Large Semantic Stores in Soar

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Semantic Knowledge

Some knowledge can be useful independent of the context in which it was initially learned

Lexical	Word meanings, synonyms, …
Mathematical	Arithmetic facts, function/relation definitions, ….
Geographical	Capitals, bodies of water, …
Historical	Wars, discoveries, reigns of power, …
Ontological	Biology, technology, art, …
Commonsensical	"Tables typically have four legs"
…	

Large Semantic Stores

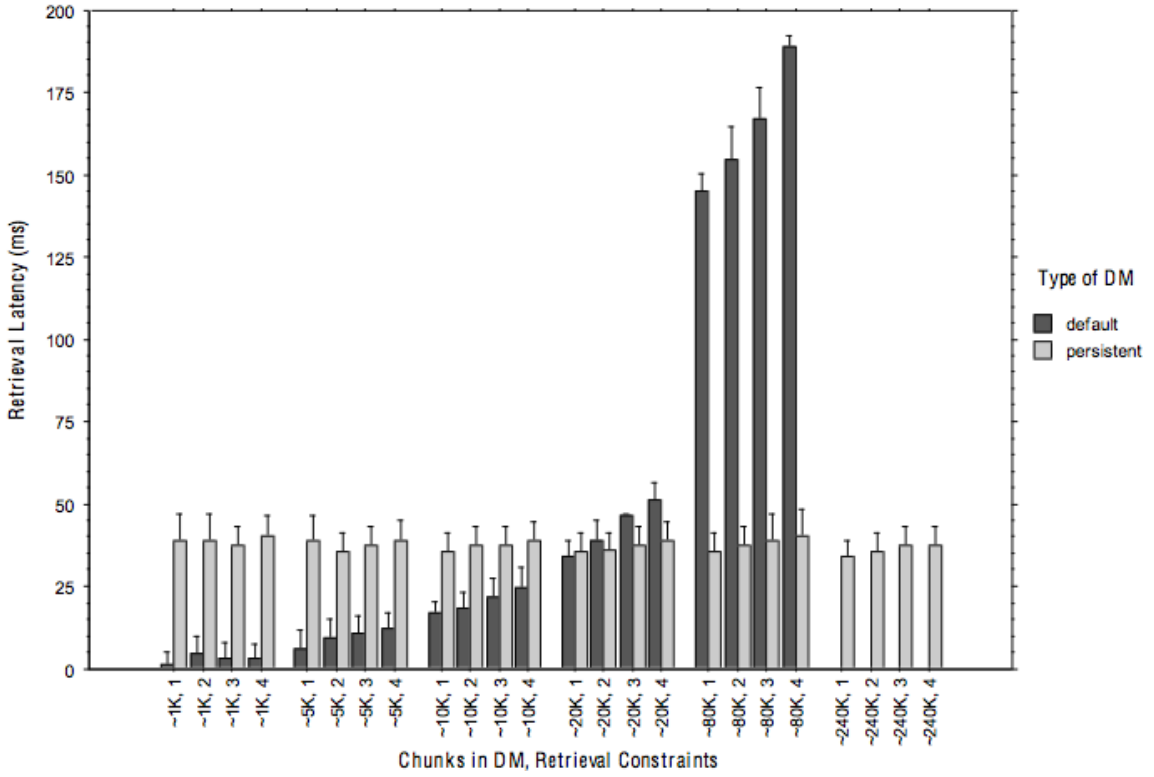
Agents contending with complex tasks will need access to large amounts of semantic knowledge

WordNet	Cyc	SUMO
Lexical	Common Sense	Ontological
> 212K senses >820K facts	>500K concepts >5M facts >1M rules	>4.5K classes >250K facts

Scaling to Large Semantic Stores

To remain reactive to dynamic environments, an agent's cognitive architecture must support bounded search over large stores of knowledge

Scaling: ACT-R DM



Douglass, S., Ball, J., & Rodgers, S. (2009). Large declarative memories in ACT-R. ICCM

Scaling: Soar (Data Chunking)

