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The "Morphology" of English Spelling:

A Look at the SRS Text-Modification Rules for English[1]

Susan R. Hertz

Abstract. Any scheme that accurately converts English text to phonemes must be based on morphological analysis--i.e., an analysis of words into prefixes, suffixes, and roots. This morphological analysis is accomplished in the SRS synthesis rule set for English [Hertz 1982] by a set of text-modification rules, which divide words into morphological units on which subsequent phoneme-generating rules are based. Because these units are not always true morphemes (for example, fibe + er for fiber on analogy with bribe + er for briber), they are more accurately called "spelling morphs." By analyzing text into spelling morphs, the text-modification rules not only simplify phoneme and stress prediction, but the handling of exceptions as well. In addition, by marking particular characterisics of these morphs (for example, syllable structure), the text-modification rules also simplify the prediction of certain low-level effects, such as aspiration.

Introduction

One of the biggest problems facing the developers of text-to-speech systems for English is the fact that the spelling of an English word is often a poor reflection of its pronunciation. For example, the spelling of the words in such pairs as enable/tenable, hanged/changed, axis/taxis, and naked/baked are quite similar, but the letters common to them

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[1]This paper is a slightly revised version of a talk that was presented at the 105th Meeting of the Acoustical Society of America, May 1983.

are pronounced quite differently. The pronunciation of these words, however, is entirely regular if their underlying morphological structure is taken into account:

enable	=	prefix (en-) + root (able)
tenable	=	root (ten) + suffix (-able)
hanged	=	root (hang) + suffix (-ed)
changed	=	root (change) + suffix (-ed)
axis	=	single morpheme
taxis	=	root (taxi) + suffix (-s)
naked	=	single morpheme
baked	=	root (bake) + suffix (-ed)

The relative success of the SRS text-to-phoneme rules for English over most other rule systems of comparable size [Hertz 1981] is primarily a result of a set of about 200 text-modification rules, which divide words into such constituent forms. This paper will focus on the nature of these forms and on their importance for predicting pronunciation.

Morphology and Phoneme Prediction

Consider, for example, the word divider, which the text-modification rules would rewrite as shown in Figure 1. The plus signs represent morph boundaries, the first hyphen marks the preceding letters as a prefix, and the second hyphen marks the following letters as a suffix. The morphological information inserted into this word allows a set of very general rules to predict its pronunciation. The rule shown in the figure, for example, applies to the i of vide, and generates the pronunciation [ay] for it because it precedes a consonant followed by a morph-final letter e.

Since English spelling is so conservative, reflecting older stages of the language, one might expect that the constituent forms important for predicting a word's pronunciation can be derived from an etymological analysis of the word. However, whereas this is frequently the case, as in the word divider, it is also often not the case, as shown in Figure 2.

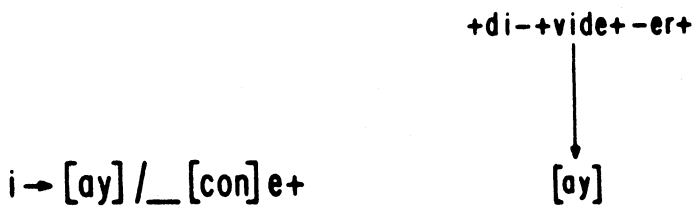

Figure 1. Morphology and Phoneme Prediction

	SPELLING:	SRS ANALYSIS:	ETYMOLOGY:
1.	fiber	+fibe+-er+	+fiber+
2.	signal	+signal+	+sign+-al+
3.	need	+nee+-ed+	+need+
	needed	+need+-ed+	+need+-ed+

Figure 2. SRS "Folk Etymologies"

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The first example in Figure 2 illustrates how the er of the word fiber is stripped, on analogy with words like divider, even though the resulting form fibe is historically incorrect. One advantage of this analysis is that the very general rule shown in Figure 1 that generates the pronunciation [ay] for the letter i of vide (in di- + vide + -er) will do so as well for the i's of words like fiber.

Whereas in this case, the SRS rules insert an etymologically non-existent morph boundary, in other cases the rules purposely fail to insert an etymologically correct boundary, as illustrated in the second example in Figure 2. Here, the etymologically correct ending -al is not stripped in the word signal, since doing so would lead to the incorrect pronunciation [s ay n ə l].

