Hierarchic syntax improves reading time prediction

Marten van Schijndel and William Schuler
Linguistics, The Ohio State University

Introduction

Previous work has debated whether humans make use of hierarchic syntax when processing language [Frank and Bod, 2011]. The present work demonstrates:

- How to improve strong 5-gram models.
- Hierarchic syntax improves reading time fit over a strong linear baseline.
- Hierarchic syntax is used during reading to resolve both local and long-distance structural dependencies.

N-gram Example

Bigram probabilities predict reading time of \textit{girl after red}:

1. The red apple that the \textbf{girl} ate . . .

\[ \text{(1)} \]

Traditional n-gram measures fail to capture entire sequence. Conditions are never generated; Probability of given sequence is deficient.

Cumulative N-gram Example

\text{Cumusurp} bigram probes predict reading time of \textit{girl after red}:

1. The red \textbf{apple} \textbf{girl} ate . . .

\[ \text{(2)} \]

Cumulative n-gram product captures entire sequence. Probability of given sequence is well-formed. Reflects processing that must be done by humans.

Experiments

Experiments used linear mixed effects models with by-item and by-subject random intercepts and by-subject random slopes. The significance of model fit differences was determined using \( \chi^2 \) tests (First Pass \( n = 194882 \); Go-Pass \( n = 193709 \)).

1) Cumulative N-grams

Can n-grams reflect more complete probabilities?

- Base factors:
  - Fixed: Sentence position
  - Fixed: Word length
  - Fixed: Region length (in words)
  - Random: Was preceding word fixed?
  - Random: All fixed effects
  - Random: 5-grams
  - Random: Cumus-5-gram

Results are similar for both measures.

2) Cumulative Surprisal

Can PCFG surprisal reflect more complete probabilities?

- Base factors:
  - Fixed: 5-gram
  - Fixed: Cumus-5-gram
  - Random: Surprisal (PTB PCFG)
  - Random: Cumus (PTB PCFG)

Results are comparable when using GCG PCFG

3) Hierarchic Syntax

Does hierarchic syntax improve over a strong linear baseline?

- Base contains factors from Experiment 1, plus:
  - Fixed: 5-gram
  - Fixed: Cumus-5-gram
  - Random: Surprisal (PTB PCFG)
  - Random: Surprisal (GCG PCFG)

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References


Contact:
vanschm@ling.osu.edu