A Functional Analysis of Historical Memory Retrieval Bias in the Word Sense Disambiguation Task

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Our Focus

Cognitive Architecture

- Underlying infrastructure for intelligent systems
- Aspects of cognition that are constant over time and across different application domains

Long-Term Memory

- Encode experience; store internally; support retrieval
- Our **goal**: develop and evaluate a suite of mechanisms that are effective and efficient across a variety of tasks

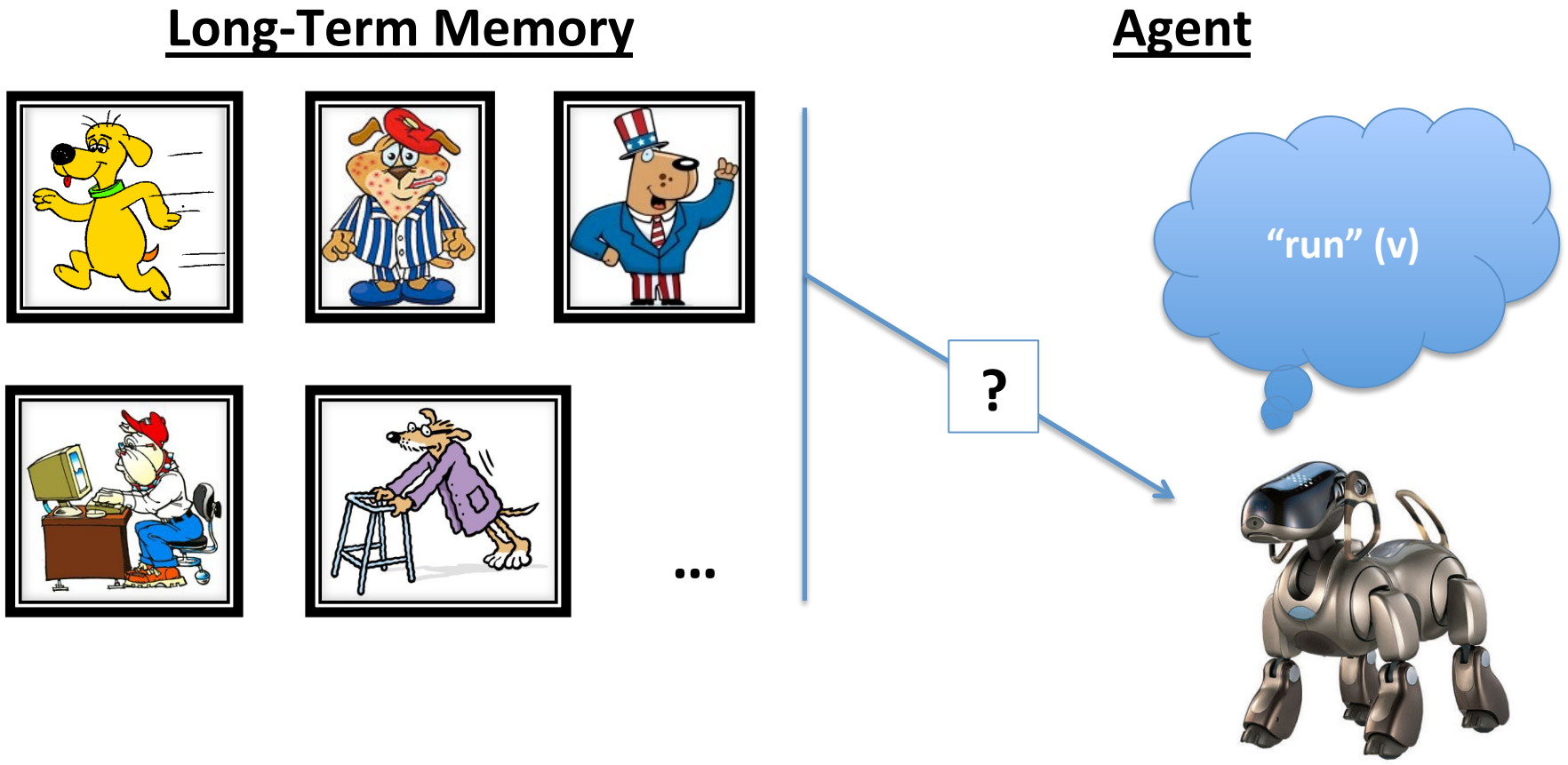
Problem: Supporting Ambiguous Cues

Given…

- a cue that could result in retrieving one of multiple previously encoded memories
- and a large store of knowledge

support retrievals that are **effective** and **efficient** across a variety of tasks.

