A short introduction to the development and evaluation of Indexing systems

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Information Retrieval
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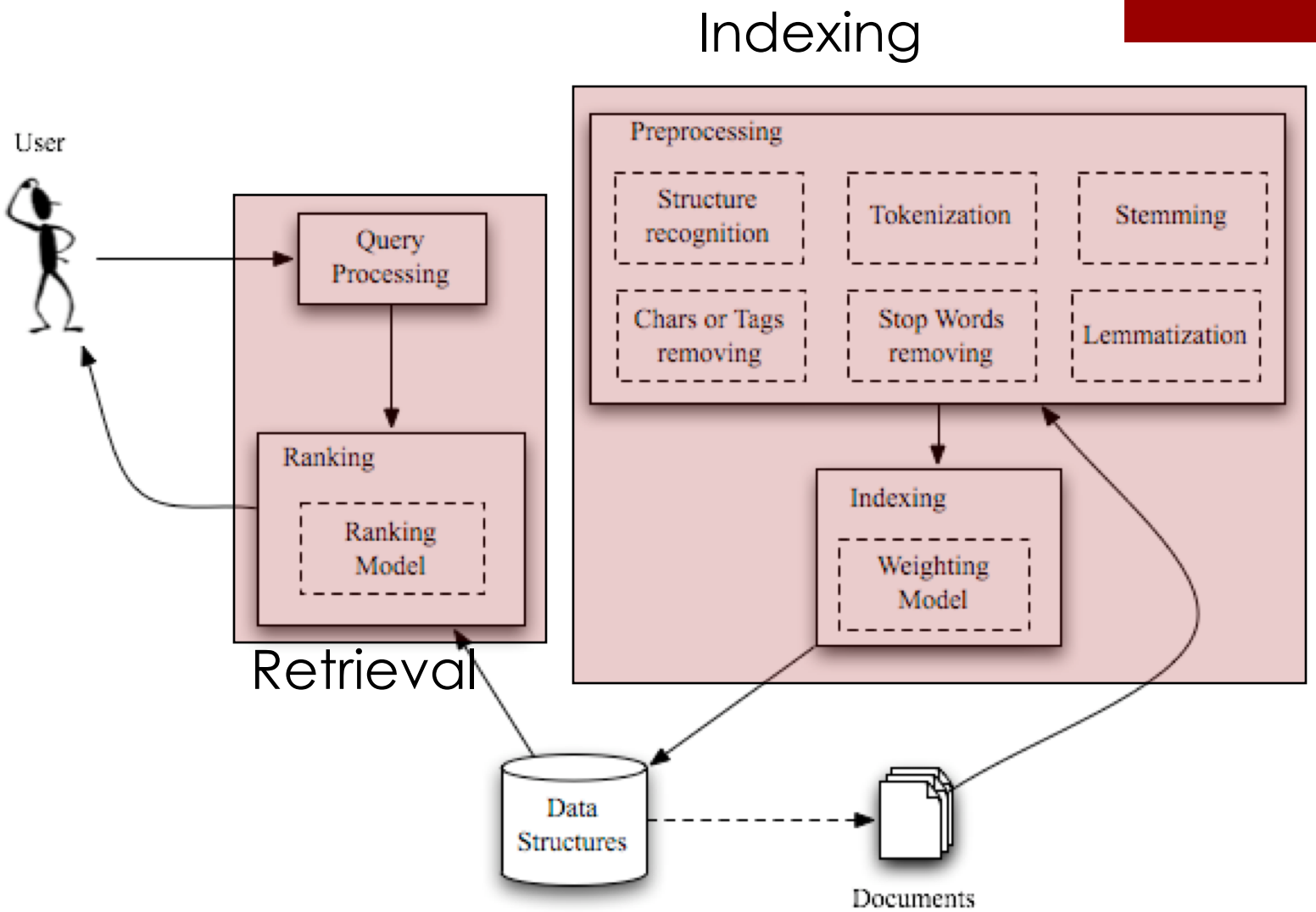
Outline

- An introduction to Lucene
  - Main features
- Implementation of a first Retrieval Engine
  - Luke: a graphical user interface to Lucene
- Exercises
  - Evaluation of a Retrival Engine