Approach

Productions condition upon all possible combinations of cue structures

Results in creation, matching, and updating an exponential number of rules

Example

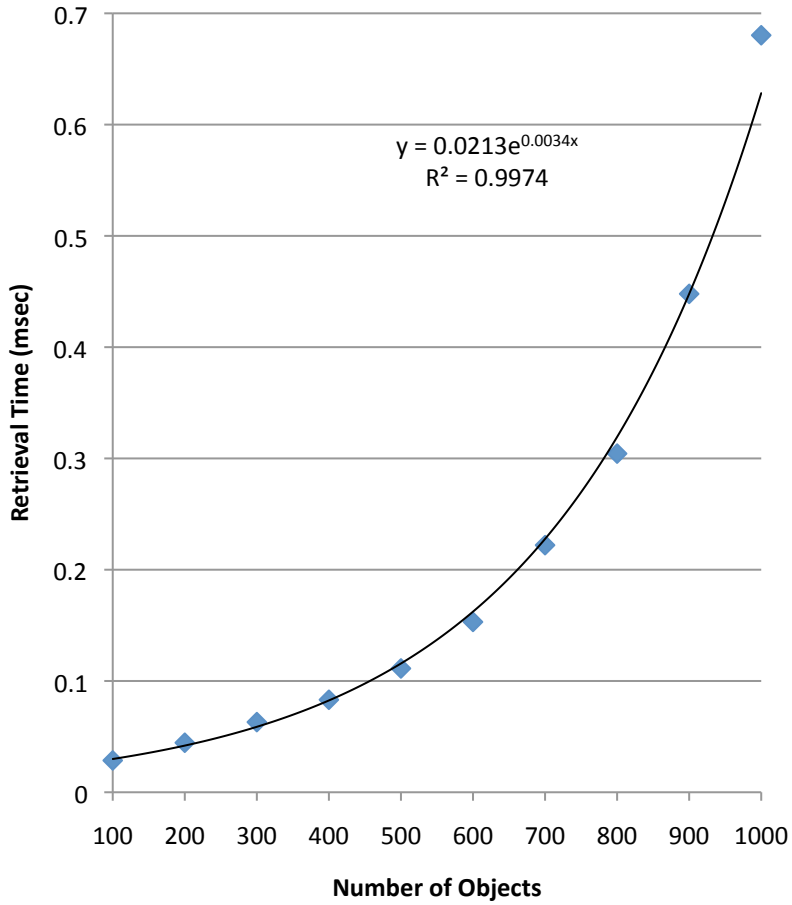
1. (a AND b AND c AND d)
2. (a AND b AND c)
3. (a AND b AND d)
4. (a AND c AND d)
5. (b AND c AND d)

…

Scaling: Soar (Working Memory)