The final example in Figure 2 illustrates how words that are morphologically related may be analyzed differently. Both need and needed are handled by the same ed-stripping rule, which produces etymologically incorrect forms for need, but correct ones for needed.[2]

Because the forms generated by the SRS text-modification rules are not always true morphemes as a linguist would use the term, they will be referred to as "spelling morphs" in this paper.

The ly-Stripping Rule

The three main types of spelling morphs--prefixes, suffixes, and roots--are marked at the text-modification rule level via a set of context-sensitive rules. The rule shown in Figure 3, for example, marks the word-final sequence ly as a suffix when it is not part of a one-syllable morph such as sly or ply--that is, when it does not follow a morph boundary and a consonant. Again, this rule, like the er-stripping rule alluded to above, generates both historically correct and incorrect roots.

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[2] Of course this particular analysis for need (and analogous divisions of similar words, such as seed and deed) would not be appropriate in systems that require etymologically correct word-class information in order to predict, say, phrase-level stress and intonational patterns.

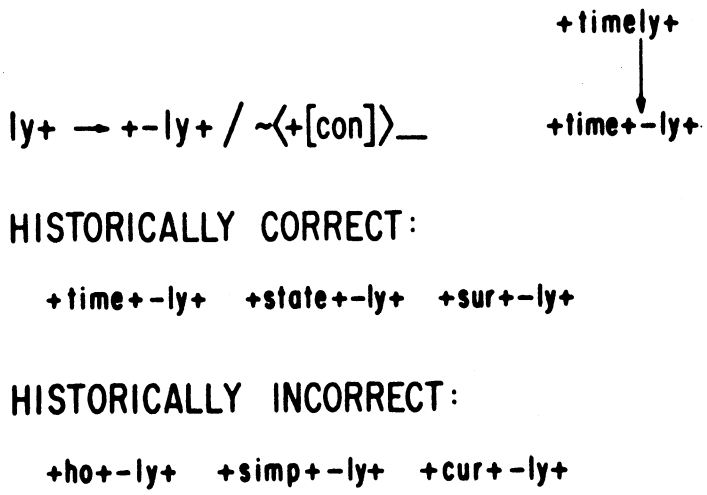

Figure 3. The ly-Stripping Rule

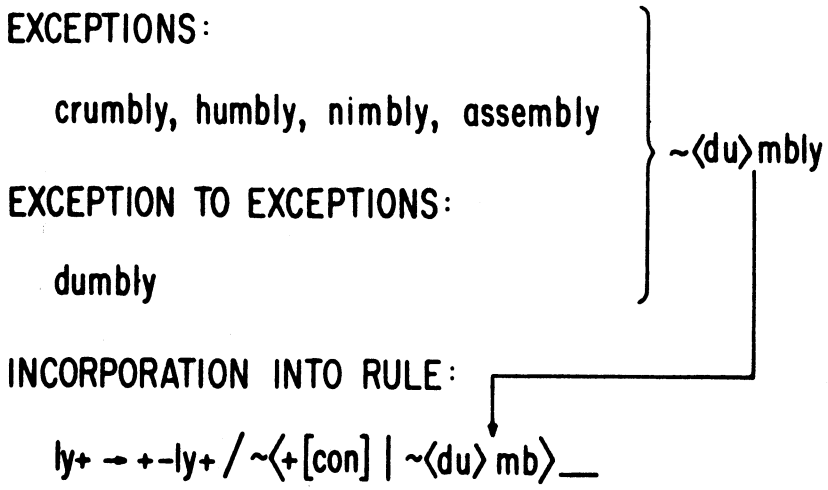

Figure 4. ...mbly Exceptions to ly-Stripping

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The ly-stripping rule, like most morph-marking rules, has a number of exceptions. Consider, for example, the words ending in mbly shown in Figure 4. Stripping the ly of these words would yield an undesirable morph-final b that would be made silent on analogy with morphs like crumb and limb, resulting in such incorrect pronunciations as [k r ʌ m l i] for crumbly. It is not enough, however, to simply exclude the sequence mbly from the ly-stripping rule, since in the word dumbly the morph-final silent b is desired.