Generic Architecture of a Information Retrieval Engine



Lucene

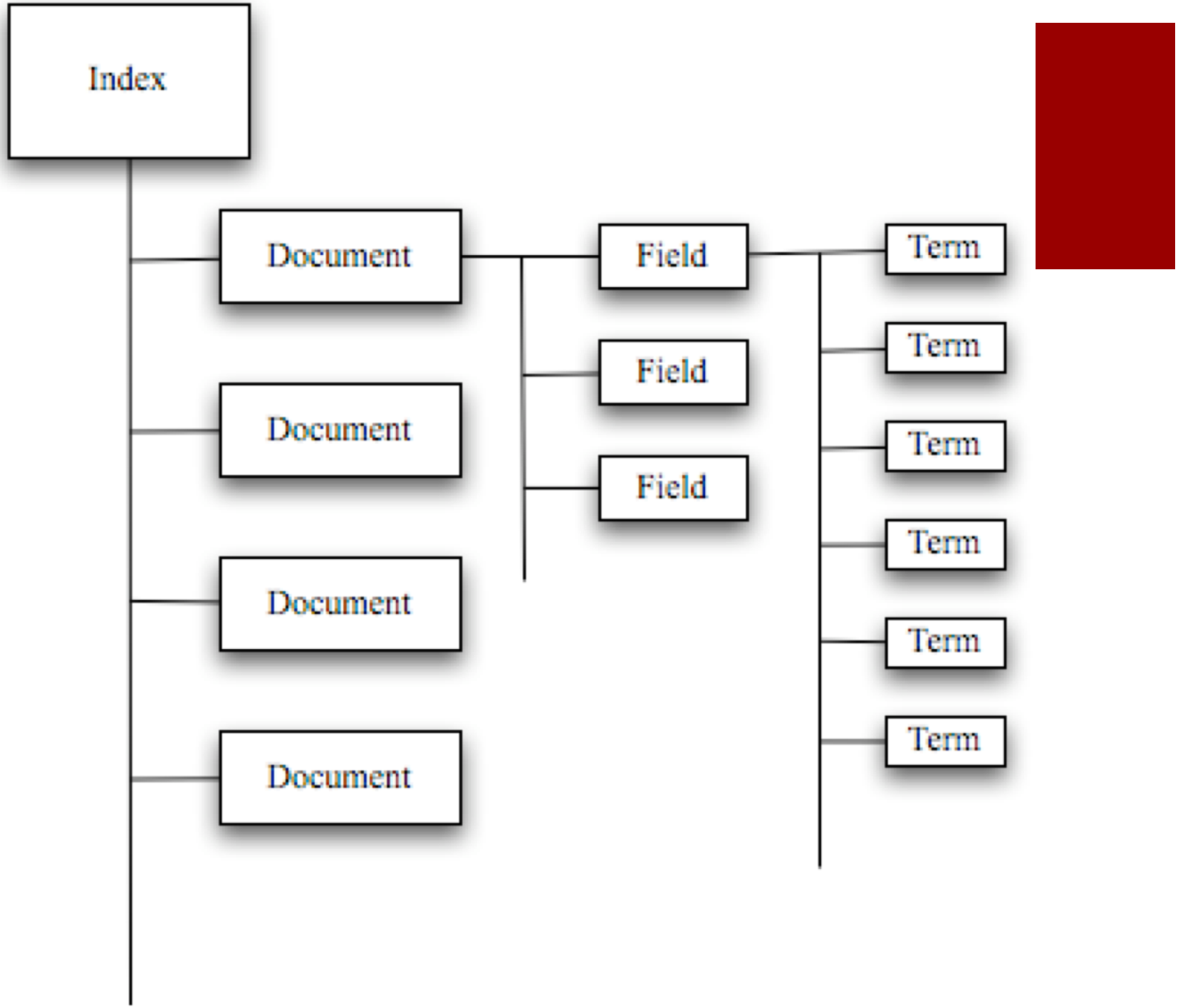
- Lucene is a Search Engine library with many features including
  - fast indexing,
  - ranked searching,
  - boolean, phrase, and span queries,
  - date-range searching,
- Written in JAVA
- Lucene is open-source and released under the Apache License
- Objective: high scalability and customization
- https://lucene.apache.org/

Lucene – Main features

- Web pages can be indexed by adopting a structured view
  - Each document is composed of different **fields**
- Several pre-processing facilities have been implemented for different languages
- Several types of queries can be used to retrieve documents
  - phrase queries, wildcard queries, proximity queries, range queries, etc…
- Documents are retrieved by exploiting
  - Single fields, separately used
  - Multiple fields (results are grouped and a single rank is provided)

A general view of Lucene

- A Lucene index represents documents as it follows
  - An **index** contains a sequence of **documents**
  - Each **document** is made of a set of **fields**
  - A **field** is a sequence of **terms**
  - Each field **does not depend** from the other fields
    - The same string occurring in two different field represent two different terms


