Parallel Evaluation in Stratal OT *<br>Adam Baker<br>University of Arizona<br>tabaker@u.arizona.edu

### 1.0. Introduction

The model of Stratal OT presented by Kiparsky (forthcoming), has not and will not prove uncontroversial among optimality-theoreticians. One might anticipate that the bulk of the controversy will rest on the serial generation of the final output in Kiparsky's model. The Stratal OT schema is given below:
(1) Insert Stratal OT schema


In this model, words are evaluated using separate OT grammars (Prince \& Smolensky 1993). Stratal Optimality Theory does away with the two-tier, Input-Output model of phonology, by acknowledging the Stem, Word, and Phrase levels.

I propose here that the parallelism of Optimality Theory can be maintained by evaluating one constraint hierarchy which chooses three optimal candidates, and by defining certain limited, principled correspondences between the candidates. Under this model, the parallelism of OT can be maintained, while gaining the empirical and psychological benefits of Stratal Optimality Theory. For the purposes of this paper, I have assumed a correspondence-theoretic approach to faithfulness (McCarthy \& Prince 1995).

### 1.1. Defining Strings

Stratal OT generates three outputs from three full grammars: the stem-level output, the wordlevel output, and the phrase-level output. The last of these is the proper output, which is to say, the utterance that comes out of the speaker's mouth. I argue that in order to achieve the desired effects of Stratal OT, we must retain these three levels. Let us consider the decomposition of the utterance, the so-called phrase level output. It is composed of a string of words:

[^0]\[

\mathrm{O}=\left[$$
\begin{array}{llll}
\mathrm{W}_{1} & \mathrm{~W}_{2} & \mathrm{~W}_{3} & \ldots \tag{2}
\end{array}
$$ \mathrm{~W}_{\mathrm{n}}\right] \quad(=Phrase Level Output)
\]

These words can further be broken down. They can be broken down morphologically into, say, derivational and inflectional forms, but phonological research has argued for dividing them on the basis of two observed levels of affixation. The first level of affixation is thought to be prephonological. The second opportunity for affixation occurs after certain phonological processes have taken place. Using this intuition we decompose the words as follows:
$W_{i}=A_{i}^{P}+R_{i}+A_{i}^{S}$
where $A^{P}$ is prefix string
$S$ is the stem
$A^{S}$ is suffix string
These are not morphologically-oriented distinctions. Rather they are based on the result of phonological research. S represents the stem, which is the result of pre-phonological morphology. There is apparently then an opportunity for phonology to take place, and then another round of morphology. This second round is represented by the affix strings $A^{P}$ (=prefix) and $\mathrm{A}^{\mathrm{S}}$ (=suffix).

### 1.2. The Input

If the output is to be generated through one constraint-ranking, the input must contain all the contrastive information necessary. The crucial criteria for the representation of the input is that it contain labeled strings, such that one stem can be distinguished from another, and one set of affixes can be distinguished from one another. Further specification of the input is an entirely separate matter. Whether the words come in a labeled string, packaged in a set, etc., will not influence the work done here.

For purposes of this paper, a subscript will denote correspondence between strings, and the following notation will serve as a generalized template fom the input:
i) $\quad\left[W_{1} W_{2} \ldots W_{n}\right]_{P}$
ii) $\quad\left[\left[\mathrm{A}^{\mathrm{P}}{ }_{1} \mathrm{~S}_{1} \mathrm{~A}^{\mathrm{S}}{ }_{1}\right]_{\mathrm{W} 1}\left[\mathrm{~A}^{\mathrm{P}}{ }_{2} \mathrm{~S}_{2} \mathrm{~A}^{\mathrm{S}}{ }_{2}\right]_{\mathrm{W} 2} \ldots\left[\mathrm{~A}^{\mathrm{P}}{ }_{\mathrm{n}} \mathrm{S}_{\mathrm{n}} \mathrm{A}_{\mathrm{n}}^{\mathrm{S}}\right]_{\mathrm{W}_{\mathrm{n}}}\right]_{\mathrm{P}}$

The Input is composed of a full phrase, which is a concatenated string of words $W_{1}-W_{n}$. A more articulated template is given in (4ii), where the words are further described as a stem with a prefixed string and a suffixed string.