On-demand procedural rule matching per-cue

Match time grows with the number of objects



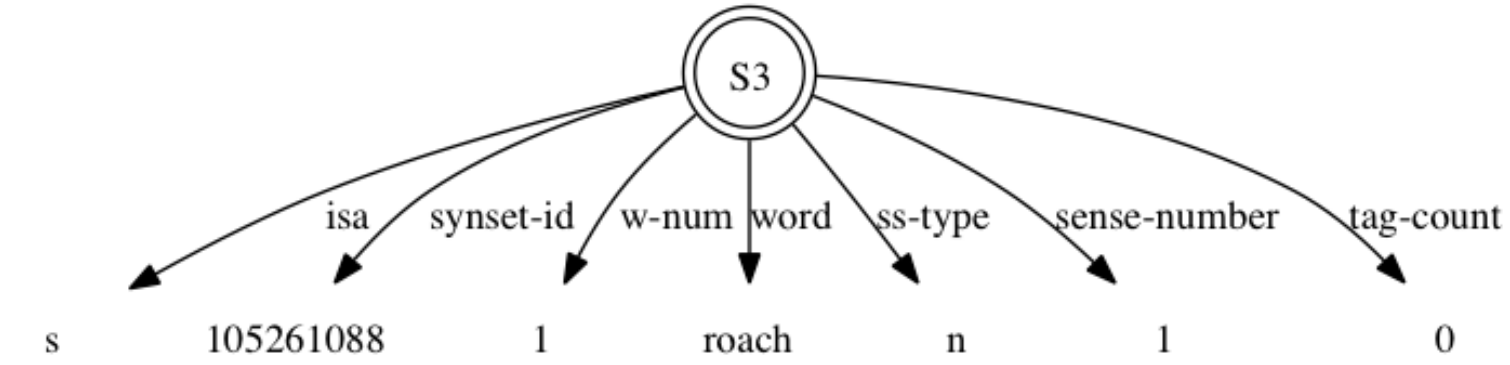
Large Semantic Stores in Soar

- Defining semantic knowledge/retrieval
- Retrieval mechanism description
- Evaluation
  - WordNet
  - Synthetic

Semantic Knowledge

Long-term identifier and augmentations
- Same representation as working memory

Similar to ACT-R declarative chunks
- No pre-defined chunk types
- Supports multi-valued attributes



Semantic Retrievals

Given

- Conjunctive set of attribute [/value pairs]
- Semantic store

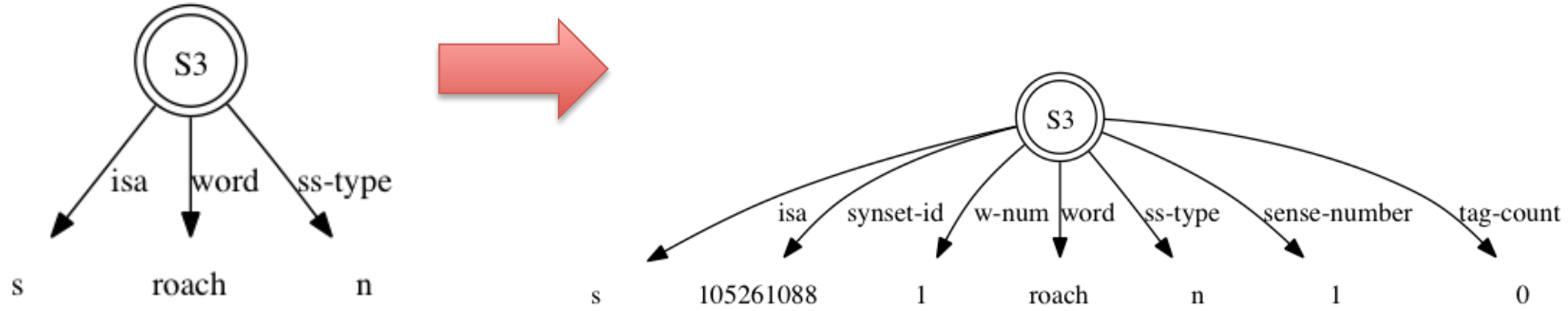
Find

- Most recently accessed identifier that contains cue structures

Does NOT Support

- Inference
- Partial matching
- Spreading activation

…



Retrieval Mechanism

Algorithm

1. Sort cue elements by rarity of occurrence
   a) *candidates* = identifiers satisfying rarest cue element
2. While *candidates* remain
   a) c = next *candidate*
   b) if c contains remaining cue elements, done

Notes

B+-trees support…

- log-time incremental updates to attribute/value frequency statistics during storage
- log-time access to incrementally updated linked list of candidates
- log-time query of candidate-cue element containment

Comparison to Other Approaches

Database Management System (DBMS)

- Constrained storage/retrieval interface yields opportunities for optimization

CYC

- Strict separation of problem/knowledge search delegates expensive inference to control knowledge

Evaluation: WordNet

WN-LEXICAL WordNet 3 data conversion

Edmond, B. (2006). WN-LEXICAL: An ACT-R Module Built from the WordNet Lexical Database. ICCM

Soar-SMem import

Instructions on wiki (~ 5 minutes)

~821.5K nodes, ~3.76M edges

~400MB on disk

WordNet Retrievals

Cue Type	Cue Size	Avg. Retrieval Time	Std. Deviation
Underspecified	1	0.1887 msec	0.0216 msec
Full word sense	7	0.2973 msec	0.0108 msec

100x faster retrievals on a comparable set of cues scaling to a 3x larger semantic store

