Using Hand-Written Rewrite Rules to Induce Underlying Morphology

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Unsupervised Morpheme Analysis – Morpho Challenge 2007

Outline

Definitions

We consider morphemes to be...

- basic units of grammar with no internal structure which may be composed together to form words
- realized as sequences of linguistic symbols (phones and/or letters)

Morphemes may be rendered differently in different contexts:

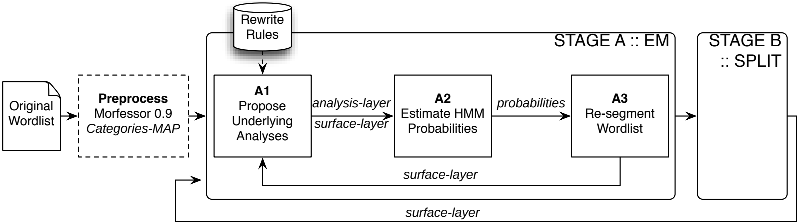
- lexical context: /s/ → en, as in ox*en*
- phonological/orthographic context: /s/ → es, as in dress*es*

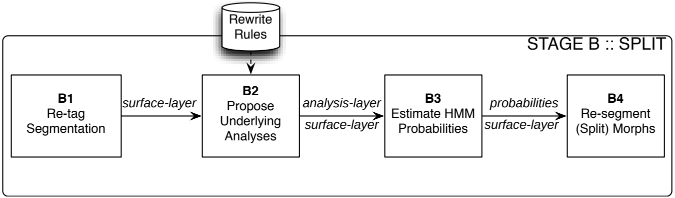
Morphological *variants* are known as allomorphs

Examples

Language	Type	Morpheme	Allomorphs
English	*stem*	/wake/	wake, wak
	suffix	/s/	s, es
Finnish	*stem*	/katto/ roof	katto, kato
	suffix	/ta/ partitive	a, ä, ta, tä
Turkish	*stem*	/kanad/ wing	kanad, kanat
	suffix	/dik/ nominalizer	dik, dük, dık, duk tik, tük, tık, tuk diğ, düğ, dığ, duğ tiğ, tüğ, tığ, tuğ

Flowchart


Rewrite Rules
STAGE A :: EM
STAGE B :: SPLIT
Original Wordlist
Preprocess
Morfessor 0.9
Categories-MAP
A1
Propose Underlying Analyses
analysis-layer
surface-layer
A2
Estimate HMM Probabilities
probabilities
A3
Re-segment Wordlist
surface-layer
surface-layer


Rewrite Rules
STAGE B :: SPLIT
B1
Re-tag Segmentation
surface-layer
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surface-layer
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probabilities
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B4
Re-segment (Split) Morphs

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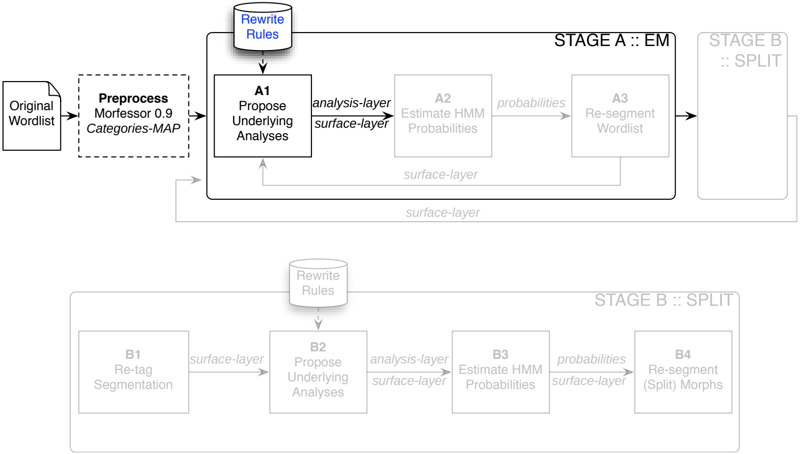
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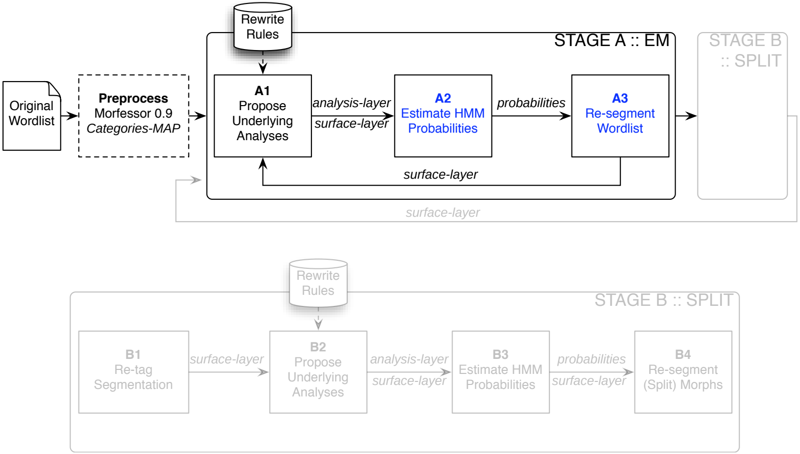
Analysis by Rewrite Rules