### 1.3. The Output

The pronounced output of the tableau is $\mathrm{O}^{\mathrm{P}}$ ( P for phrase). There are two other optimal candidates as well that we will see, $\mathrm{O}^{\mathrm{S}}$ ( S for stem) and $\mathrm{O}^{\mathrm{W}}$ (W for word). These latter two are not pronounced, but apparently $\mathrm{O}^{\mathrm{W}}$ is apparently the level of interface for ideal orthographies (Keith Snider, personal communication).

### 1.4. The Candidate Set

For formal reasons, each candidate must be labeled as candidate for the stem, the word, or the phrase; there is no fence-sitting when we evaluate Stratal OT in parallel. This has the
effect of tripling the candidate set, but luckily we are no worse on computational intractability issue: $3 \infty=\infty$.

An additional benefit of the parallel evaluation of stratal OT is that we are able to evaluate all potential stems in one candidate. Theoretically this is not to particular advantage, but it makes evaluation of tableau a bit nicer.

### 1.5 Defining the Correspondences

Consider figure (1), which represents the Stratal OT serial evaluation of outputs. There are three dimensions of faithfulness at work, or, according to the theoretical assumptions of this paper, three dimensions of correspondence. These three dimensions of correspondence represent the power of Stratal Optimality Theory.
(5) Strings in Correspondence in Serially-Evaluated Stratal OT

## S1 is in correspondence with

i) Input From Stem Morphology Output of Stem OT Grammar
ii) Output of Word Morphology Output of Word OT Grammar
iii) Output of Phrase Morphology Output of Phrase OT Grammar

The crux of this paper is the fact that these three dimensions of correspondence can occur within the same evaluation of candidates. H-Eval selects a single phrase-level output, but for each word it also selects an optimal stem candidate, and an optimal word candidate. Let us recast (5) in terms of the variables defined in (2) and (3). The reader will recall the terms S1 and S2 from McCarthy \& Prince (1995), the former referring to the string which demands faithfulness, and the latter being the string of which faithfulness is demanded.

|  | S1 is in correspondence with |
| :--- | :--- |
| i) | S2 |
| S | $O^{S}$ |
| ii) $\left[A^{P}+O^{S}+A^{S}\right]$ | $O^{W}$ |
| iii) $\mathrm{O}^{W}{ }_{1}+\mathrm{O}^{W}{ }_{2}+\ldots+\mathrm{O}^{W}{ }_{n}$ | $O^{P}$ |

Note the three types of outputs that H-Eval selects. There will be one $\mathrm{O}^{\mathrm{S}}$ and one $\mathrm{O}^{\mathrm{W}}$ for each word in the input, as well as one $\mathrm{O}^{\mathrm{P}}$, which is the "final" output, the output that will be pronounced.

For notional convenience we can define the following strings:

$$
\begin{align*}
& \mathrm{W}_{\mathrm{i}}=\mathrm{A}_{i}^{\mathrm{P}}+\mathrm{O}_{\mathrm{i}}^{\mathrm{S}}+\mathrm{A}_{\mathrm{i}}^{\mathrm{S}}  \tag{7}\\
& \mathrm{P}=\mathrm{O}_{1}^{\mathrm{W}}+\mathrm{O}^{\mathrm{W}}{ }_{2}+\ldots+\mathrm{O}^{\mathrm{W}}{ }_{\mathrm{n}}
\end{align*}
$$

The following is a formal statement of the correspondence relations. Note that there is a notion of corresponding strings which is in addition to the classic idea of correspondence. This is the necessary distinction between the (potentially numerous) stems in the input and output (using the labels which have been previously discussed).
(8) Formal Definitions of the Correspondence Relations

## SO $^{\text {S }}$ - Stem / Stem Output Correspondence

Let S 1 be stem i in the input.
Let S 2 be a stem j in a stem candidate.
$\mathrm{i}=\mathrm{j} \rightarrow \mathrm{S} 1 \Re \mathrm{~S} 2$
WO ${ }^{\text {w }}-[$ Prefix + Stem Output + Suffix $] /$ Word Output Correspondence
Let $S 1$ be the concatenated string $A^{P}{ }_{i}+O_{i}^{S}+A_{i}^{S}$.
Let S 2 be a word j in a word candidate.
$\mathrm{i}=\mathrm{j} \rightarrow \mathrm{S} 1 \Re \mathrm{~S} 2$
$\mathrm{PO}^{\mathrm{P}}-\left[\mathrm{W}_{1} \ldots \mathrm{~W}_{\mathrm{n}}\right] /$ Phrase Output
Let S 1 be the concatenated string $\mathrm{O}^{\mathrm{W}}{ }_{1}+\mathrm{O}^{\mathrm{W}}{ }_{2}+\ldots+\mathrm{O}^{\mathrm{W}}{ }_{\mathrm{n}}$
Let S 2 be a phrase candidate.
Then S1 $\because$ S2
Let us now leave the world of definitions and attend to some data.

