The Automatic Characterization of Grammars from Small Wordlists

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### Vowel Harmony Overview

An unsupervised algorithm for detecting and describing vowel harmony systems in small wordlists. It answers the following questions about an unknown language:

- Does the language have harmony?
- What are its harmonizing sets?
- Does it have neutral (transparent or opaque) vowels?
- Does it have secondary harmony?

### Vowel Harmony Algorithm

The algorithm is designed to work on short wordlists (down to about 500 types) without frequency counts. If the standard orthography roughly approximates a phonemic representation, no transcription is needed. If available, token frequencies may be used to improve results. Furthermore, the algorithm can provide a mapping between harmonizing sets if the researcher provides vowel features as input.

```java
if frequencies provided then
trim tail off wordlist
while true do
    calculate tier-adjacent V-V co-occurrence matrix
    calculate MI between each vowel pair
    identify vowels whose MI distributions uniform within threshold.
    assign these to the neutral vowel set and remove from consideration.
if number of non-neutral vowels <= 1 then
    return
run k-means (k = 2) clustering on the remaining vowels
if no features provided then return
else
    map vowels between harmonizing sets by finding pairs that share the most features in common.
    collapse vowels along the harmonizing feature.
    return for secondary harmony.
```

### Results

#### Table 1: Vowel co-occurrences are taken from corpus.

<table>
<thead>
<tr>
<th>Lang.</th>
<th>Types</th>
<th>1ary H?</th>
<th>Correct</th>
<th>2ary H?</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turkish</td>
<td>303,013</td>
<td>✓</td>
<td>8/8</td>
<td>✓</td>
<td>4/4</td>
</tr>
<tr>
<td>Finnish</td>
<td>396,770</td>
<td>✓</td>
<td>8/8</td>
<td>✓</td>
<td>2/2</td>
</tr>
<tr>
<td>Hungar</td>
<td>53,839</td>
<td>✓</td>
<td>11/15</td>
<td>✓</td>
<td>8/8</td>
</tr>
<tr>
<td>Uyghur</td>
<td>392,403</td>
<td>✓</td>
<td>7/8</td>
<td>✓</td>
<td>3/3</td>
</tr>
<tr>
<td>Warlipi</td>
<td>28,885</td>
<td>✓</td>
<td>3/3</td>
<td>✓</td>
<td>1/1</td>
</tr>
<tr>
<td>German</td>
<td>225,327</td>
<td>✓</td>
<td>5/5</td>
<td>✓</td>
<td>1/1</td>
</tr>
<tr>
<td>English</td>
<td>101,438</td>
<td>✓</td>
<td>6/6</td>
<td>✓</td>
<td>1/1</td>
</tr>
</tbody>
</table>

### Next Steps

We are continuing to develop this algorithm.

- **Leveraging paradigms** from our morphological segmentation will allow it to map harmonizing vowels with explicitly provided features.
- The same distributional processes can discover other typological features: whether a language exhibits stem alternations, has agglutinative morphology, tends towards prefixation or suffixation, reduplication, etc.

### References


### Segmentation Overview

An unsupervised morphological segmentation algorithm designed with small wordlists in mind. Our algorithm is built around the concept of paradigms. Each root is attached to a paradigm containing all the proposed suffixes with which it is attested. This algorithm achieves state-of-the-art results on English and Turkish. We are preparing gold standards for testing on other languages as well.

### Segmentation Algorithm Summary

The morphological segmentation algorithm combines three processes: segmentation, paradigm construction, and pruning.

- **Segmentation** - A Bayesian model estimates probability \( P(r, s, t|w) \) over candidate roots, affixes, and transformations for each word

\[
P(r, s, t|w) = \frac{P(r) \times P(s) \times P(t)f(r, s)}{\sum_{r', s', t'} P(r', s', t')}
\]

- **Paradigm Construction** - Affix appearing with each root are grouped together into paradigms. The more common its paradigm, the greater its support.

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-ed, -ing, -s)</td>
<td>772</td>
</tr>
<tr>
<td>(-ed, -ing)</td>
<td>331</td>
</tr>
<tr>
<td>(-ed, -er, -ing, -s)</td>
<td>219</td>
</tr>
<tr>
<td>(-ly, -ness)</td>
<td>208</td>
</tr>
</tbody>
</table>

- **Pruning** - Affixes which do not appear in enough well-supported paradigms are pruned. For example, if \( close \) is incorrectly segmented as \( close-t \), the \( close \) paradigm becomes \( -er, -est, -ed, -ing, -s, -t \). Pruning corrects the \( -t \).

### Next Steps

We are still developing this tool. We expect improvements to come from integration with the vowel harmony analyzer as well as more theoretically involved morphological transformations.

- Have run it on other languages: Tagalog, Navajo, Yoruba, Somali; but cannot score the outputs yet.
- Are designing a segmentation annotation scheme to create more gold standards.
- Will leverage the vowel harmony tool to create more coherent paradigms.
- Will enrich transformations for languages with non-concatenative morphology.

### Acknowledgements

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