KeyConcept: Exploiting Hierarchical Relationships for Conceptually Indexed Data

Master's Thesis Defense

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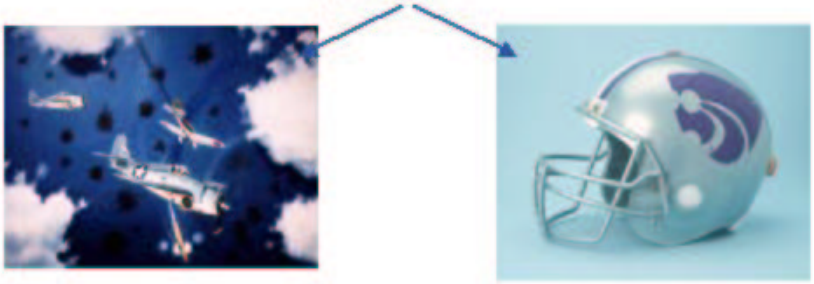
Outline

- Motivation
- Related Work
- KeyConcept Architecture
- Exploiting Hierarchy
- Data Sets
- Experiments
- Future Work
- Conclusion

Motivation – Problem

- Search engines perform keyword search
- Index based purely on word content

"wildcats"



- What did the user really want?

Motivation - Solution

- Train and Index based on word *and* concept
- User additionally indicates desired concept
- Use structural knowledge of training data to improve conceptual search

Related Work - I

- "Web Search Using Automatic Classification" - Chandra Chekuri, Michael H. Goldwasser, Prabhakar Raghavan, Eli Upfal.
  - Uses keyword + concept as query input
  - Classifies all documents into 20 categories – loses hierarchical information
- "Yahoo! As An Ontology – Using Yahoo! Categories To Describe Documents" - Yannis Labrou, Tim Finin.
  - Collects documents based on Yahoo! directory structure
  - Pre-classified document collection thus made available

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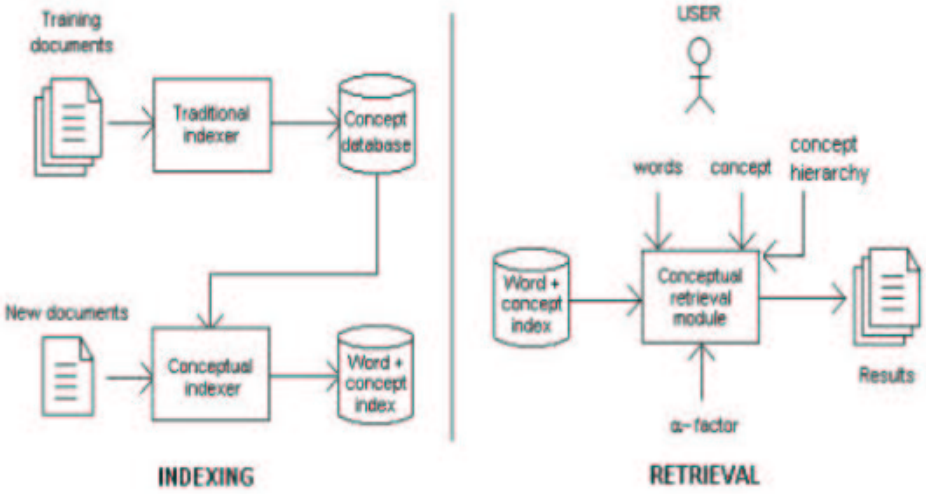
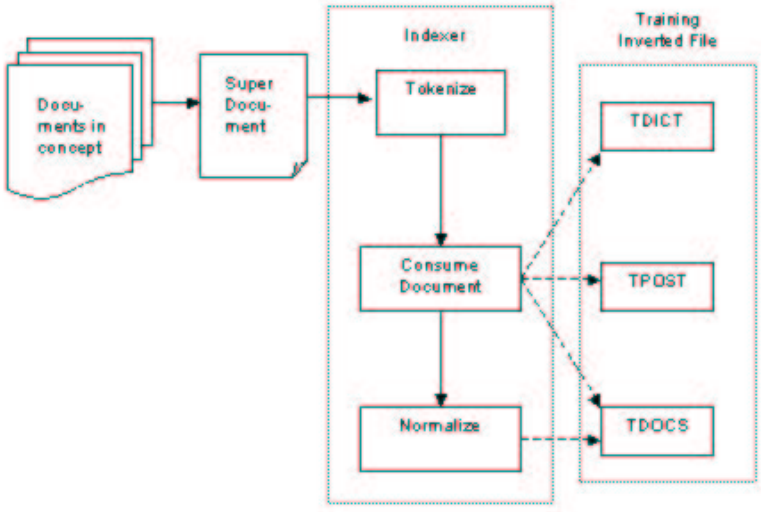
Related Work - II

