$/*haš*-šoo (1/8 *shoo*)   vs.   *hiči*šoo (7 *shoo*)

McCawley sets up '?iti & piki' as the underlying form for '?ippiki'.[2]
But his underlying form '?iti' is not satisfactory for the following
reasons :

(a) He has to delete the final 'i' to get '?ippiki' and the i-deletion
rule must be very *ad hoc* because 'i' is not deleted in the case of
'hiti & piki' :

   ?iti & piki $\longrightarrow$ *?ip*piki

   hiti & piki $\longrightarrow$ *hiči*hiki

(b) One might suggest that one can set up /hit/ rather than /hiti/
as the underlying form for 'hiči'. But observe that numerals
ending in a vowel behave one way and those in a consonant
behave another with respect to the shape of the counters
following them and that 'hiči' takes the counter of the same shape
that occurs after 'ni', 'go' and 'kyuu'. For instance, consider the
following :

   ni/go/kyuu-*hiki* (2/5/9 animals)   vs.   hiči*hiki* (7 animals)

   ni/go/kyuu-*ho* (2/5/9 steps)   vs.   hiči*ho* (7 steps)

Therefore, the underlying form for 'hiči' should end in a vowel,
as in the case of those for 'ni', 'go' and 'kyuu'.

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From the above discussion it follows that the underlying formsfor '?iči/it'
and 'hači/hat' must end in a consonant. Otherwise, one will face
difficulties in accounting for the difference between ?*it*ten/*hat*ten and
*hiči*ten, *?ip*piki/*hap*piki and *hiči*hiki, and the like.

(2) /yo-/ : The underlying form /yo-/is set up to take care of the
following phonetic facts :

(a) There is no difference in pitch pattern or accent between 'san' and
'yon' but counters following them are often different in their
phonetic forms :

> san*zen*(3, 000)　　　　vs.　yon*sen*(4, 000)
>
> sam*bon*(3 pencils etc.)　vs.　yon*hon*(4 pencils etc.)
>
> sam*pacu*(3 shots)　　　vs.　yon*hacu*/yom*pacu*(4 shots)

(b) 'yo' is one of the alternative phonetic forms :

> *yo*?en(4 *yen*)　　　* *sa*?en(3 *yen*)
>
> *yo*nen(4 years)　　　* *sa*nen(3 *years*)
>
> *yo*nin(4 persons)　　* *sa*nin(3 persons)
>
> *yo*jikan(4 hours)　　* *sa*jikan(3 hours)

(c) 'yon' and 'yo' take a counter of the phonetic form that occurs
after numerals ending in a vowel :

> yon*sen*(4, 000)　　　　vs.　ni/go/kyuu-*sen*(2/5/9, 000)
>
> yon*hon*(4 pencils etc.)　vs.　ni/go/kyuu-*hon*(2/5/9 pencils etc.)
>
> yon*hacu*(4 shots)　　　vs.　ni/go/kyuu-*hacu*(2/5/9 shots)

Therefore, we may safely assume that 'yon' has the underlying
form /yo-/ and that 'n' is inserted later by some phonological rule.
This rule will be discussed later in the section of the '*n*-insertion
rule'.

(3) /jupu/ : This form is posited to account for the alternation
juu/jup. This underlying form has some advantage over the form

ending in a consonant, /jup/. Firstly, we have only to drop the final 'u' of /jupu/ to get the phonetic 'jup'. And the dropping of 'u' is a phonetic phenomenon that often occurs in Japanese. Secondly, we can get the phonetic 'juu' by deleting the intervocalic 'p'. The deletion of 'p' in this environment is another general operation which is needed in Japanese phonology. On the other hand, if one chooses /jup/ as the underlying form it will be very difficult to get the phonetic form /juu/ from /jup/; one will need the u-insertion rule which will have to be very *ad hoc*, in addition to the p-deletion rule.

