A new model of local coherences resulting from Bayesian belief update

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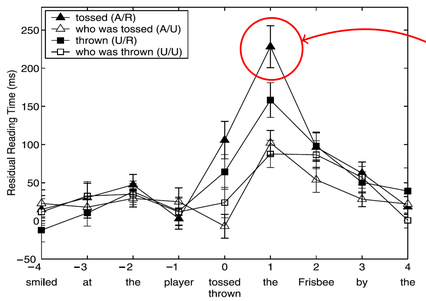
Abstract

Local coherences are cases in which it appears that the parser is systematically ignoring contextual information about possible syntactic structures and pursuing analyses that are probable only locally. We describe a new model of local coherence effects under rational comprehension, proposing that they arise as a result of updating bottom-up prior beliefs about the structures for a given string to posterior beliefs about the likelihoods of those structures in context. The critical intuition embodied in the model is that larger updates in probability distributions should be more processing-intensive. An experiment demonstrates that this model makes the correct predictions for the data from the original Tabor et al. experiment.

Local coherences

Tabor, Galantucci, and Richardson (2004):
verb ambiguity × relative clause reduction

(1) The coach smiled at the player *tossed* a frisbee …
(2) The coach smiled at the player *who was tossed* a frisbee …
(3) The coach smiled at the player *thrown* a frisbee …
(4) The coach smiled at the player *who was thrown* a frisbee …



super-additive interaction 'the player tossed'

The original explanation

The intuition (Tabor et al., 2004)

- 'local coherence' in *the player tossed a frisbee*
- makes a great sentence by itself
- this parse competes with global parse

The model (Tabor & Hutchins, 2004)

- 'self-organized parsing'
- parsing: activating lexically anchored tree fragments
- fragments activate compatible fragments
- locally coherences make system take longer to stabilize

See Levy (2008) and Gibson (2006) for alternative explanation.

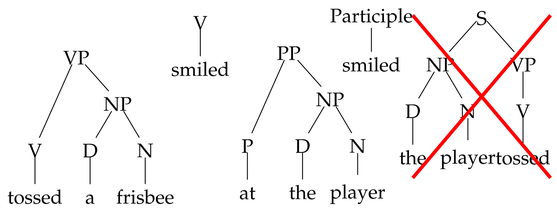
Motivation & Goals

Question why use such an irrational strategy?

Goal 1 present a model maintaining Tabor et al.'s intuition in a rational framework

Goal 2 show that it correctly predicts the Tabor et al. data

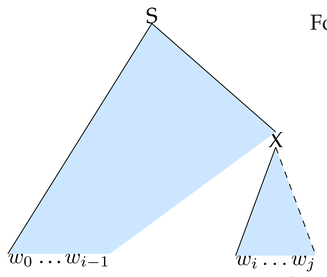
The intuition



A new sentence composed of familiar parts

- These likely structures can be incompatible
- **belief update**: deciding what to throw away

The model



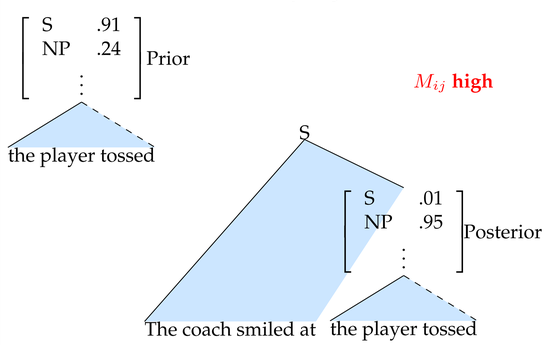
To integrate new word(s) w_i^j into a sentence …

For each syntactic category X:

