TREES PROBE DEEPER THAN STRINGS: AN ARGUMENT FROM ALLOMORPHY

Hossep Dolatian + Shiori Ikawa + Thomas Graf

Stony Brook + Fuji Women’s + Stony Brook

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What the title means

• Title: *Trees probe deeper than strings: an argument from allomorphy*

1. Data: look at how allomorphy patterns can be modeled
2. Precedent: most formal work looks at how allomorphy is regular over string representations
3. Novelty: look at how tree-based representations show finer expressivity

• Disclaimer: String-based representations are more practically useful (FSAs, NNs). We’re exploring tree-based representations to gain a deeper understanding.

4. Finding: Direction of allomorphy affects the complexity of transformation in different ways depending on the representation
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Representations in morphology

- Two commonly used representations for morphology: strings and trees
- Strings more commonly used by morphophonologists
- Trees used by some morphosyntacticians (Halle and Marantz, 1993) but not all of them (Stump, 2001)
- Main ‘benefit’ of trees: directly encodes semantics
  
  | can be undone | cannot be done |
  | un- do -able | un- do -able |

- Strings require just finite-state machines (Beesley and Karttunen, 2003), while trees need tree transducers.
  
  ⇒ most formal work on morphology just uses the easier strings
What is allomorphy

- As a case study on tree formalizations, we look at morphologically-conditioned allomorphy.
- A morpheme has two or more allomorphs and their distribution is based on morphological context.
- E.g., the English plural: *cat-s* but *ox-en*.
- The plural suffix is the **target** of allomorphy, while the **trigger** is the type of root.
**Typology of allomorphy**

- **Basic typology**
  The target $y$ of allomorphy can be
  - local/adjacent to the trigger $x$, or non-local
  - structurally higher than the trigger $x$, or lower

| Adjacency      | Direction | Inward          | Outward         |
|----------------|-----------|-----------------|-----------------|
| Local          |           | $x < y$         | $y < x$         |
| Non-adjacent   |           | $x < \cdots < y$ | $y < \cdots < x$ |

- Inward (outward) = the trigger $x$ is below (above) the target $y$
- For the English plural, the trigger $x$ and target $y$ are local and inward

- Local cases are easy and equivalent over strings/trees. We’ll focus on the non-local
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Non-local allomorphy is when the trigger and target are non-adjacent.

The trigger can be below/above the target

Below = Inward: Kiowa:

| héíb-e-gùù-mòò-tòò | héíb-é-gùù-mòò-t!òò |
|----------------------|-----------------------|
| enter-TRₓ-DISTR-NEG-MODᵧ | enter-INTRₓ-DISTR-NEG-MODᵧ |
| MOD→-tòò / TR ... _ | MOD→-t!òò / INTR ... _ |

Above = Outward: Slovenian

| žanj-e-∅-m     | Ž-e-l-a             |
|----------------|--------------------|
| reapᵧ-ASP-PRES-2P.SG | reapᵧ-ASP-PTCₓ-F.SG |
| √reap →žanj | √reap →ž / _ .... PTC |

Both are sequential FSTs for strings, but different tree transducers!
Non-local and inward

- Inward Kiowa:

| héíb-e-guy-mɔɔ-tɔɔ | héíb-é-guy-mɔɔ-t!ɔɔ |
|---------------------|---------------------|
| enter-\text{TR}_x-\text{DISTR-NEG-MOD}_y | enter-\text{INTR}_x-\text{DISTR-NEG-MOD}_y |
| MOD→-tɔɔ / TR ... _ | MOD→-t!ɔɔ / INTR ... _ |

- If we assume a large but finite bound between trigger $x$ and target $y$, then we need multiple rewrite rules with large contexts.