Incidentally, McCawley sets up 'zipu' or 'zyupu' as the underlying form for 'zyuu'.[3] Let us leave 'zipu' out of account for the present because 'zip' in 'zippiki' and others is not an established standard form in Japanese.[4] Our underlying segment /p/ is significantly different from McCawley's /p/ in the following point :

Formative-initially our /p/ becomes 'h' when preceded by a vowel. Within a formative, after a vowel, /p/ becomes 'w' when followed by the vowel 'a', and 'ϕ' when followed by any vowel other than 'a'. This will be stated informally as :

$$
p \longrightarrow \left\{ \begin{array}{l} h/V + - V \\ w/V - a \\ \phi/V - \left\{ \begin{array}{l} i \\ u \\ e \\ o \end{array} \right\} \end{array} \right\}
$$

On the other hand McCawley's /p/ becomes 'h' or 'p' and he sets up further rules such as 'h→?', '?→w', '?→ϕ'. Let us compare his analysis and ours in connection with the derivation of 'juu' and 'kawa' :

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his analysis		our analysis	
	zyupu		jupu
p→h	zyuhu	p→φ	juu
h→?	zyu?u		
?→φ	zyuu		

his analysis		our analysis	
	kapa (river)		kapa
p→h	kaha	p→w	kawa
h→?	ka?a		
?→w	kawa		

Our analysis is straightforward, compared with his rather un-
wieldy analysis.

Moreover we may show that his rules 'h→?', '?→w' and '?→φ' are
rather *ad hoc* for the following reasons :

(a) The intermediate forms 'zyuhu', 'zyu?u' or 'kaha', 'ka?a' are
rather unnatural because they do not occur in actual speech.

(b) His rules fail to capture the complementary distribution of 'p',
'h', 'w' and 'φ'.

(c) The distribution of '?' is predictable in Japanese. It occurs formative-
initially before a vowel, or formative-internally when preceded by
a vowel and followed by any vowel other than 'i' or the vowel
identical with the preceding one, or after a syllabic nasal before a
vowel :

?iči(one), ka?o(face), kai(meeting) *ka?i

?otoosan(father) *?oto?osan, han?igo(antonym)

Therefore, the most natural way to treat '?' is in terms of the
?-insertion rule something like :

$$\phi \rightarrow ? / \begin{Bmatrix} \begin{Bmatrix} + \\ n \end{Bmatrix} - V \\ V_m - V_n \end{Bmatrix}$$

where V_m is a vowel, V_n is any
vowel except i, and $V_m \neq V_n$

Then his rule 'h→?' is unnecessary and *ad hoc*. He also sets up
another rule to the effect that 'y→?'[5] and this will be shown to
be another *ad hoc* rule.

(d) There is independent evidence to show that the ordering is
'w→?' rather than '?→w'. That is to say, when we have a phonetic
form 'X-wa-Y (X is not null, Y may be null)' we have an
optional alternative 'X-(?)-a-Y' but not the other way around[6]:

OPT   tawara→(ta?ara)→taara (straw-bag)

   mawasu→(ma?asu)→maasu (turn)

   sawaru→(sa?aru)→saaru (touch)

   kowai→ko?ai (fearful)

   kowasu→ko?asu (break)

   Kuwašii→Ku?ašii (detailed)

   siwagare (goe)→ši?agare (goe) (→šagare(goe)) (a hoarse
   voice)

Cf.   de+ai→de?ai (meeting) *dewai

   si+ai→ši?ai (game) *šiwai

   ki+ai→ki?ai (a yell) *kiwai

   so+aku→so?aku (coarse) *sowaku

   su+asi→su?aši (bare feet) *suwaši

III. Phonological Rules for Numeral-Counter Compounds

(1) *i*-insertion rule : This rule is posited to derive phonetic forms '?iči'
and 'hači' in '?iči/hači—mai' etc. from the underlying /it/ and /hat/,

respectively. This rule will be formulated as follows :

$$
(I') \quad \phi \rightarrow \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ -\text{back} \end{pmatrix} \bigg/ \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{cor} \\ -\text{voice} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \quad \begin{pmatrix} +\text{voice} \end{pmatrix}^{(7)}
$$

This rule is independently motivated in Japanese phonology in that it
is needed to account for the combinations of verb stems and auxiliaries
such as the following :

Verb Stem		Auxiliary

$$
\begin{Bmatrix} \text{harap (pay)} \\ \text{tat (stand)} \\ \text{aruk (walk)} \\ \text{sas (sting)} \\ \text{yorokob (rejoice)} \\ \text{oyog (swim)} \\ \text{nom (drink)} \\ \text{sin (die)} \\ \text{nor (get on)} \end{Bmatrix} + \begin{Bmatrix} \text{masu} \\ \text{nagara} \end{Bmatrix} \rightarrow \begin{Bmatrix} \text{harai}^{(8)} \\ \text{tači} \\ \text{?aruki} \\ \text{saši} \\ \text{yorokobi} \\ \text{?oyogi} \\ \text{nomi} \\ \text{šini} \\ \text{nori} \end{Bmatrix} \cdot \begin{Bmatrix} \text{masu} \\ \text{nagara} \end{Bmatrix}
$$