- "Ontology-Based Web Site Mapping For Information Exploration" - Xiaolan Zhu, Susan Gauch, Lutz Gerhard, Nicholas Kral, Alexander Pretschner.
  - Uses ontologies to map user profiles to site maps
- "Collaborative Learning of Term-Based Concepts for Automatic Query Expansion" - Stefan Klink, Armin Hust, Markus Junker, Andreas Dengel.
  - Each query gets a concept assigned through relevance feedback

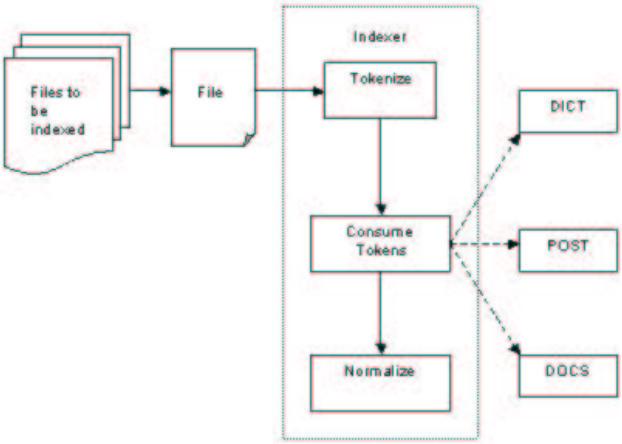
KeyConcept Architecture



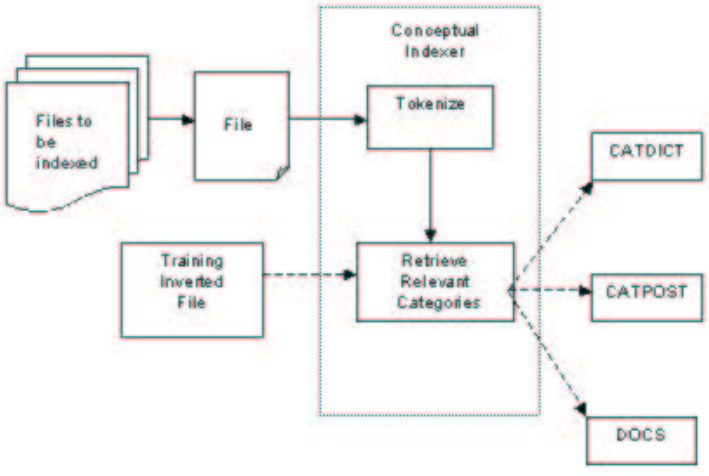
KeyConcept - Training



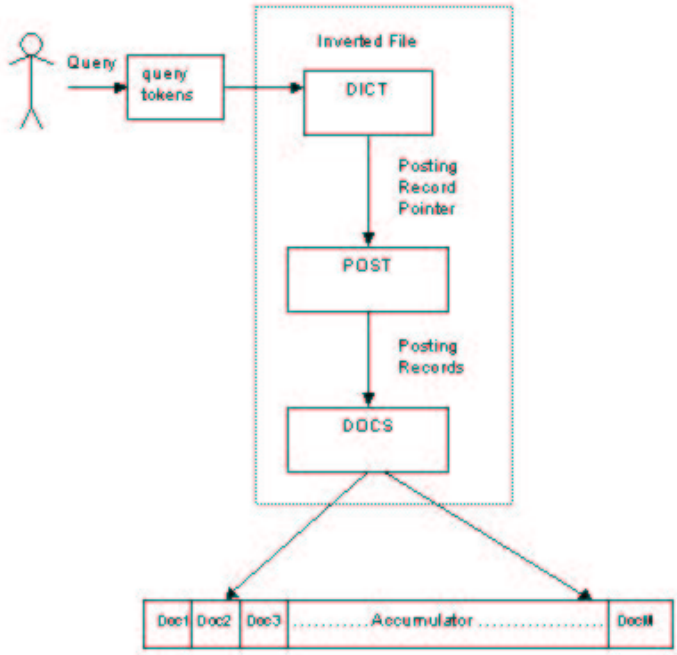
KeyConcept - Indexing



KeyConcept - Classification