### 2.0. A Brief Analysis of Yawelmani Yokuts ${ }^{1}$

What follows is a short ranking argument to illustrate the power of my parallel evaluation of Stratal OT. I assume some familiarity with Yawelmani, which demands three levels of phonological processes. The prototypical illustrative form is [sudokhun], underlyingly /sudu:khin/. A rule-based analysis might proceed as follows, with each ordering relation being crucial.

| A Rule-Based Analysis of Yawelmani Opacity |  |  |
| :---: | :---: | :---: |
| Rules | /sudu:khin/ | Explanation |
| Vowel Harmony | sudu:khun | [+hi] vowels must agree wrt [round] |
| Lowering | sudo:khun | Long [+high] vowels $\rightarrow$ [-high] |
| Shortening | sudokhun [sudokhun] | A long vowel shortens in a closed syllable |

In Stratal OT terms, features rounding harmony at the Stem Level, lowering of high vowels at the Word Level, and shortening of vowels in trimoraic syllables at the Phrase Level. I will now proceed with the parallel analysis.

If rounding is to occur at the 'Stem Level,' then we know that the relevant dimension of faithfulness is that of $\mathrm{SO}^{\mathrm{S}}$. The optimal stem candidate will have harmony with respect to roundness. If our markedness constraint is $\operatorname{AGREE}([r n d])$ - defined as 'adjacent [+hi] vowels agree with respect to rounding" - then we know that AGREE([rnd]) » IDENT([rnd])-SO ${ }^{\text {S }}$ :

[^1]$\operatorname{AgREE}([\mathrm{rnd}])$ ) $\operatorname{IdENT}([\mathrm{rnd}])-\mathrm{SO}^{\mathrm{S}}$

| / [ [sudu:khin] $]_{\mathrm{w}} /$ | AGREE([rnd]) | IDENT([rnd])-SO ${ }^{\text {S }}$ |
| :---: | :---: | :---: |
| a. [sudu:khin] ${ }_{\text {S }}$ | *! |  |
| Sne ${ }^{\text {b }}$ b. [sudu:khun]s |  | * |

Note that this tableau indicates selection of the optimal $\mathrm{O}^{\mathrm{S}}$, the "output of the stem level" in Stratal OT terms. The optimal candidate is marked with 'Snes' to indicate this. Candidate (a) fatally violates AGREE, but candidate (b) wisely satisfies AGREE and violates instead the constraint demanding faithfulness between $\mathrm{O}^{\mathrm{S}}$ and the input stem. ${ }^{2}$ Crucially ' S ' does not (directly) determine the final output, but merely $\mathrm{O}^{\mathrm{S}}$.

Next our grammar must lower the high vowel (long high vowels are disallowed in Yawelmani). Our new correspondence relation is between W and $\mathrm{O}^{\mathrm{W}}$ ( $\mathrm{FAITH}^{\mathrm{W}} \mathrm{WO}^{\mathrm{W}}$ ). Recall that W is defined as the concatenation of $\mathrm{O}^{\mathrm{S}}$ with the prefix and the suffix strings. In this present case there are no additional affixes, so W ends up being identical to $\mathrm{O}^{\mathrm{S}}$.

Since the grammar preserves vowel length instead of vowel height, we know that the faithfulness preserving length must dominate that preserving [high]. A ranking argument is given below. This current ranking is displayed along with the previous. There are no ranking relationships between this ranking and the one in (10), which is indicated by the dark line.
(11) $\quad$ Max- $\mu-\mathrm{WO}^{\mathrm{W}}$, *LONGHigh » IDENT-WO ${ }^{\mathrm{W}}$

| /[[sudu:khin] ${ }_{\text {S }}{ }_{\text {W }} /$ | MAX- $\mu$-WO ${ }^{\text {W }}$ | *LONGHIGH | ID-WO ${ }^{\text {W }}$ | AGR([rnd]) | $\mathrm{ID}([\mathrm{rnd}])-\mathrm{SO}^{\text {S }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| a. [sudu:khin] ${ }_{\text {S }}$ |  |  |  | *! |  |
| S ${ }^{\text {res b }}$ [sudu:khun]s |  |  |  |  | * |
| q. [sudu:khun]w |  | *! |  |  |  |
| r. [sudukhun]w | *! | M, |  | , | (1) |
| O s. [sudo:khun] ${ }_{\text {W }}$ |  |  | * |  |  |
| t. [sudo:khin] ${ }_{\text {W }}$ |  |  | **! | * |  |