This complicated set of exceptions, however, like most such exceptions, can be described relatively compactly in SRS rule notation--in this case, as the class of words ending in the letters mbly, so long as these letters are not preceded by the letters du. This pattern can be incorporated directly into the ly-stripping rule, as shown in the figure.

Rule Ordering and Exceptions to ly-Stripping

In addition to these exceptions, there are other words, such as imply and comply, that will be exceptions to the ly-stripping rule only if it is ordered before the prefix-stripping rules. If the prefix stripping rules were ordered first, for example, comply would be divided into the prefix com- and the root ply, as shown in Figure 5. Since this root has only one syllable, it would then automatically be excluded from the ly-stripping rule, as described in the above discussion for Figure 3. Unfortunately, however, the ly-stripping rule, like most suffix-stripping rules, must be ordered before the prefix-stripping rules, since the opposite ordering would produce many more exceptions.

Analyses Favoring ly-Stripping before Prefix-Stripping

Consider, for example, the analyses given in Figure 6, which favor placing the ly-stripping rule first. The first example illustrates how stripping the ly in the word surly leaves the root sur. Since this root has only one syllable, it will automatically be excluded from the later prefix-stripping rules, in this case from the rule that strips the prefix sur- in words like surprise and surpass. If, instead, the prefix-stripping rules were ordered first, this word would incorrectly receive the pronunciation [s ɚ l ay], on analogy with words like comply.

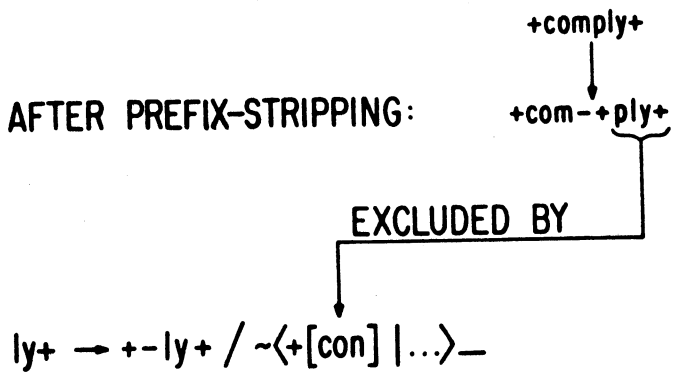

Figure 5. Rule Ordering and Exceptions to ly-Stripping

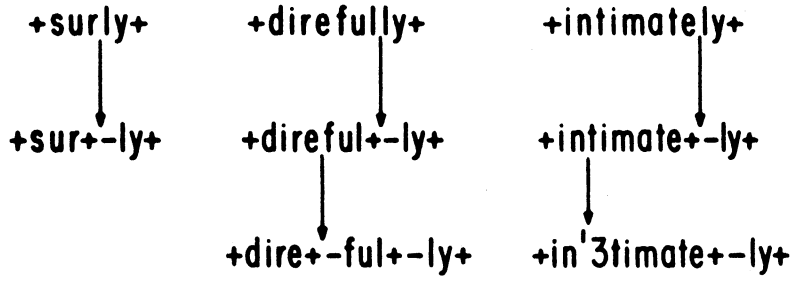

Figure 6. Analyses Favoring ly-Stripping before Prefix-Stripping

The second example illustrates how stripping the ly of the word direfully uncovers the suffix -ful, which is in turn stripped by a subsequent rule, leaving the root dire. Again, this root, having only one syllable, will automatically be excepted from the prefix-stripping rules--in this case, from the rule that strips the di of words like divide and direct.

The final example shows how stripping the ly of the word intimately leaves the root-final ending -ate, an ending which causes third degree of stress (that is, highest stress) to be placed two syllables before it, in this case on the syllable in. Once marked as stressed, this syllable will automatically be excluded from the rule that strips the in in words like invent and intuitive.

There are many more analyses of this type that favor placing the ly-stripping and many other suffix-stripping rules before the prefix-stripping rules.