Example: Ambiguous Cues



Prior Work: Historical Memory Bias

Effectiveness

Rational analysis posited that human memory optimizes over history of past memory access

Efficiency

Current implementations of base-level activation do **not** scale to large stores of knowledge

Our Contributions

Task analysis. Word sense disambiguation across 3 commonly used data sets

Effectiveness. Evaluate the functional benefit of biasing retrievals based upon the history of past memory access

Efficiency. High-fidelity, high-performance methods to support historically biased retrievals from large knowledge stores

Word Sense Disambiguation (WSD)

Task. Computationally identify the meaning of words in context

Our focus is not language processing, therefore we appropriate a simplified, highly structured problem formulation.

Our WSD Formulation

Input

- Sequence of sentences (sequence of words)
- Each word specified as lexical string and part-of-speech (noun, verb, adjective, adverb)

Given

- Machine Readable Dictionary (MRD): for each word…
  - Set of available senses: for each sense…
    - Definition
    - Tag frequency

WSD Example

Input*

Sentence

*He will be succeeded by Ivan Allen Jr., who became a candidate in the Sept. 13 primary after Mayor Hartsfield announced that he would not **run** for reelection.*

Word

"run" (v)

MRD†

a) [0] "become undone; 'the sweater unraveled'

b) [0] "come unraveled or undone as if by snagging; 'Her nylons were running'"

c) [0] "reduce or cause to be reduced from a solid to a liquid state, usually by heating; 'melt butter'; 'melt down gold'; The wax melted in the sun'"

d) [3] "cause to perform; 'run a subject'; 'run a process'"

…

h) **[7] "run, stand, or compete for an office or a position; 'Who's running for treasurer this year?'"**

…

r) [106] "move fast by using one's feet, with one foot off the ground at any given time; 'Don't run—you'll be out of breath'; 'The children ran to the shore'"

…

(41 total options; 1 appropriate in this context)

* Kucera and Francis 1967

† Miller 1995

Evaluation Data Sets

Sentences. English all-words*

	SemCor†	Senseval-2‡	Senseval-3‡
Inputs	185,269	2,260	1,937
Random Performance	38.73%	40.56%	32.98%

MRD. WordNet** v3

212,558 senses

* http://www.cse.unt.edu/~rada/downloads.html
† Miller et al. 1993
‡ Navigli 2009
** Miller 1995

Evaluation Methodology

Task

…

7. “announce” (v)
8. “not” (r)
9. “run” (v)
10. “reelection” (n)

…

1. “run” (v)

2. 

3. 