This tableau illustrates the selection of both $\mathrm{O}^{\mathrm{S}}$ and $\mathrm{O}^{\mathrm{W}}$. The selection of $\mathrm{O}^{\mathrm{S}}$ is the same as in (10), so we leave it aside here. The region of the candidate set that deals with Word candidates is indicated with a jagged line. Of course the division is not formally necessary, the candidate type being indicated by a subscript, but is pleasing to the theorist's eye.

Candidate (q) fails for violating the high-ranking prohibition on long and high vowels. Candidate (r) satisfies this constraint, but only at the expense of the high-ranking prohibition on mora-deletion. (s) is optimal, satisfying *LONGHIGH only at the minimal expense of an IDENT violation. Candidate ( t ) is an interesting case, because it appears to be faithful to the input with its [hin] suffix; faithfulness to the input is not valued in the word, however; in selection of the word, the only faithfulness that matters is that to $\mathrm{O}^{\mathrm{S}}$ and its appendages (which in this case are empty). ( t ) therefore fails for it gratuitous IDENT-WO ${ }^{\mathrm{W}}$ violation: it is not sufficiently identical to $\mathrm{O}^{\mathrm{S}}$.

Finally we must shorten our trimoraic syllable. Yawelmani shortens a vowel rather than delete a consonant, which informs the constraint ranking: MAX-C-PO ${ }^{\mathrm{P}}, * \mu \mu \mu »$ MAX $^{*}-\mu-\mathrm{PO}^{\mathrm{P}}$. This

[^2]again is appended to our previous constraint-ranking. An explanation follows the tableau. The shaded region of the tableau has not yet been evaluated, because the constraint interactions involved will require separate illustration.
(12) MAX-C-PO ${ }^{\mathrm{P}}, * \mu \mu \mu »$ MAX- $^{*}-\mathrm{PO}^{\mathrm{P}}$

| /[[sudu:khin] $]_{\text {] }}$ / | MAX-C-PO ${ }^{\text {P }}$ | ${ }^{*} \mu \mu \mu$ | MAX- $\mu-\mathrm{PO}^{\text {P }}$ | MAX- $\mu$-WO ${ }^{\text {W }}$ | *LONGHIGH | ID-WO ${ }^{\text {W }}$ | AGR([rnd]) | $\mathrm{ID}([\mathrm{rnd}])-\mathrm{SO}^{\text {S }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| a. [sudu:khin] |  |  |  |  |  |  | *! |  |
| Sos b. [sudu:khun]s |  |  |  |  |  |  |  | * |
| q. [sudu:khun]w |  |  |  |  | *! |  |  |  |
| r. [sudukhun] ${ }_{\text {W }}$ |  |  |  | *! |  |  |  |  |
| Oņ3 s. [sudo:khun] ${ }_{\text {w }}$ |  |  |  |  |  | * |  |  |
| t. [sudo:khin] ${ }_{\text {w }}$ |  |  |  |  |  | **! | * | mmmm |
| w [sudo:khun]w |  | *! |  |  |  |  |  | 寺 |
| x. [sudo:hun] ${ }_{\text {w }}$ | *! |  |  |  |  |  |  |  |
| Pas y. [sudokhun]w |  |  | * |  |  |  |  |  |

Since our input in (12) consists of one word, P is identical to $\mathrm{PO}^{\mathrm{P}}$. Candidate (w) fails for its trimoraic syllable [du:k], and while candidate (x) satisfies this constraint, it fatally deletes a consonant. Candidate ( y ) is optimal for properly deleting a mora to avoid the trimoraic syllable. Thus (y) receives the 'Pre', which is the pronounced form (tantamount to the plain 'res' in Classic OT).