The above rule (I') needs some modification in its environment so that
it can take care of the phonetic fact observed in the above combi-
nations. Thus, we get :

$$
(I) \quad \phi \rightarrow \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ -\text{back} \end{pmatrix} \bigg/ \begin{pmatrix} +\text{cons} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \begin{pmatrix} +\text{voice} \end{pmatrix}
$$

(2) *u*-deletion rule : This rule is designed to delete in certain environ-
ments the final 'u' of the underlying form /roku/ and /jupu/.
Before formulating the rule we have to take into consideration the
fact that the environments in which the *u*-deletion occurs are dif-
ferent between /roku/ and /jupu/.

jupu-pen(10 times)   vs.   roku-pen(6 times)

jupu-kai(10 times)   vs.   roku-kai(6 times)

jupu-too(10th grade)   vs.   roku-too(6th grade) *rottoo

jupu-sai(10 of age)   vs.   roku-sai(6 of age) *rossai

jupu-čaku(10th in the race)   vs.   roku-čaku(6th in the race)

                                           *ročaku

Therefore, the rule will be formulated as follows :

$$(\text{II}')\begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ +\text{back} \end{pmatrix} \rightarrow \phi / \left\{ \begin{matrix} \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{ant} \\ -\text{cor} \\ -\text{voice} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \begin{pmatrix} -\text{son} \\ -\text{voice} \end{pmatrix} \\ \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{back} \\ -\text{voice} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ -\text{cor} \\ -\text{voice} \end{pmatrix} \end{matrix} \right\}$$

Further observe that the deletion of 'u' often occurs in the combi-
nation of two formatives into noun compounds :

gaku-koo→gakkoo(school)

tatu-pitu→tappitu(skillful penmanship)

datu-kai→dakkai(recapture)

katu-sai→kassai(applause)

katu-ša→kašša(pulley)

tetu-tei→tettei(thoroughness)

setu-čaku→seččaku(binding)

These phonetic facts may be taken care of by the same rule if the
above rule (II') is reformulated into the following :

$$\text{(II)} \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ +\text{back} \end{pmatrix} \rightarrow \phi / \left\{ \begin{matrix} \left[\begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{ant} \\ -\text{voice} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \begin{pmatrix} -\text{son} \\ -\text{voice} \end{pmatrix} \right] \\ \left[\begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{back} \\ -\text{voice} \end{pmatrix} - \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ -\text{cor} \\ -\text{voice} \end{pmatrix} \right] \end{matrix} \right\}$$

(3) p-rule : This rule is set up to take care of the phonetic distribution of the underlying /p/. As already mentioned, the underlying segment /p/ becomes phonetic 'p', 'h', 'w' or is deleted, depending on the environment in which it occurs. The informal statement of the distribution is as follows :

$$p \rightarrow \left\{ \begin{matrix} \text{h/V} + -\text{V} \\ \text{w/V}-\text{a} \\ \phi/\text{V}- \begin{pmatrix} \text{i} \\ \text{u} \\ \text{e} \\ \text{o} \end{pmatrix} \end{matrix} \right\}$$

This will be formulated into :

$$\text{(III)} \begin{pmatrix} +\text{cons} \\ -\text{cont} \\ +\text{ant} \\ -\text{cor} \\ -\text{voice} \end{pmatrix} \rightarrow \left\{ \begin{matrix} \begin{pmatrix} -\text{son} \\ +\text{cont} \\ +\text{low} \end{pmatrix} / \begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix} \begin{pmatrix} +\text{FB} \\ -\text{seg} \end{pmatrix} - \begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix} \\ \begin{pmatrix} -\text{voc} \\ -\text{cons} \\ +\text{back} \end{pmatrix} / \begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix} - \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{low} \end{pmatrix} \\ \phi \quad / \begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix} - \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ -\text{low} \end{pmatrix} \end{matrix} \right\}$$

This rule [9] may account for the alternation p/h/w/ϕ such as the following ;

p/h   jupu + piki→juppiki (ten animals etc.)

kyuu + piki→kyuuhiki (nine animals etc.)

p/w/ϕ   warap + ta→warapta→waratta (laughed)

warap + nai→warapa + nai→warawanai (not laugh) ⁽¹⁰⁾

warap + masu→warapi + masu→waraimasu (laugh)

Incidentally, observe that the above derivations show the ordering of
the application of the rules, that is, the *p*-rule must follow both the
i-insertion and the *u*-deletion rule.