(1) a.

```
  MOD
   /
  _
     /
  _
  TR
→  -tɔɔ
```

b.

```
  MOD
   /\W
  W
     /\W
  W
→  -t!ɔɔ
```
BOTTOM-UP TREE TRANSDUCERS

- If we want to acknowledge non-locality, then we need a deterministic bottom-up tree transducer.
- In a bottom-up tree transducer, the transduction of a node depends on its label and the states of all its daughters.
- Example: if a node is b and both of its daughter nodes are in $q_o$
  - transform it into $d$
  - move to state $q_e$
If we want to acknowledge non-locality, then we need a deterministic bottom-up tree transducer.

In a bottom-up tree transducer, the transduction of a node depends on its label and the states of all its daughters.

Example: if a node is b and both of its daughter nodes are in $q_o$
  
  ▶ transform it into $d$
  ▶ move to state $q_e$

```
  b
 /\  \
a b
  \
  \
  \
  \
  qo qo v  a  a
  |   |   |
  qo qo w  w
  a  a
```

```
  b
 /\  \
 a qe qe
  \
  \
  \
  d  qe
  a  qe
   \
   \
   a  a
    \
    \
    a  a  w  w
```
**Non-local trees**

- **MOD** does not dominate **TR/INTR**
- **We need a waiting strategy**
  - output nothing when reading **MOD**
MOD does not dominate TR/INTR
We need a waiting strategy
- output nothing when reading MOD
**Non-local trees**

- **MOD** does not dominate **TR/INTR**
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  - output nothing when reading **MOD**
Non-local trees

- **MOD** does not dominate **TR/INTR**
- **We need a waiting strategy**
  - output nothing when reading **MOD**
  - output the blue part when reading $x$, depending on whether **TR/INTR** occurs below $x$
Non-local and outward

- Kiowa was non-local and inward.
- Things get a bit more complicated for non-local and outward allomorphy.

Slovenian:

| žanj-e-∅-m | Ž-e-l-a |
| --- | --- |
| reap$_y$-ASP-PRES-2P.SG | reap$_y$-ASP-PTC$_x$-F.SG |

\[\sqrt{reap} \rightarrow Žanj\] \[\sqrt{reap} \rightarrow Ž / \_ \_ \_ \_ \_ \_ \_ PTC\]

- If we assume there’s a finite bound between target and trigger, then it’s just a local transduction.

(2) a. \[\Rightarrow Ž\]

b. \[\Rightarrow Žanj\]
• But if we treat this allomorphy as truly non-local, then we get some formalization problems
• We need a deterministic top-down tree transducer.
• But if we treat this allomorphy as truly non-local, then we get some formalization problems
• We need a deterministic top-down tree transducer.
• But if we treat this allomorphy as truly non-local, then we get some formalization problems.
• We need a deterministic top-down tree transducer.
Problems for outward allomorphy

- The labels of y’s siblings are needed in the case of Slovenian.

- The state assigned to a daughter $x_i$ depends only on the label of its mother and the state assigned to the mother.

- Crucially the labels of siblings are not taken into consideration.
The labels of y’s siblings are needed in the case of Slovenian.

The state assigned to a daughter $x_i$ depends only on the label of its mother and the state assigned to the mother.

Crucially the labels of siblings are not taken into consideration.

Look-ahead of depth 1 at x is need (Sensing Tree Transducer, cf. Graf and De Santo 2019)
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Summarize: string vs. tree-based representations don’t make much of a difference for most types of allomorphy

**Table**: Summary of formal results for directionality and locality of allomorphy types; patterns marked with * are ISL if one does not assume unboundedness

| Pattern           | String-based computation                     | Tree-based computation                          |
|------------------|-----------------------------------------------|------------------------------------------------|
| Inward & local   | ISL                                           | ISL                                            |
| Inward & non-local| Left-to-right sequential*                     | bottom-up sequential*                          |
| Outward & local  | ISL                                           | ISL                                            |
| Outward & non-local| Right-to-left sequential*                     | top-down sequential*                           |
|                  |                                               | or STFTT* (sensing)                            |

But for outward non-local cases, trees disambiguate the effects of different computations
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