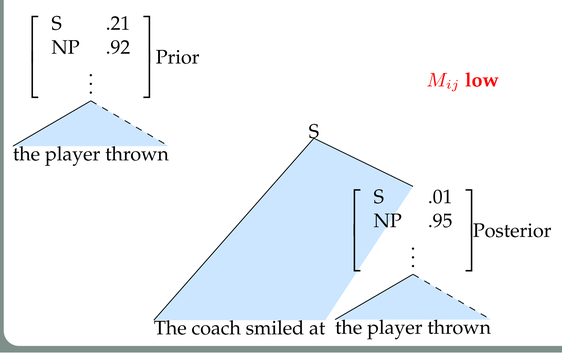
- begin with 'bottom-up' **Prior**: $P(X_i^{k \geq j} | w_i^j)$
- integrate with 'top-down' knowledge to reach **Posterior**: $P(X_i^{k \geq j} | w_0^j)$
- M_{ij} = amount of modification required to update prior to posterior when integrating w_i^j

An example

The coach smiled at *the player tossed* …



The coach smiled at *the player thrown* …



The experiment

Implementation

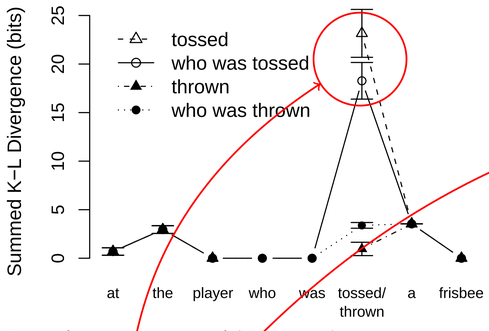
- stochastic context-free grammar (SCFG)
- calculate the posterior and get very good approximation of prior using a modified Earley parser (Stolcke, 1995)
- calculate prior & posterior for each nonterminal category
- measure M_{ij} as Kullback-Leibler (K-L) divergence between prior & posterior, summed over categories

$$M_{ij} \stackrel{\text{def}}{=} \sum_{X \in N} D\left(P(X_i^{k \geq j} | w_0^j) \,||\, P(X_i^{k \geq j} | w_i^j)\right)$$

Methods

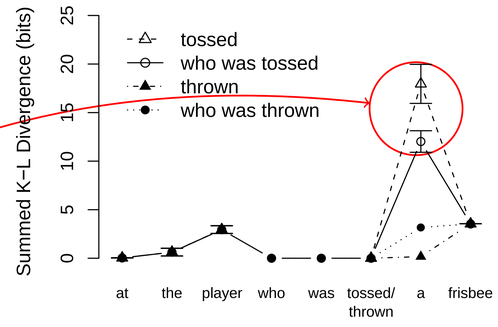
- defined small SCFG
- estimated probabilities from parsed Brown corpus
- 12 of Tabor et al.'s items (so model knew verb & syntax)
- same 4 conditions as Tabor et al.:
- three sizes of w_i^j to integrate: 1-, 2-, & 3-words
- prediction: M_{ij} will be highest for *the player tossed*

Results: One-word integration



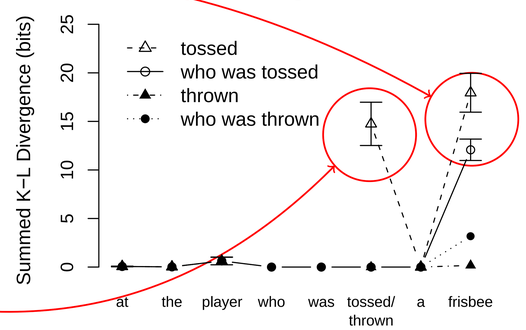
main effect: tossed > thrown

Results: Two-word integration



super-additive interaction 'the player tossed'

Results: Three-word integration



Conclusions

A new model

- context-independent beliefs about likely structures for words being integrated (Prior) are updated to in-context beliefs (Posterior)
- rational if prior beliefs are available more rapidly (e.g., maybe they are precomputed)
- can account for the results of the Tabor et al. experiment

Next step

Broad coverage predictions

- Extend model to use a broad-coverage grammar and make predictions for local coherences in naturalistic text

References

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