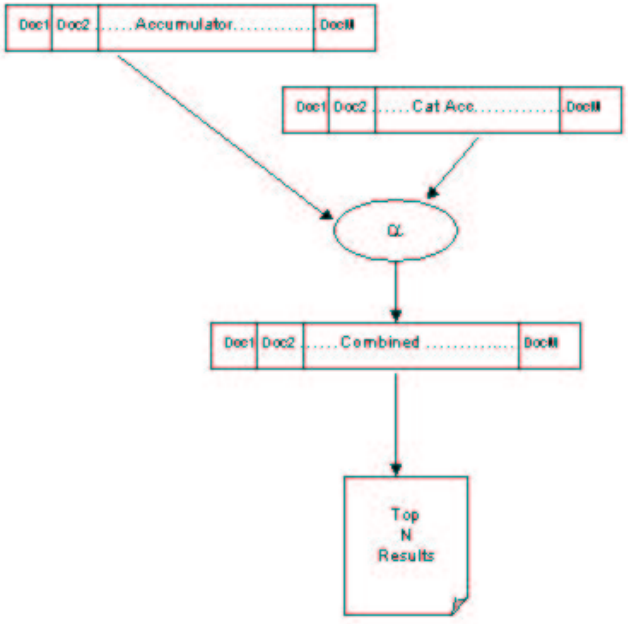


KeyConcept - Retrieval



KeyConcept – Keyword + Conceptual

- Retrieval process similar for keyword and concepts
- Keyword and Concept accumulators are combined using an α-factor



Exploiting Hierarchy

- Open Directory Project (dmoz.org) used for training documents
- ODP ontology contains hierarchical information
- Two types
  - Pruning results
  - Retrieval based on hierarchy

0 Arts
Music
Styles
Collecting
Instruments
Trading
Television
Networks
Video_Production
Cable_TV
Interactive
.
.
.
Directories
1 Business
2 Sports

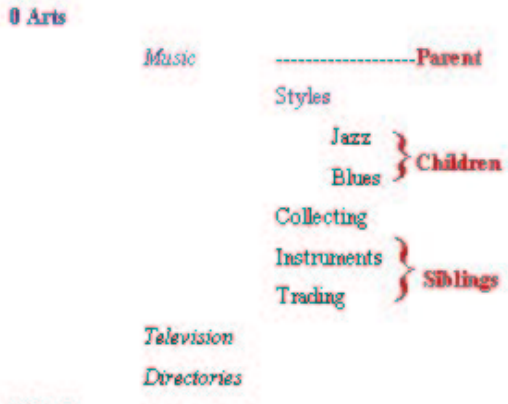
Exploiting Hierarchy I - Pruning Result Sets