- Written as cascaded (ordered) rewrite rules and compiled into regular expressions.
- Rules are meant to be run in the analysis direction on a surface segmentation
- For efficiency, we only permit two types of analyses per segment s:
  - analyses where all the rules that could have applied, did. (u'')
  - analyses where no rules applied $(u' = s)$
- Example Rule capturing the fact that English suffix /s/ is written as es after sibilants (s, z, sh, ...):

$$\underset{\text{underlying}}{\text{ø}} \longrightarrow \underset{\text{surface}}{\text{e}} \,/\, [+\text{SIB}] + \_s \tag{1}$$

Flowchart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Stage A :: Basic EM

- We estimate transition and emission probabilities of a morfessor-style HMM via maximum likelihood.
- Emission probabilities are estimated by observing cooccurrences of segments s_i in the surface layer, u_i in the analysis layer, with tags t_i to estimate the probability $P(u_i|t_i)$ of emitting underlying morphemes:

$$P(u_i|t_i) = \sum_{s \in \text{allom.-of}(u_i)} P(u_i, s|t_i) \tag{2}$$

Where:

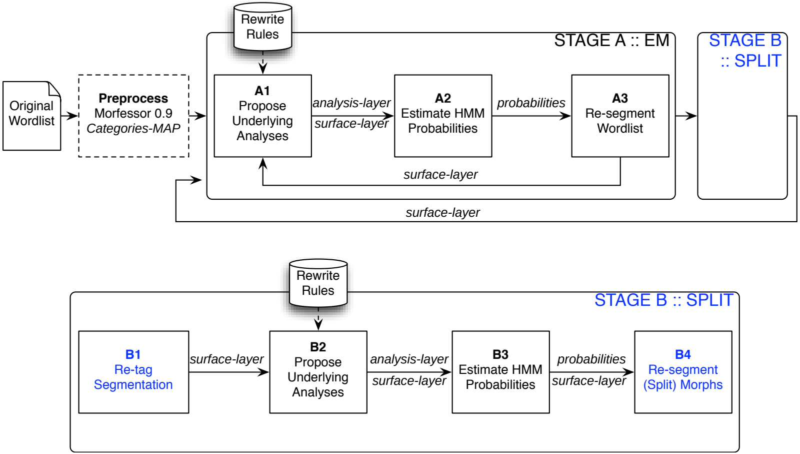
$$u_i = \begin{cases} u_i' & \text{if } u_i = s_i \\ u_i'' & \text{otherwise} \end{cases}$$

Stage A :: Basic EM

- Find the maximum probability segmentation of the wordlist by finding the argmax of the following equation for each word:

$$\underset{\mathbf{u},\mathbf{t}}{\text{argmax}} P(\mathbf{u}|\mathbf{t})P(\mathbf{t}) \approx \underset{\mathbf{u},\mathbf{t}}{\text{argmax}} \left[\prod_{i=1}^{n} P(u_i|t_i)P(t_i|t_{i-1}) \right] \quad (3)$$

Flowchart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Stage B :: Split Segments

- Re-tag the segmentation first, using Creutz and Lagus's 2004-2005 heuristic technique, such that only morphs exhibiting prototypical affix- or stem-distributional features are tagged as such.
- The remainder are tagged as noise; this makes them unavailable to be used in splitting.
- Key: Forcably split segments that are too frequent break under normal circumstances.

F-Measure Results

Language	Method	Precision	Recall	F-Measure
English	Morf.-*CatMAP*	82.17%	33.08%	47.17%
	Bernhard2	61.63%	60.01%	60.81%
	Tepper2-b300	75.62%	51.72%	61.43%
				1% impr.
Finnish	Morf.-*CatMAP*	76.83%	27.54%	40.55%
	Bernhard2	59.65%	40.44%	48.20%
	Tepper-b600	62.01%	46.20%	52.95%
				10% impr.
Turkish	Zeman	65.81%	18.79%	29.23%
	Morf.-CatMAP	76.36%	24.50%	37.10%
	Tepper-b100	61.15%	49.22%	54.54%
				47% impr.

Summary

- Our approach, which utilizes a small amount of knowledge in an otherwise unsupervised framework, is successful at learning underlying morphology.
- Learning improvements over unsupervised approaches are more dramatic for languages with more allomorphic effects, like Turkish (not surprising).
- There is hope that with a technique such as ours we can pinpoint generalizations about the most effective rules, which would be useful towards developing features for templates from which to learn rules.

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