(4)   *p-s*-voicing rule : When we check the numeral-counter compounds
in Japanese we find alternations p/b and s/z occurring after the
numeral 'san'. Let us cite some of them :

sə*m*bai (3 glassfuls etc.) vs.	rop*p*ai	Cf. sam*p*acu (3 shots)
sam*by*aku (300)	vs. rop*py*aku	Cf. sam*p*aku (3 nights)
sam*b*on (3 pencils etc.) vs.	rop*p*on	Cf. sam*p*un (3 minutes)
san*z*en (3, 000)	vs. roku*s*en	Cf. san*s*ai (3 of age)
san*z*oku (3 pairs of shoes etc.)	vs. roku*s*oku	Cf. san*s*oo (3 ships)
san*z*un (3 *sun*)	vs. roku*s*un	Cf. san*s*acu (3 books)

Similar alternations are also observed in noun compounds such as
the following :

gan + pari→gam*b*ari (endurance)

ten + piki→tem*b*iki (deduction in advance)

man + piki→mam*b*iki (shop-lifting)

en + pan→?em*b*an (streotype)

dan + pira→dam*b*ira (broadsword)

Cf.   sin + pai→šim*p*ai (anxiety)

kan + pan→kam*p*an (dry-plate)

kin + pin→kim*p*in (money and goods)

sin+san→šinẓan (newcomer)

ken+san→kenẓan (checking)

kan+sake→kanẓake (warmed sake)

man+sai→manẓai (comic cross-talk)

Cf. gen+san→gensan (decreased production)

bun+sai→bunsai (literary talent)

ten+sen→tensen (dotted line)

It needs additional work to tell whether or not there are more lexical items that undergo the voicing rule than those which do not. In this paper I tentatively regard as exceptions those which do not undergo the rule.

The above data will enable us to formulate the voicing rule into the followihg :

$$(\text{IV}) \quad [-\text{voice}] \rightarrow [+\text{voice}] \; / \; [+\text{nasal}] \begin{pmatrix} -\text{seg} \\ +\text{FB} \end{pmatrix} \left\{ \begin{pmatrix} \underline{} \\ +\text{cons} \\ -\text{cont} \\ +\text{ant} \\ -\text{cor} \end{pmatrix} \\ \begin{pmatrix} \underline{} \\ -\text{son} \\ +\text{cont} \\ +\text{ant} \\ +\text{cor} \end{pmatrix} \right\}$$

This rule must follow the *p*-rule in application because it applies to some of *p*'s which are derived from the underlying /p/ by the application of the *p*-rule, while some of those *p*'s do not undergo the voicing rule. Therefore, if the voicing rule precedes the *p*-rule it will be much more difficult to formulate the *p*-rule ; moreover, that *p*-rule, if ever set up, will be less general.

One more thing to be mentioned here is that this rule is part of

a more general rule which takes care of the so-called sequential
voicing in Japanese. That rule is not relevant here.

(5) *n*-insertion rule : This rule is posited to derive the phonetic form
'yon' from the underlying /yo-/. As already noted, at page 4, the
underlying form /yo-/ is set up to account for several phonetic
facts. From the data available we can formulate the *n*-insertion rule
as follows :

$$\text{(V)} \quad \phi \rightarrow [+\text{nasal}] / \begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{accent} \end{pmatrix} \begin{pmatrix} \overline{\quad\quad} \\ -\text{FB} \\ -\text{seg} \end{pmatrix} [+\text{seg}]$$

The feature [+accent] is given by the accent placement rule which
must precede this *n*-insertion rule and the feature [+accent] is
necessary in the above rule to exclude ungrammatical *'yonnén',
*'yonnín', *'yonjíkan' etc.. In other words, 'yo-nén', 'yo-nín', 'yo-
jíkan' are exempt from the above rule because the accent is not on
the numeral 'yo' but on the following counter. The feature
[+accent] also takes care of the following alternations :

yóndo/yodó (4 times)   yómban/yobán (4th)
yóndai/yodái (4 vehicles)   yóndan/yodán (4th grade)
yóngoo/yogóo (4 *goo*)   yómmai/yomái (4 sheets
yómmoo/yomóo (4 *moo*)   of paper)
yónjoo/yojóo (4 *joo*)

And the striking fact is that this yon/yo alternation occurs only
before a voiced segment, that is, only before the counters beginning
with a voiced segment. Therefore, the accent placement rule must
be so formulated that it will take care of this phonetic fact. The
formulation of the rule is beyond the scope of this paper.