At this point we can finally examine the ways in which our faithfulness constraints interact with the markedness constraints. We have introduced the ban on trimoraic syllables ${ }^{*} \mu \mu \mu$, but this is freely violated in both $\mathrm{O}^{\mathrm{S}}$ and $\mathrm{O}^{\mathrm{W}}$. We can thus rank our $\mathrm{SO}^{\mathrm{S}}, \mathrm{WO}^{\mathrm{W}}$, and $\mathrm{PO}^{\mathrm{P}}$ faithfulness constraints with respect to $* \mu \mu \mu$. The ranking is given and illustrated below.
(13) MAX- $\mu-$ SO $^{\text {S }}$, MAX $-\mu-\mathrm{WO}^{\mathrm{W}},{ }^{*} \mu \mu \mu »$ MAX $^{\varsigma} \mu-\mathrm{PO}^{\mathrm{P}}$

| /[[sudu:khin] ${ }_{\text {s }}{ }_{\text {w }} /$ | MAX- $\mu$-SO ${ }^{\text {S }}$ | MAX- $\mu$-WO ${ }^{\text {W }}$ | * $\mu \mu \mu$ | MAX- $\mu-\mathrm{PO}^{\text {P }}$ |
| :---: | :---: | :---: | :---: | :---: |
| a. [sudukhun]s | *! |  |  |  |
| Sns b. [sudu:khun]s |  |  | * |  |
| c. [sudokhun] ${ }_{\text {w }}$ |  | *! |  |  |
| Wrasd. [sudo:khun] ${ }_{\text {W }}$ |  |  | * |  |
| e. [sudo:khun] ${ }_{P}$ |  |  | *! |  |
| P |  |  |  | * |

The important observation here is that the $* \mu \mu \mu$ violation is tolerated in $\mathrm{O}^{\mathrm{S}}$ and $\mathrm{O}^{\mathrm{w}}$ in order to avoid MAX- $\mu-\mathrm{SO}^{\mathrm{S}}$ and $-\mathrm{WO}^{\mathrm{W}}$ violations. But, $\mathrm{O}^{\mathrm{P}}$ obeys $* \mu \mu \mu$ by deleting a mora in its optimal output.

We have then described our subset of Yawelmani data (our Yawelmani datum, in fact) using parallel evaluation.

### 3.0. Further Work

This section will briefly conclude the squib by pointing in directions for further research, and noting a fairly important prediction that this approach makes.

### 3.1. A Multi-Stem Analysis

I confess to not having hunted down data to perfectly illustrate the second round of affixation, and then further phonological interactions after the syntax. All of the Stem and Word candidates can simply be composed of numerous stems, i.e. "[ugabuga] $]_{\mathrm{S} 1}[\text { yawizawi }]_{\mathrm{s} 2}[\text { nitocomplito }]_{\mathrm{s} 3}$." It follows straightforwardly that the stem candidate that has the three most optimal candidates will always be selected for its few violations than one that, say, is lacking a stem (PARSE-M anyone?), or has a single non-optimal candidate.

### 3.2. The Important Prediction

An important prediction is built into this parallel evaluation that is not implicit in Stratal Optimality Theory. To put it in Stratal OT terms: the rankings of markedness constraints do not change with respect to one another. In a single Con, one cannot have $M_{1}$ » $M_{2}$ in one place and $\mathrm{M}_{2}$ » $\mathrm{M}_{1}$ in another; that would be ludicrous.

This is a fairly strong prediction: all variation between levels is the result of variations between the ranking of faithfulness and markedness constraints, but never between markedness
and other markedness constraints. If it is true, it would also have the advantage of simplifying the factorial typology.

I hereby exhort theoreticians everyone neither to accept this nor discard it lightly! There are always several constraint-rankings perform any one alternation, and it seems that it may be possible (note the double qualification), that the prediction is true.

### 4.0. Conclusion

Thanks for reading.
5.0. References

McCarthy, John and Alan Prince. 1995. "Faithfulness and Reduplicative Identity." University of Massachusetts Occasional Papers in Linguistics 18: Papers in Optimality Theory. Ed. by Jill Beckman, Suzanne Urbanczyk and Laura Walsh Dickey. Pp. 249-384.
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[^0]:    * I am indebted to Keith Snider for introducing me to Stratal Optimality Theory, convincing me of the value of Lexical Phonology, and modeling what an academic should be. This paper is the result of his instruction, although I reserve the responsibility for all errors as my own.

[^1]:    ${ }^{1}$ The constraint rankings in this analysis, except where they relate to my specifically parallel evaluation, are in fact the work of Keith Snider (2003), who in turn based his analysis on Kiparsky (forthcoming).

[^2]:    ${ }^{2}$ If we were actually evaluating a phrase, we could mark the stems with subscripts to indicate their identities. These subscripts have been left out here because they would be superfluous.