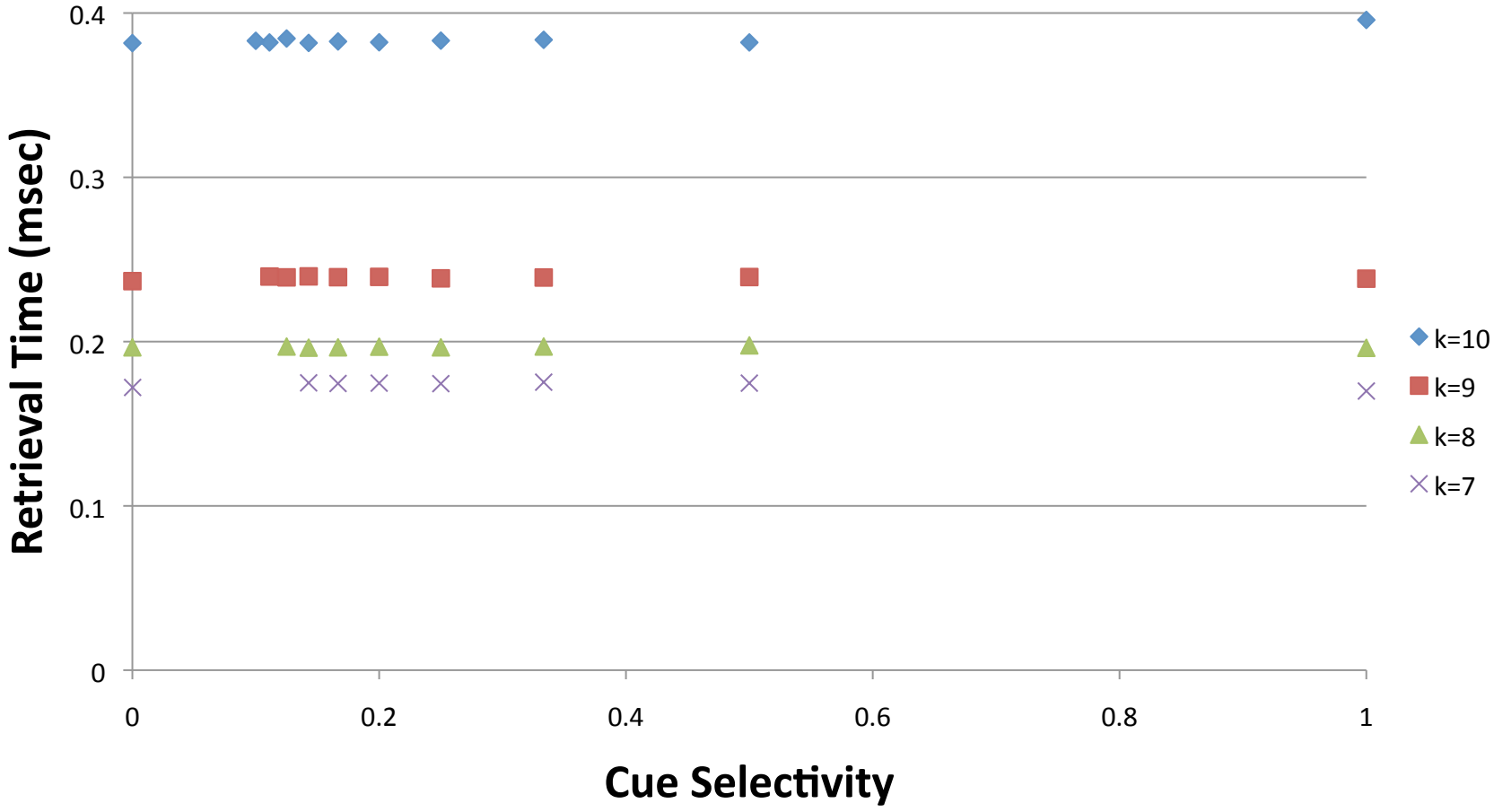
Evaluation: Synthetic

Focus on scaling

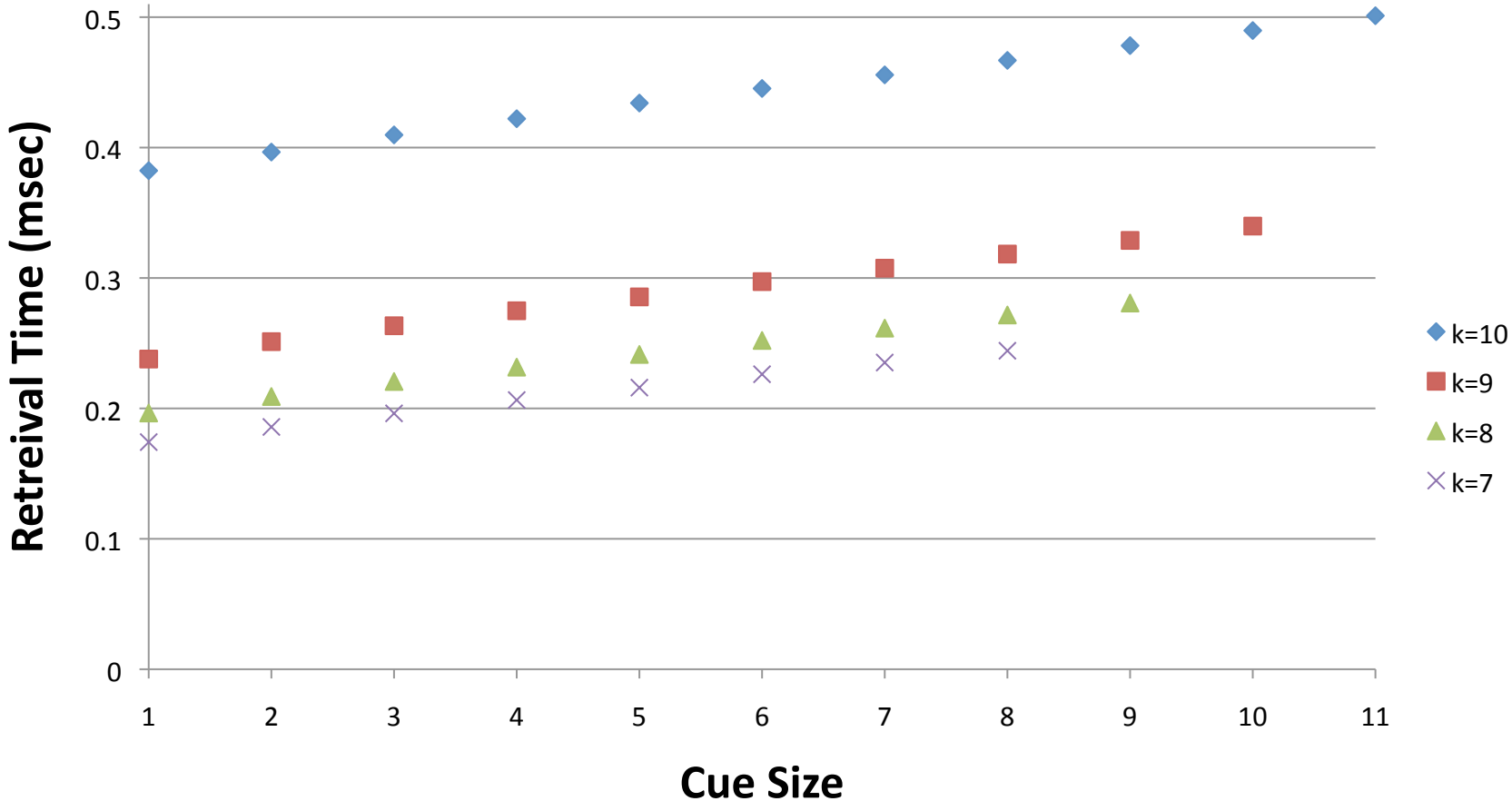
- Generator with single size parameter (k)
- Easily construct queries to control for selectivity

k	Nodes: k!	Edges: [k+1]!	Store Size (MB)
7	5K	40K	3.00
8	40K	362K	27.81
9	362K	3.6M	291.95
10	3.6M	39.9M	2048.00