Moreover, notice that the feature matrix $\begin{bmatrix} -\text{FB} \\ -\text{seg} \end{bmatrix}$ in rule (V) stands

for '—' in /yo-/ and this '—' is necessary to block the application of this rule to other numerals ending in a vowel, but not followed by '—':

/ni/ + /mai/→*ni*m*mai

/go/ + /mai/→*go*m*mai

The *n*-insertion rule must follow the voicing rule to give the correct forms 'yon*h*yaku', 'yon*s*en' etc., not *'yon*b*yaku', *'yon*z*en'.

(6) sibilation and palatalization rule : Before a high front vowel dental stops and fricatives become palatal affricates and fricatives, respectively :

ti→či   di→ji   si→ši   zi→ži

As for the first two, they may be assumed to go through the intermediate stage as follows :

ti→ci (→či)   di→ẓi (→ji)

This assumption will be confirmed by the fact that *t* and *d* are also affected in a similar way by the immediately following high back vowel as follows :

tu→cu   du→ẓu

Thus, these phonetic facts will be taken care of by a sibilation rule as follows :

$$(VI) \quad a. \begin{pmatrix} -voc \\ +cor \end{pmatrix} \rightarrow [+strid] \Big/ - \begin{pmatrix} +voc \\ -cons \\ +high \end{pmatrix}$$

Notice that this rule applies vacuously to si and zi since s and z already have the feature [+strid]. In the next place, palatalization occurs before a high front vowel, i :

ci→či   ẓi→ji   si→ši   zi→ži

The rule will be formulated as follows :

(VI) b. $\begin{pmatrix} -voc \\ +cor \end{pmatrix} \to [+high] / - \begin{pmatrix} +voc \\ -cons \\ +high \\ -back \end{pmatrix}$

Rules (VIa) and (VIb) may be conjoined into :

(VI) $\begin{pmatrix} -voc \\ +cor \end{pmatrix} \to \begin{pmatrix} +strid \\ \langle +high\rangle \end{pmatrix} / - \begin{pmatrix} +voc \\ -cons \\ +high \\ \langle -back\rangle \end{pmatrix}$

(7) assimilation rule : Whenever two non-nasal consonants come into contact across a formative boundary, the first consonant assimilates to the second completely, that is, it becomes the identical consonant with the second :

> it + pai→?ippai (1 glassful etc.)
>
> rok + pai→roppai (6 glassfuls etc.)
>
> jup + ten →jutten (10 points)
>
> jup + kai→jukkai (10 times)
>
> it + sai→?issai (1 of age)
>
> it + čaku→?iččaku (1st in the race)
>
> jup + čaku→juččaku (10th in the race)

This phonetic fact can be stated in terms of a phonogical rule quite similar to a transformational rule in syntax :

(VII) a. $\begin{pmatrix} +cons \\ -nasal \end{pmatrix}$, $\begin{pmatrix} -seg \\ +FB \end{pmatrix}$, $\begin{pmatrix} -son \\ \alpha\ ant \\ \beta\ cor \\ \gamma\ back \\ -voice \end{pmatrix}$

1	2	3				
1	2	3	→	3	2	3

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where $\alpha = \pm$, $\beta = \pm$, $\gamma = \pm$

Rule (VIIa) can also take care of the phonetic facts such as the following :

(a)
$$\left\{ \begin{array}{l} \text{tor (take)} \\ \text{kar (cut)} \\ \text{kap (buy)} \\ \text{arap (wash)} \end{array} \right\} + \left\{ \begin{array}{l} \text{te} \\ \text{ta} \end{array} \right\} \rightarrow \left\{ \begin{array}{l} \text{to}t \\ \text{ka}t \\ \text{ka}t \\ \text{? ara}t \end{array} \right\} \left\{ \begin{array}{l} \text{te} \\ \text{ta} \end{array} \right\}$$