Revised ly-Stripping Rule

Thus words like imply and comply, which require the opposite ordering, must be treated as exceptions, even though they are entirely regular in any conventional sense. Either they must be placed in an exception dictionary or they must be excluded explicitly in the suffix-stripping rule itself along with words like crumbly and humbly, as shown in Figure 7.

Suffix-Stripping vs. Prefix-Stripping

Although there are exceptions to the suffix-stripping rules of the sort just illustrated, these exceptions are few in number. Because there are so many words which look and behave as though they contained a true historical suffix, even though they do not, the strategy of not respecting etymological accuracy allows for very general suffix-stripping rules.

Prefixes, on the other hand, are of such a nature that the rules that recognize them cannot benefit as much from failing to respect historical origins; the prefix-stripping rules usually must refer to a relatively large, but nevertheless manageable, number of word-specific letter sequences as exceptions or conditions. Contrast, for example, the ly-suffix-stripping rule shown in Figure 7 with the two dis-prefix-stripping rules given in Figure 8.

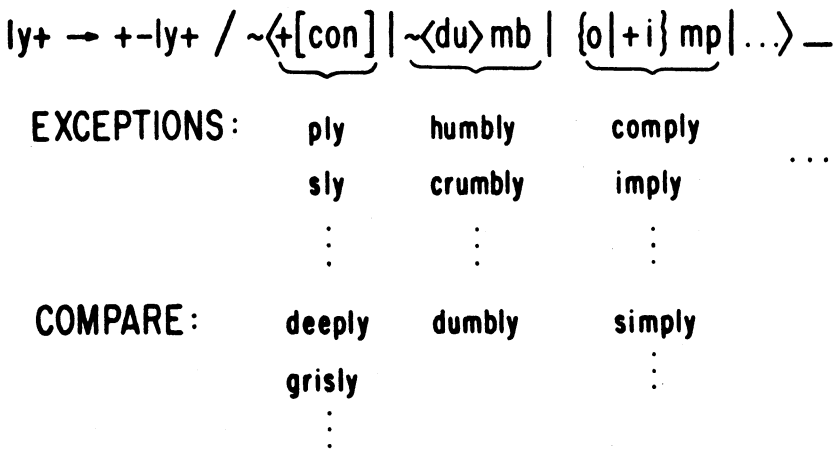

Figure 7. Revised ly-Stripping Rule

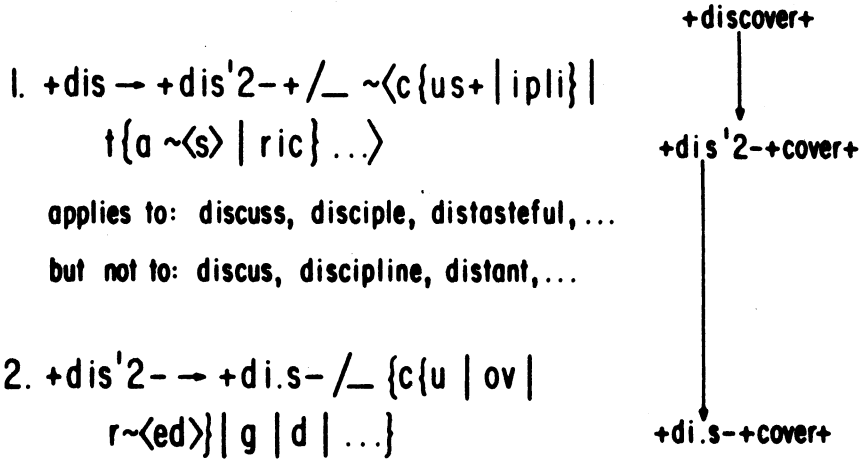

Figure 8. The dis-Stripping Rules

The dis-Stripping Rules

The first rule in Figure 8 marks the morph-initial sequence dis as a prefix with secondary stress when it precedes anything but one of the sequences in angle brackets. More specifically, the letters dis are stripped when they do not precede the letters cus followed by a morph boundary, the letters cipli, the letters ta when not followed by s, etc. This rule would apply, for example, to words like discuss, disciple, distasteful, and discover, but not to words like discus, discipline, and distant, excluded by the sequences in angle brackets. The figure shows the result of applying the rule to the word discover.