Agent

Evaluating Effectiveness

Non-Adaptive Baselines

- Lesk*
- Simplified Lesk†
- Static Frequency

Memory-based Approach

Single Bias Models

- Recency‡
- Dynamic Frequency
- …

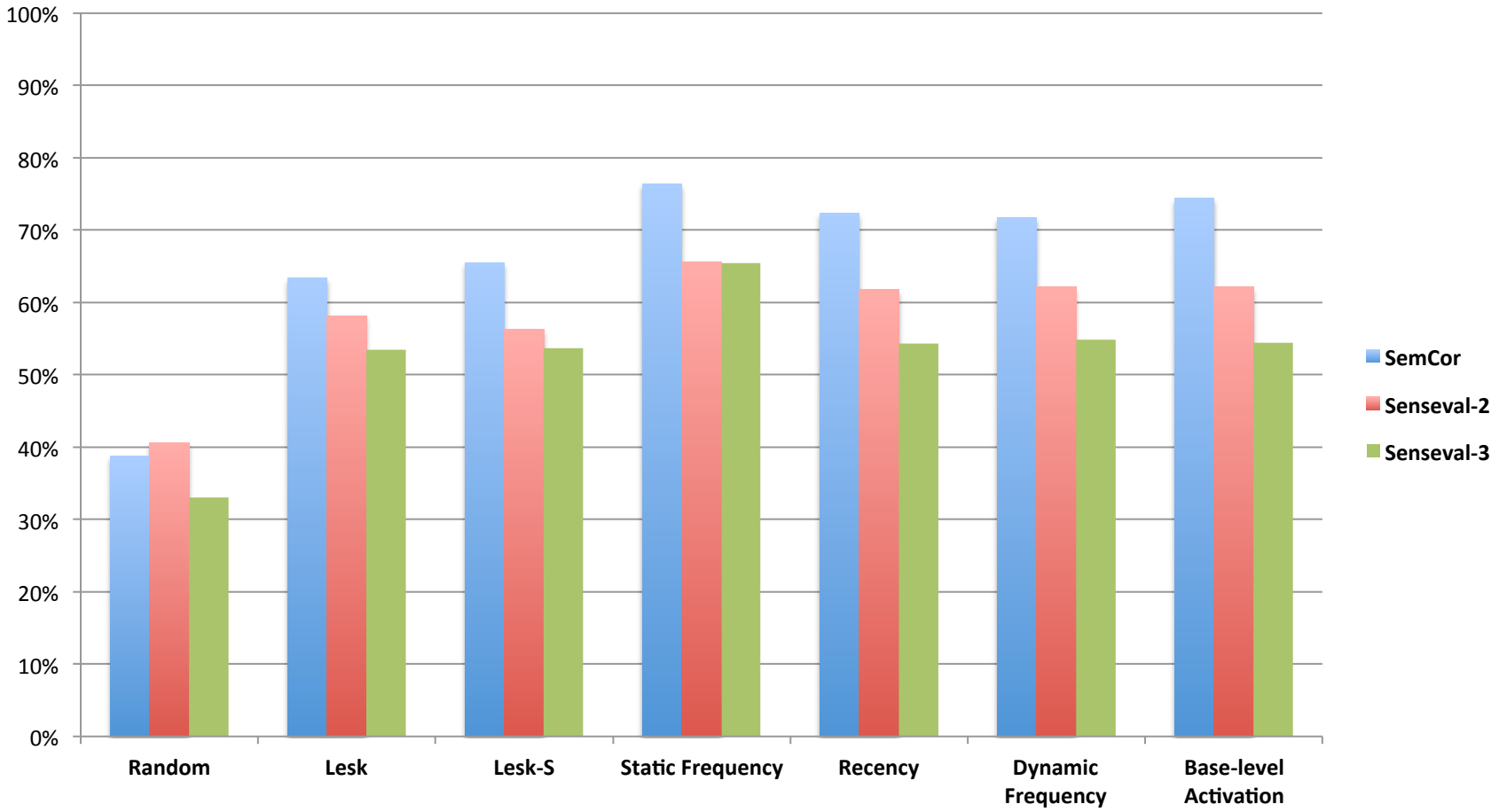
Joint Bias Models

- Base-level Activation**
- …

* Lesk 1986
† Kilgarriff and Rosenzweig 2000
‡ Gale, Church, and Yarowsky 1992
** Anderson et al. 2004