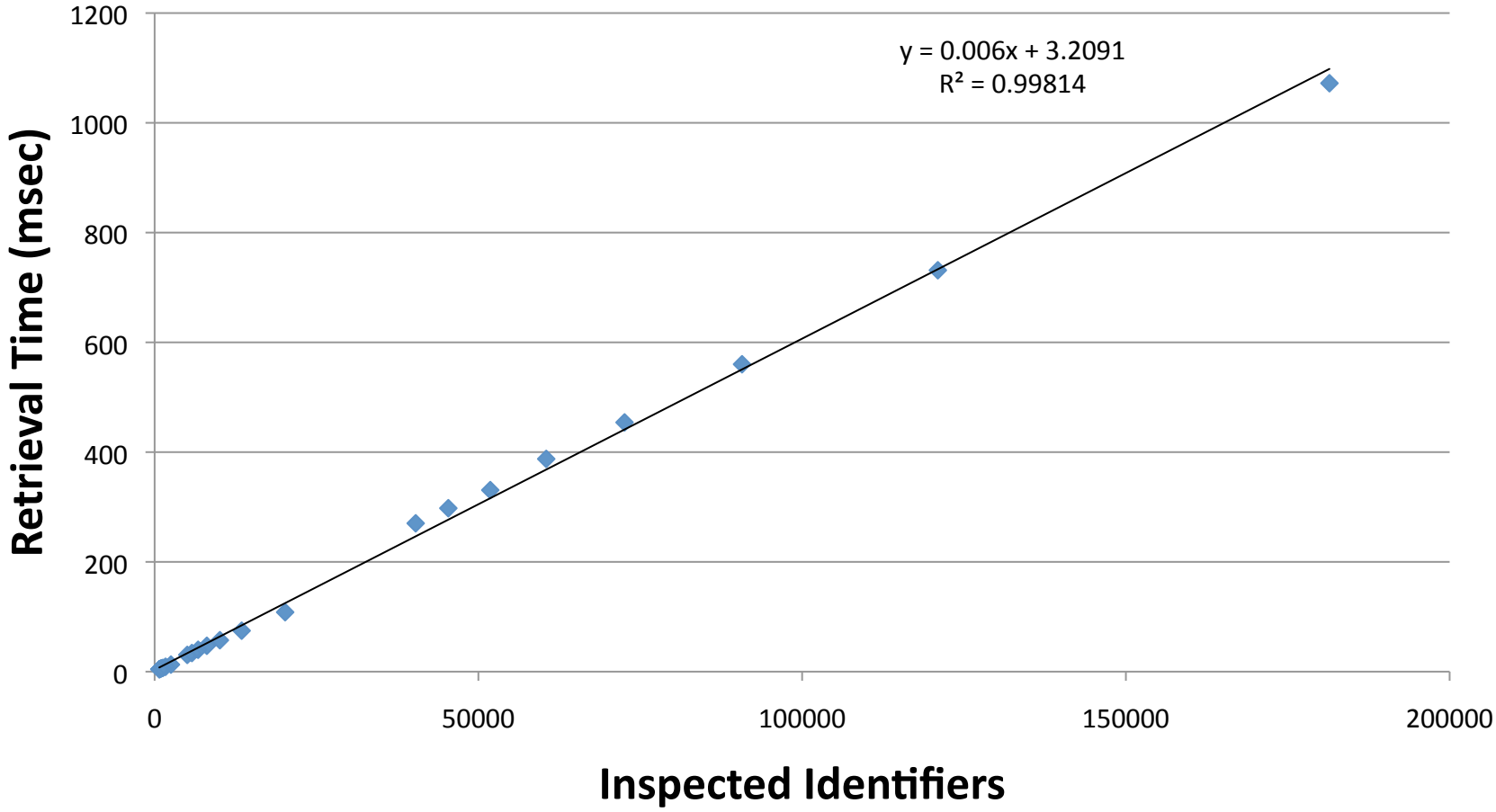
Underspecified Cues (individual features)