- Search
  - Keyword: "rock"
  - Concept: arts/music/styles
- Retrieve
  - Document *d* belongs to arts/television/interactive
    - Level 1: *d* not pruned
    - Level 2: *d* pruned

0 Arts ----------**Level 1**
Music ----------**Level 2**
Styles
Collecting
Instruments
Trading
Television
Networks
Video_Production
Cable_TV
Interactive
.
.
.
Directories
1 Business
2 Sports

Exploiting Hierarchy II – Hierarchy-based Retrieval

- Search
  - Keyword: "rock"
  - Concept: arts/music/styles
- Retrieve neighboring concepts in hierarchy
  - Children
  - Siblings
  - Grandchildren
  - Parent
  - Combinations



Data Sets

- Training Data
  - Open Directory Project – dmoz.org
  - Cut-off at third level of the tree
  - 2,991 concepts and 125,000 documents
- TREC Data
  - 100,000 documents from TREC's WT2g Collection
  - 50 queries from each WT2g topic
  - Relevance judgments provided for each query
- Pruning Queries
  - TREC queries are too restrictive
  - Set of 24 queries – single-word, 2-word and 3-word length

KeyConcept Example - Input

KeyConcept Example - Output

KeyConcept Example – Top Concepts

KEYCONCEPT

A Conceptual Search Engine

DEMOS PEOPLE HOME API

1. 7447	Top/Health/Medicine/Informatics	1.000000
2. 58346	Top/Health/Resources/Consumer	0.868753
3. 122532	Top/Health/Medicine/Directories	0.837018
4. 178733	Top/Health/Medicine/Osteopathy	0.761746
5. 7441	Top/Health/Medicine/Reference	0.754035
6. 53837	Top/Health/Resources/Professional	0.742564
7. 58443	Top/Health/Professions/Physician_Assistant	0.720177
8. 95540	Top/Health/Nursing/Internet	0.713841
9. 117579	Top/Health/Pharmacy/Drugs_and_Medications	0.685251

Experiments

- Determine baseline parameters
  - Concept matching formula
  - α-factor
- Use Pruning on results
  - Simple pruning without conceptual retrieval
  - Pruning with conceptual retrieval
- Retrieve using hierarchical relationships
  - Parent, Children, Grandchildren
  - Combinations

Baseline Estimation – Concept Matching Formula

- Search engines use tf * idf scoring formula
  - tf = term frequency (how many times does word appear in document ?)
  - idf = inverse document frequency (how frequent is the word in the collection as a whole ?)
- Does cdf help ?
  - cdf = Concept document frequency (how many times did the word occur in the concept while training ?)
- Yes it does !
  - Best precision results for tf * idf * cdf while classification

Baseline Estimation - α-factor

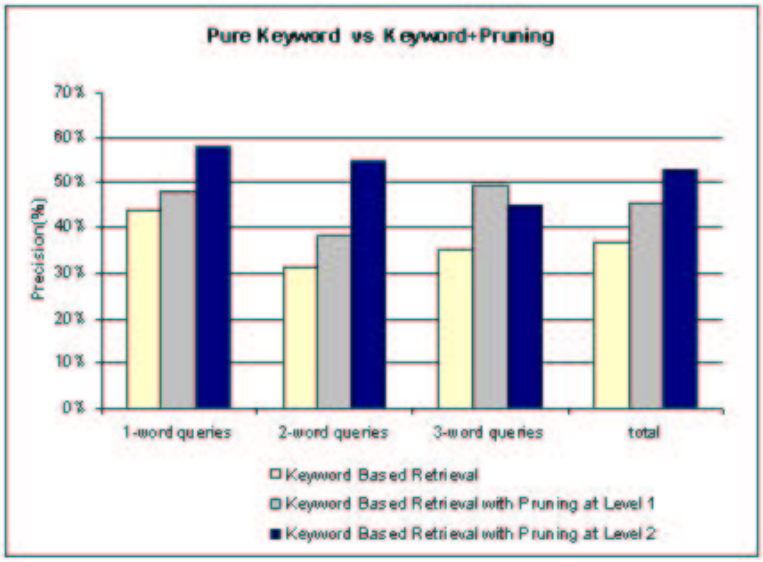
- How many concepts does the user need to specify?
  - Three
- Final document score =