The second rule in the figure then applies to a subset of the words handled by Rule 1--namely, to words like discuss and discover, in which the s belongs to the second syllable. It rewrites the prefix, inserting a dot to represent the syllable boundary, and deleting the secondary stress mark to indicate that the vowel of the prefix is reduced. Again, the figure shows the result of applying this rule to the word discover. Note that after this rule applies to this word, the irregular morph cover is still delimited in the same way that it would be in words like recover, uncover, and cover (where the syllable and morph boundaries coincide), and it can thus be handled in the same way.

Prefix-Stripping and Aspiration

The information about syllable structure provided by these rules is used by the lower level rules that handle phonetic details--for example, by the rules that aspirate voiceless stops when they occur at the beginning of stressed syllables. Thus, after the two dis-stripping rules apply, the aspiration rules will correctly aspirate the syllable-initial voiceless stop of a word like discolor, but not the non-syllable-initial voiceless stop of a word like discover, as illustrated in Figure 9.

Prefix-Stripping and Vowel Reduction

Another kind of information that prefix-stripping rules provide for the later rules that handle phonetic details is information about the quality of reduced vowels. For example, the rules mark the prefix a- with an equals sign, rather than with a dash, in words like ascribe and ascetic (see Figure 10), in order to indicate that this prefix should be pronounced [ə] rather than [ɪ]. That is, it should not be

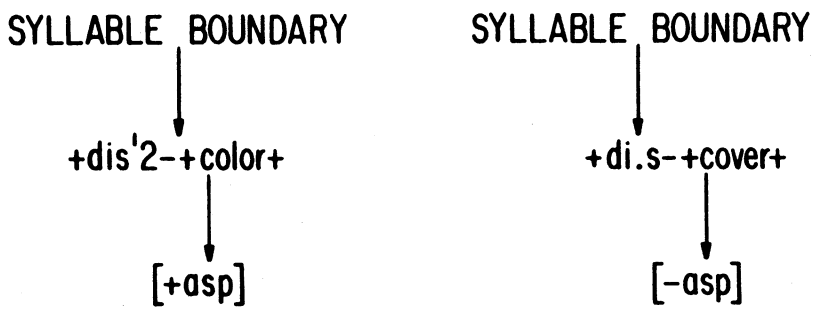

Figure 9. Prefix-Stripping and Aspiration

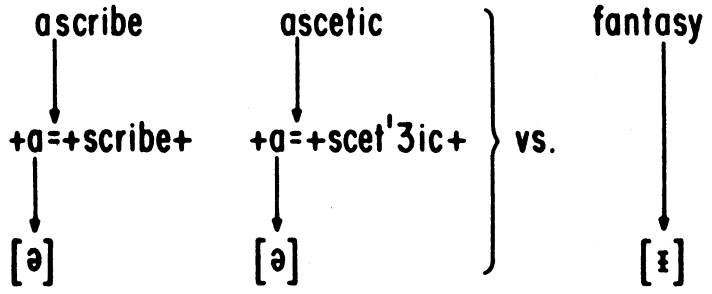

Figure 10. Prefix-Stripping and Vowel Reduction

the higher variant, as the reduced vowel often is before [s] (for example, in the second syllable of the word fantasy).

Note that although the stress and phoneme patterns of the word ascetic are predictable without stripping the prefix (the ending -ic almost always being preceded by highest stress), the prefix-stripping rule is nevertheless necessary in order to insure that the reduced vowel of the first syllable be pronounced correctly.

Conclusion

This paper has described how a small set of SRS text-modification rules analyze English words into spelling morphs. It has shown that such spelling morphs are important both for the prediction of stress and phoneme patterns, and for the prediction of low-level phonetic effects such as aspiration. In general, it is the failure of the text-modification rules to respect historical origins, together with the way that they handle exceptions, that is responsible to a large extent for the accuracy and compactness of the SRS text-to-speech rules for English.

References

Hertz, Susan R. 1981. SRS text-to-phoneme rules: a three-level rule strategy. In Proc. 1981 Int. Conf. ASSP, pp. 102-105 (New York: IEEE).

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