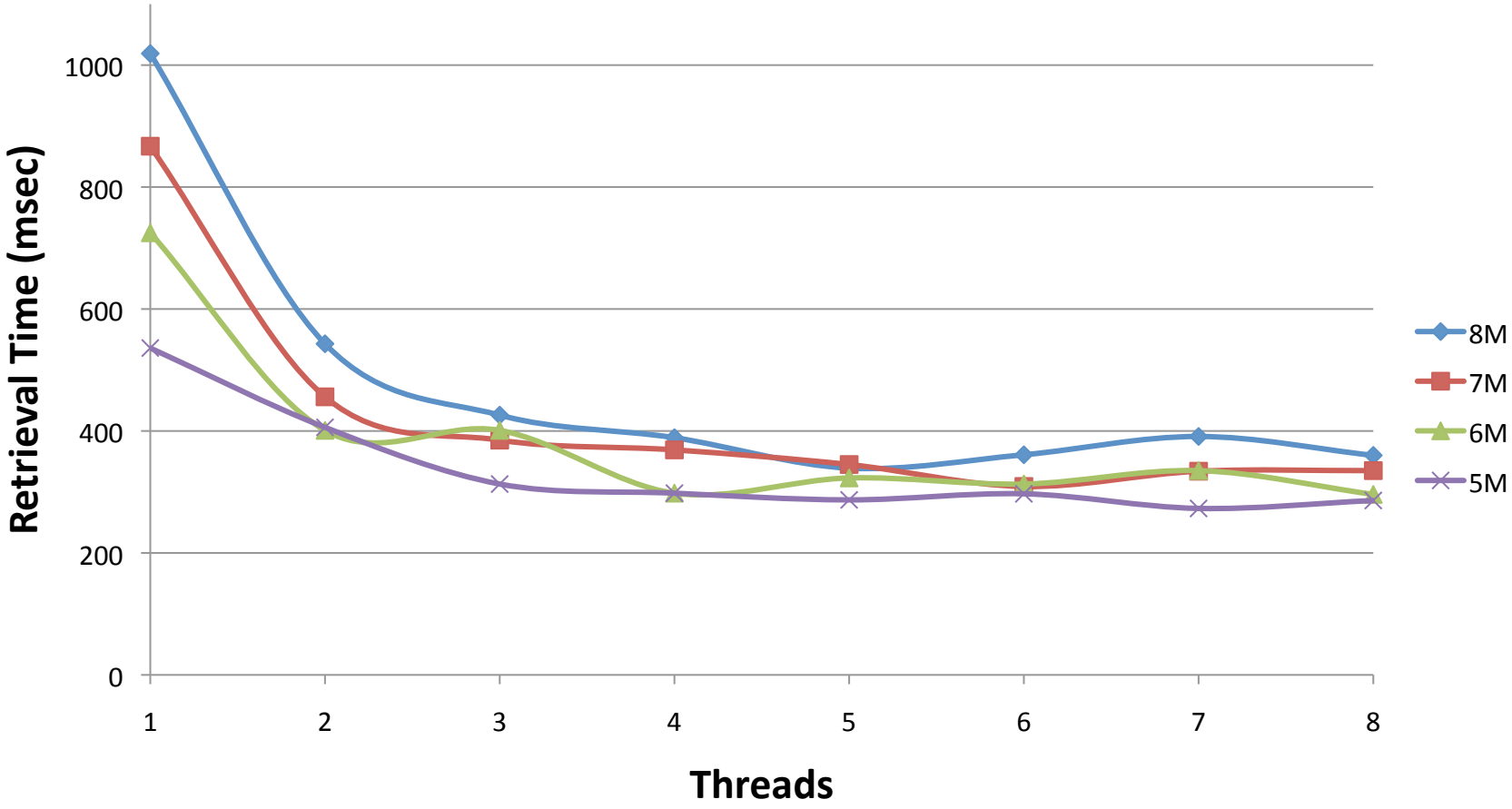
Successful Cues



Worst-Case Failure



Benefits of Parallelism



Evaluation

Nuggets

- Demonstration of semantic retrievals scaling to very large, synthetic and real-world stores
- Available in Soar 9.3.0

Coal

- Worst-case performance is not tractable
  - Parallelism
  - Heuristic search
- No model of typical cues and how they could affect performance of retrievals
- Limited retrieval bias