  α * concept score + (1- α) * keyword score
- What α yields the best precision ?
  - 0.3 or 30% importance to concept score

Pruning

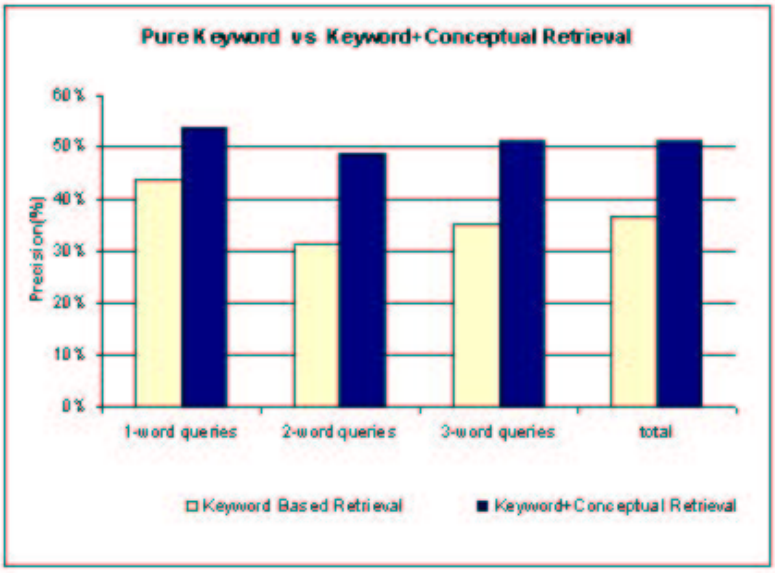
- Compare effects of pruning with simple keyword search
- Contrast simple keyword search with conceptual search
- Pruning can be combined with conceptual search
- Pruning at Level 1 and Level 2

Simple Keyword Search vs. Pruning



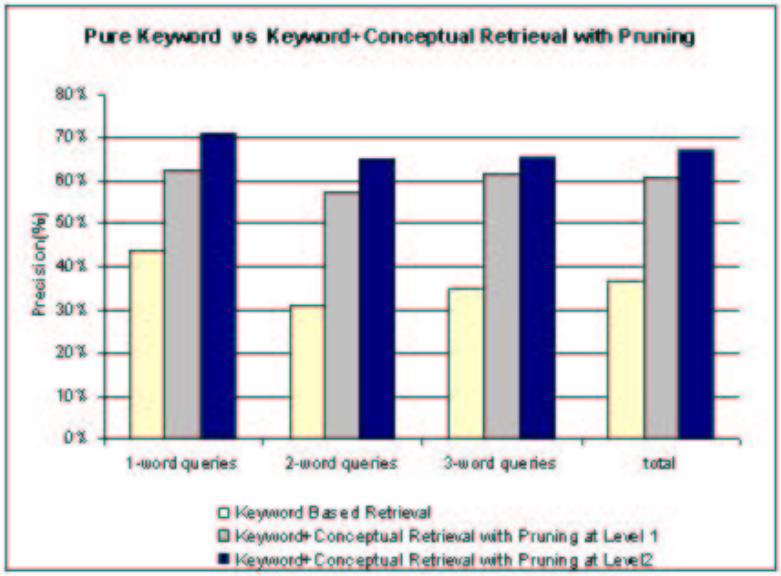
- Best results for single-word queries
- Overall, level 2 pruning more effective than level 1 pruning