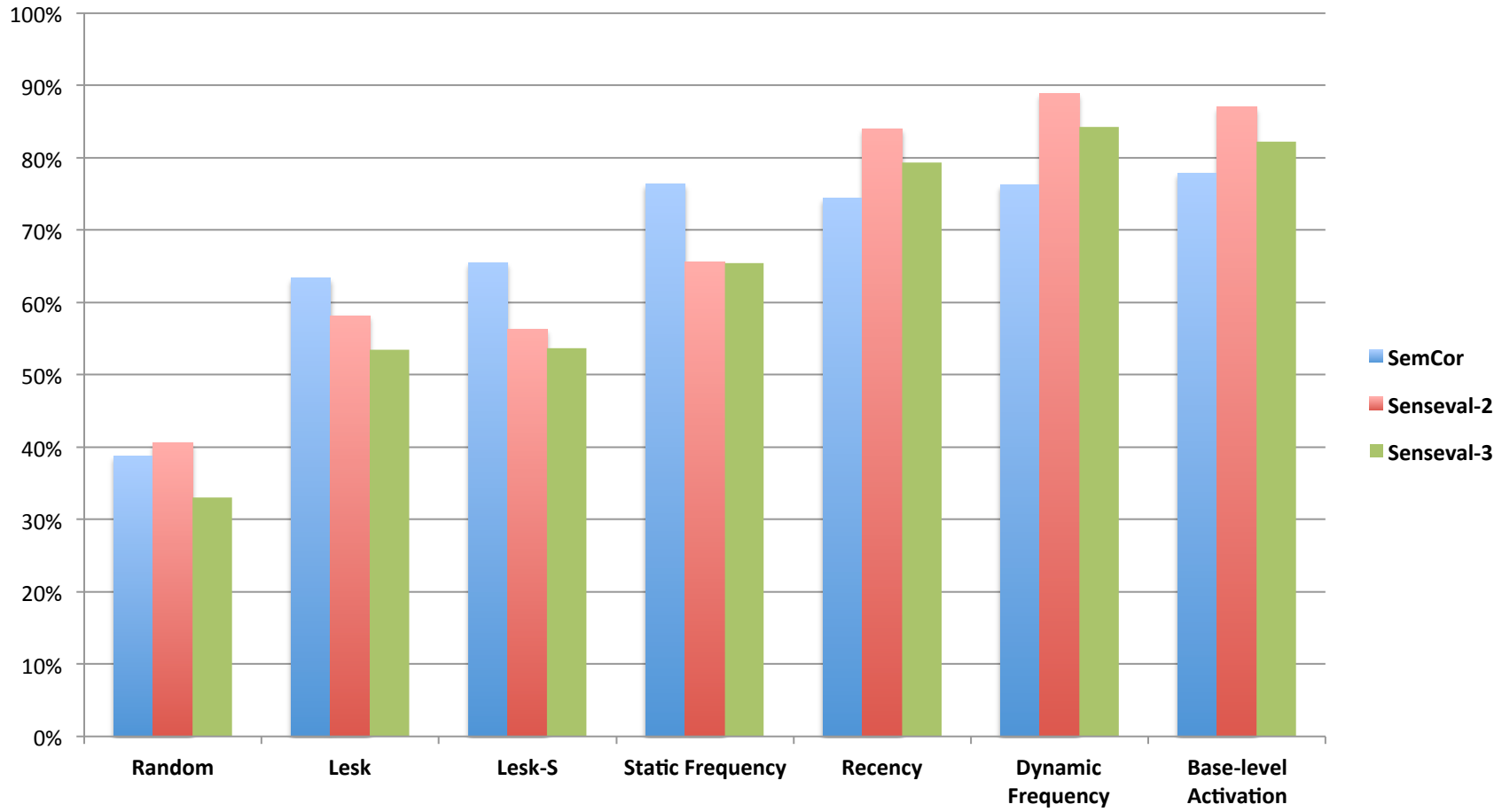
Task Performance

(1 corpus exposure)