(b) tatu + pitu→ta*p*pitu (skillful penmanship)

datu + kai→da*k*kai (recapture)

katu + sai→ka*s*sai (applause)

katu + ša→ka*š*ša (pulley)

setu + čaku→se*č*čaku (binding)

It is a widely-observed phonetic fact that a nasal consonant assimilates to the immediately following consonant at the point of articulation and this is also observed in Japanese. Thus, we need the rule such as the following :

$$\text{(VII)} \quad \text{b.} \quad [+\text{nasal}] \rightarrow \left(\begin{array}{l} \alpha \ \text{ant} \\ \beta \ \text{cor} \\ \gamma \ \text{back} \end{array} \right) / - \left(\begin{array}{l} +\text{cons} \\ \alpha \ \text{ant} \\ \beta \ \text{cor} \\ \gamma \ \text{back} \end{array} \right)$$

where $\alpha = \pm$, $\beta = \pm$, $\gamma = \pm$

The feature $[\gamma \ \text{back}]$ is necessary to distinguish 'ñ' from 'ŋ'. For example, observe the following :

kon*ñ*aku→ko*ññ*aku (devil's tongue jelly)

kon*ŋ*ari→ko*ŋŋ*ari (be done brown)

The above two assimilation rules must follow both the *n*-insertion and the palatalization rule to get correct phonetic forms such as 'yoŋkai (4 times)' not *'yon*kai', '(dai) yo*ñ*šin (4th trial)' not *'yon*šin'.

(8) nasal syllabicization rule : It is a well-known fact that Japanese
has syllabic nasal and its distribution is predictable by a rather
simple rule ; a syllabic nasal occurs formative-finally or formative-
internally before a consonant. Thus, the rule will be stated as
follows :

$$(\text{VIII}) \quad [+\text{nasal}] \rightarrow [+\text{syllabic}] \; / \; -\left\{ \begin{array}{c} \left(\begin{array}{c} +\text{FB} \\ -\text{seg} \end{array} \right) \\ [+\text{cons}] \end{array} \right\}$$

In this paper this phonetic property is not marked on the phonetic
forms since it is predictable by this rule and moreover it is not
directly relevant to our discussion.

(9) ʔ-insertion rule : '?' is phonetically a constriction at the glottis and

it is represented by the feature matrix $\left(\begin{array}{c} -\text{cons} \\ -\text{voc} \\ +\text{low} \end{array} \right)$.

As mentioned, at page 6, the distribution of '?' is predictable in
Japanese and it can be stated informally as follows :

$$\phi \rightarrow ? \left\{ \begin{array}{l} \left\{ \begin{array}{c} + \\ \text{n} \end{array} \right\} - V \\ V_m - V_n \end{array} \right\} \quad \begin{array}{l} \text{where } V_m \text{ is a vowel, } V_n \text{ is any} \\ \text{vowel except } i, \text{ and } V_m \neq V_n \end{array}$$

This will be formulated as :

$$(\text{IX}) \quad \left\{ \begin{array}{c} \left(\begin{array}{c} +\text{FB} \\ -\text{seg} \end{array} \right) \\ [+\text{syll}] \end{array} \right\} , \quad \left(\begin{array}{c} -\text{voc} \\ -\text{cons} \\ +\text{low} \end{array} \right) , \quad \left(\begin{array}{c} +\text{voc} \\ -\text{cons} \end{array} \right)$$

$$\begin{array}{ccc} 1 & 2 & 3 \\ 1 & 3 \rightarrow 1 & 2 \quad 3 \end{array}$$

$$\text{except when } 1=3 \text{ or when } 1=\begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix} \text{ and } 3=\begin{pmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ -\text{back} \end{pmatrix}$$

In formulating the above rule[11] I follow Chomsky and Halle when they set up a metathesis rule as follows :

Metathesis

SD : $\begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix}$, $[-\text{cons}]$, $\begin{pmatrix} +\text{voc} \\ -\text{cons} \end{pmatrix}$

      1   2   3

SC :   1 2 3 → 2 1 3 except when 2=3=[a]

(The Sound Pattern of English, p. 361)

And further notice that the ?-insertion rule must be applied after the application of the relevant rules discussed above to derive correct phonetic forms.