Pure Keyword vs. Conceptual Search



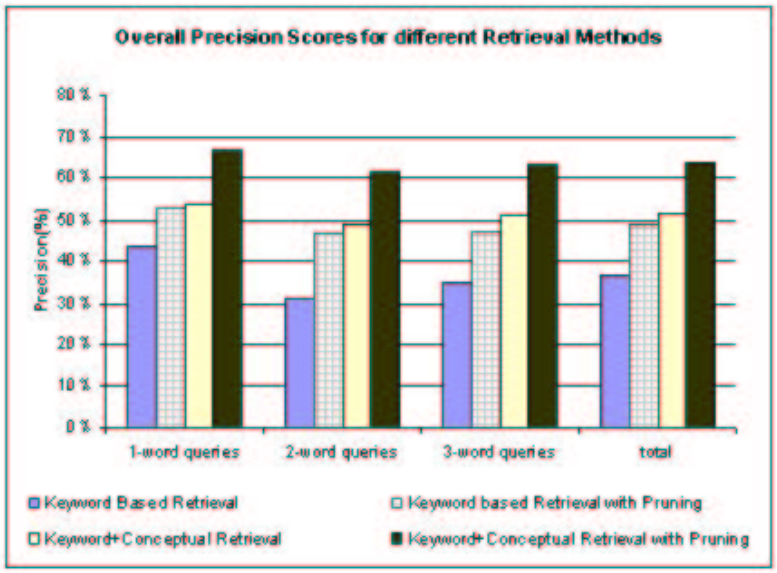
- Conceptual search performs better than simple keyword search for all query lengths

Pure Keyword vs. Conceptual Search with Pruning



- Keyword + Conceptual search + Pruning results = Great Precision

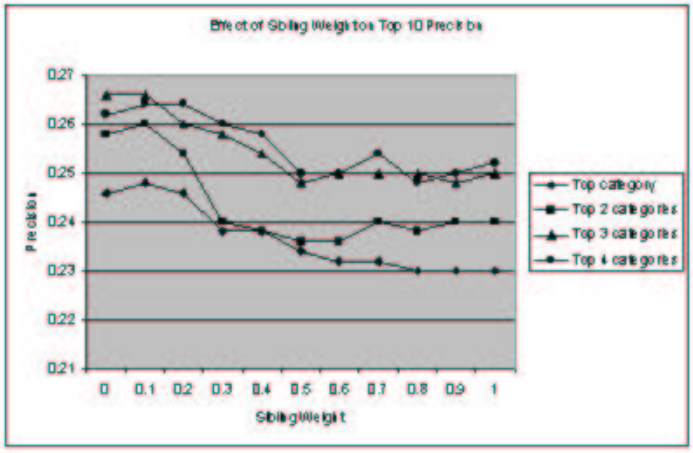
Overall Comparison



- Level 1 and level 2 results averaged for comparison
- And the winner is … Keyword + Conceptual + Pruning