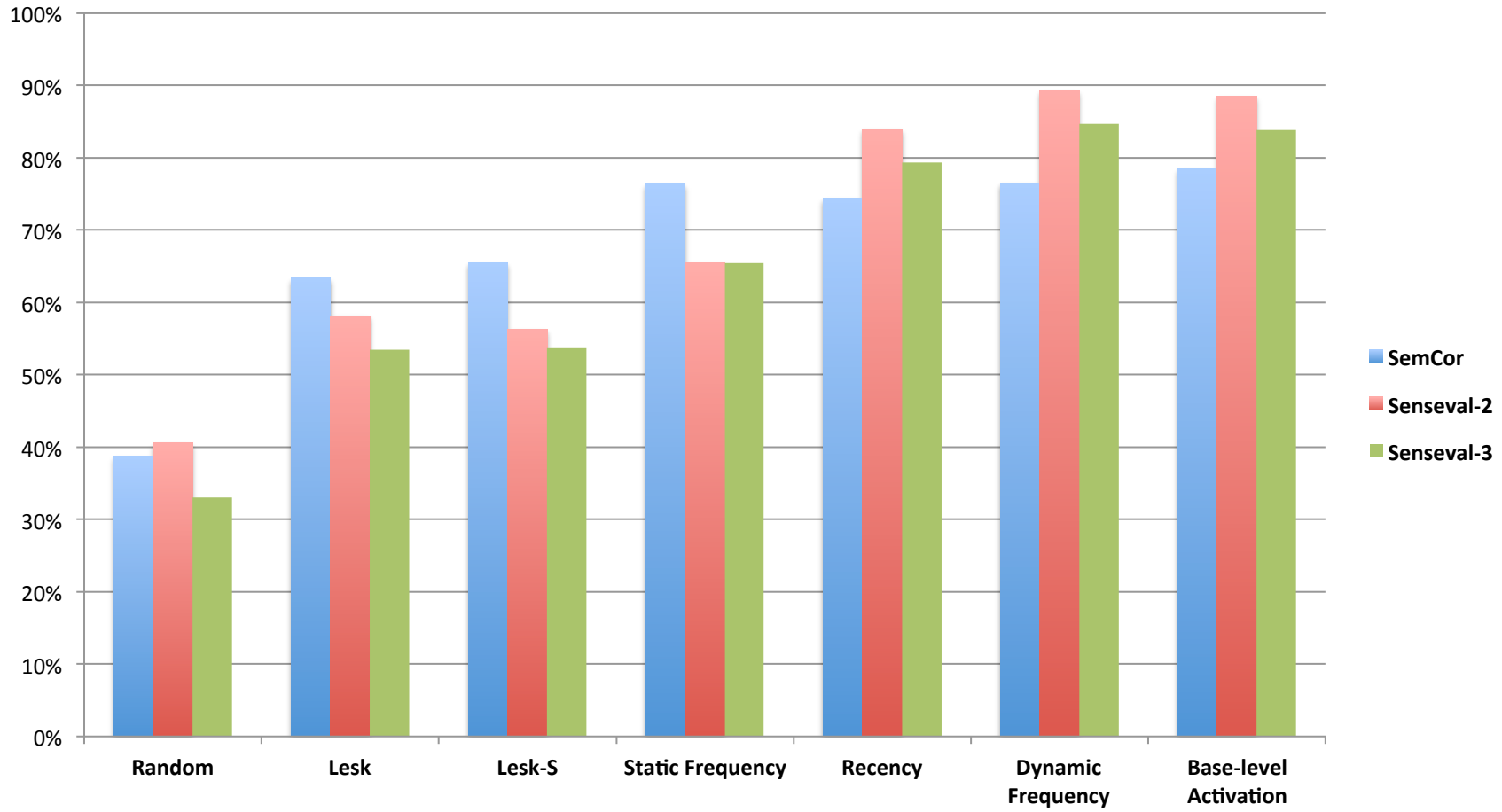
Task Performance

(2 corpus exposures)



Task Performance

(10 corpus exposures)



Effectiveness Summary

3 historical memory biases, 3 WSD data sets

- Improvements over non-adaptive algorithms after little corpus exposure
- Task-independent method **not** dependent on…
  - Definition quality (Lesk)
  - Relative frequency representation (Static Frequency)

Evaluating Efficiency

Metric of Interest. Maximum query time

Reflects agent reactivity given a large amount of stored knowledge (WordNet*)

Our Goal. 50 msec.

Necessary for reactive control in robotics, computer games, and interactive systems

* Douglass, Ball, and Rogers 2009

Single Bias Models

Recency and Dynamic Frequency are *locally efficient*[*]

- Constant time computation
- Local effects

Max. Query Time (msec): Soar v9.3.1

	SemCor	Senseval-2	Senseval-3
Recency	0.85	0.82	0.80
Dynamic Frequency	0.87	0.82	0.78

[*] Derbinsky, Laird, and Smith 2010

Base-level Activation

Motivation

- High WSD performance
- Important component of many cognitive models

Challenge

- Exponential decay of **all** memories at each time step

Approach

- Novel *locally efficient* approximation
  - Observation: present over-estimates future
  - Only update on access (+ *c* older)
- Bounded memory window*

$$\ln\left(\sum_{j=1}^{n} t_j^{-d}\right)$$

* Petrov 2006

Base-level Approximation Evaluation

	SemCor	Senseval-2	Senseval-3
Max. Query Time: Soar v9.3.1	1.34 msec	1.00 msec	0.67 msec
Task Performance Difference	0.82%	-0.56%	-0.72%
Minimum Model Fidelity*	90.30%	95.70%	95.09%

* The smallest proportion of senses that the approximation selected within a corpus exposure that matched those of the base-level activation model.

Efficiency Summary

Single Bias Models

- > 50x faster than real-time

Base-level Activation Approximation

- > 30x faster than real-time
- Comparable task performance, high fidelity

Discussion

Contributions

- Evaluated effectiveness of historical memory retrieval biases on 3 WSD data sets
- Implemented and evaluated methods to efficiently support biased retrievals over large knowledge stores

Future Work

- Evaluate additional …
  - tasks
  - bias types (ex. context)
  - reasoning and learning mechanisms

Thank You :)

Questions?