IV. Summary

We have set up underlying forms for the Japanese numerals from one to ten as follows :

/it/, /ni/, /san/, /yo-/, /go/, /roku/, /hiti/, /hat/, /kyuu/, /jupu/

And we have formulated nine phonological rules to map the underlying forms into the actual phonetic forms. They are as follows and they must be applied in the following order :

    (I)   *i*-insertion rule

    (II)   *u*-deletion rule

    (III) *p*-rule

    (IV) *p-s*-voicing rule

(V)   *n*-insertion rule

(VI)   sibilation-palatalization rule

(VII) (a) (b)   assimilation rule

(VIII)   nasal syllabicization rule

(IX)   ʔ-insertion rule

We have also demonstrated that the above underlying forms and phonological rules together can account for the apparent phonetic irregularities observed in the numeral-counter compounds in Japanese[12]

FOOTNOTES

(1) According to James D. McCawley, *The Phonological Component of a Grammar of Japanese*, 1968, p.67, 'ʔ' is phonetically a constriction at the glottis, but the exact [phonetic value of 'ʔ' is not directly relevant to our discussion in this paper.

(2) James D. McCawley, *op. cit.* p.79.

(3) James. D. McCawley, *op. cit.* p. 119.

(4) Some Japanese may say '*ji*kko', '*ji*ppon' and so on, but this is a matter of idiolect. Such Japanese will probably say '*ri*kku (rucksack)', '*ši*kkin' (attendance at office)' etc. instead of the standard '*ryu*kku',' *šu*kkin'.

(5) He sets up the rule 'y→ʔ' to account for the alternation ʔiu/yuu. But we can explain the alternation without using that rule. Let us compare his analysis and ours :

his analysis		our analysis	
	Hip & ta		yup & ta
sharpening	yip & ta	(1) assimilation	yut & ta
p→h	yih & ta	(2) u→i	yit & ta
h→ʔ	yiʔ & ta	(3) y→ϕ	it & ta
assimilation	yit & ta	(4) ʔ-insertion	ʔit & ta
y→ʔ	ʔit & ta		

Our rules (1)—(4) are general in that they are independently motivated in Japanese phonology. Rule (2) is in any case needed to take care of the alternation yuku/ʔiku (go) etc. and (3) is a general rule which takes care of the phonetic fact that 'y' is always dropped before 'i' and 'e'. And moreover our intermediate form 'yutta'

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is an optional alternative which sometimes occurs in actual speech.

(6) Old Japanese had all of 'wa', 'wi', 'wu', 'we' and 'wo', but 'w' in 'wu' first dropped and then 'w' in 'wi', 'we', 'wo' also dropped one after another in the historical development of Japanese and now 'w' is retained only in 'wa'. This diachronic fact is compatible with the tendency to drop 'w' even in 'wa' so long as it does not involve ambiguity, and the same fact will provide some support for the ordering 'w→?', rather than '?→w'.

(7) $\begin{bmatrix} +\text{FB} \\ -\text{seg} \end{bmatrix}$ is a feature matrix of a formative boundary.

(8) This form is derived through the further change 'harapi→harai', which is taken care of by the *p*-rule to be discussed later.

(9) To my knowledge, the only exception to this rule among counters is /pa/ which is used to count birds. Observe the following and notice the peculiar behavior of /pa/, compared with other counters which begin with /p/, such as /pai/, /pon/, /piki/ etc. :

/pa/ : ?ičiwa   niwa   sanba   yonwa   gowa   rokuwa

/pai/ : ?ippai   nihai   sanbai   yonhai   gohai   roppai

/pa/ : hičiwa   hačiwa   kyuuwa   juppa/juuwa

/pai/ : hičihai   happai   kyuuhai   juppai   *juuhai

There are several ways available to take care of this exception, e. g. in terms of a distinct underlying segment, a diacritic feature or a minor rule. But additional research will be needed here to determine which is the simplest solution since the solution must be the simplest not only here but also in the whole component of Japanese phonology.

(10) This 'a' is inserted by the *a*-insertion rule which is in any case necessary in Japanese phonology. This rule cannot be discussed in this paper.

(11) In rule (IX), note the use of the feature [+syll]. In Japanese vowels and a syllabic nasal have this feature in common, so [+syll] may capture this natural class in Japanese. Moreover, it may be possible to replace the feature [+voc] by [+syll] in all the rules discussed in this paper. But this replacement, if ever made, does not influence the point of our discussion here.

(12) The earlier version of this paper was read at the general meeting of the Shizuoka Branch of the Phonetic Society of Japan, on August 4, 1972.