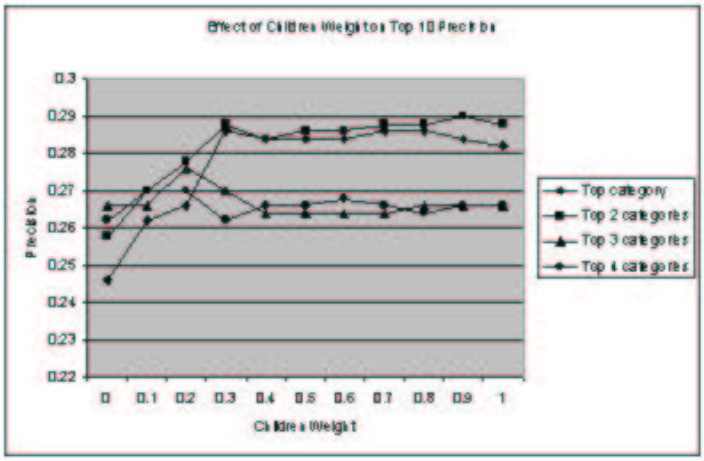
Retrieval using Hierarchy

Retrieval using Hierarchical Relationships - Siblings



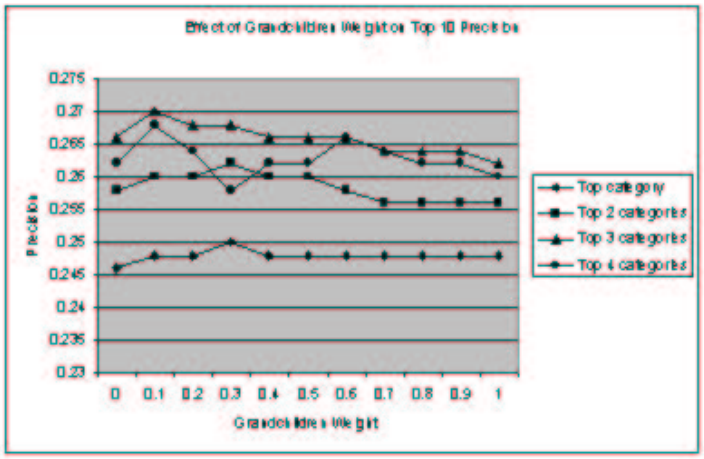
- Adding siblings of chosen concepts doesn't help
- Merely increases noise

Retrieval using Hierarchical Relationships - Children



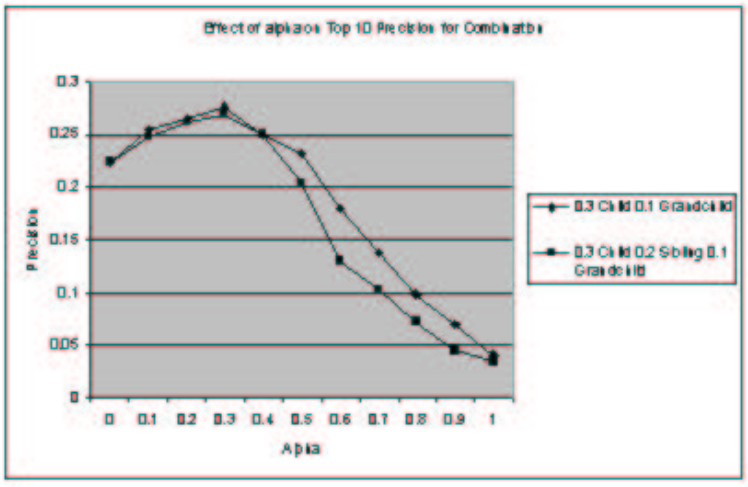
- Best results among hierarchical neighbors
- Maximum increase when user specifies only one concept
  - Weight given to children = 0.3 or 30%

Retrieval using Hierarchical Relationships - Grandchildren



- Modest increase in precision at a weight of 0.1 for grandchildren
- Maybe combinations of the above would help…?

Retrieval using Hierarchical Combinations



- Most promising hierarchical relations chosen – children and grandchildren
- Slight increase – not significant

several charts later…

Conclusions

- cdf (the frequency of word occurrence in a concept) needed during conceptual classification
- $\alpha = 0.3$ yields maximum precision
  - Keyword retrieval more important than pure conceptual retrieval
- Pruning along with conceptual retrieval gives the best results
  - Precision increase from 36.70% to 63.77%
- Using children of chosen concept obtains best increase in precision (from 24.6% to 28.6%)
  - Including parent of concept showed no improvement due to sparse data in top two levels of ODP

Future Work

- Better Data
  - More content in the top two levels of the ODP ontology
- Contextualization
  - Detect user's intent by gathering information about user's context of search
    - Open windows, past search history etc.
- Personalization
  - Track user's preferences and interests
  - Implement user profile in a similar hierarchy