Index
Document
Document
Document
Document
Field
Field
Field
Term
Term
Term
Term
Term
Term

Inverted Indexing

- The index stores statistics about terms in order to make term-based search more efficient.
- Lucene's index falls into the family of indexes known as an inverted index.
  - it can list, for a term, the documents that contain it.
  - This is the inverse of the natural relationship, in which documents list terms.
- Once a query is sumbitted to the system
  - Query terms (composing the query) are used to efficiently recover the documents containing them

Overview of a Lucene Index

- **Field names**. This contains the set of field names used in the index.
- **Stored Field values**. This contains, for each document, a list of attribute-value pairs, where the attributes are field names.
  - These are used to store auxiliary information about the document, such as its title, url, or an identifier to access a database.
  - The set of stored fields are what is returned for each hit when searching.
  - This is keyed by document number.
- **Term dictionary**. A dictionary containing all of the terms used in all of the indexed fields of all of the documents.
  - The dictionary also contains the number of documents which contain the term, and pointers to the term's frequency and proximity data.

Overview of a Lucene Index

- **Term Frequency data**. For each term in the dictionary, the numbers of all the documents that contain that term
- **Term Proximity data**. For each term in the dictionary, the positions that the term occurs in each document.
- **Normalization factors**. For each field in each document, a value is stored that is multiplied into the score for hits on that field.

Structure of the Lucene Project

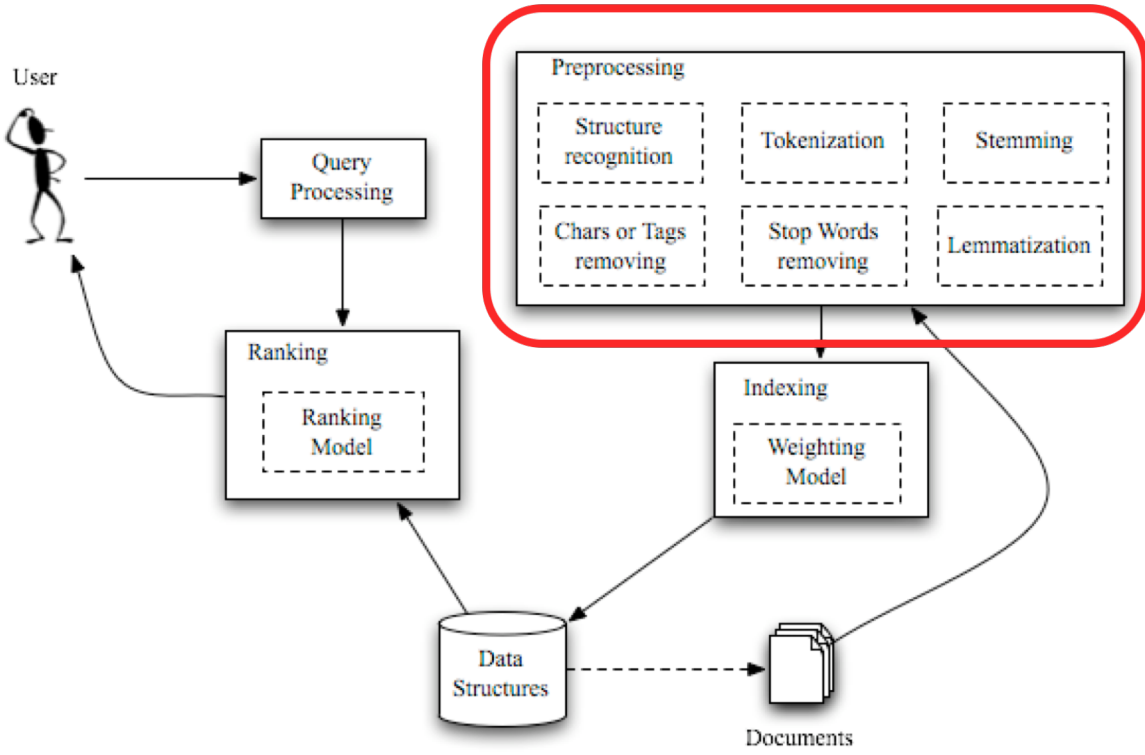
- `org.apache.lucene.document`: it contains the classes used to represent a document
- `org.apache.lucene.analysis`: it contains the classes needed to pre-process docunmens
  - used to determine the set of terms
  - used both before indexing and search
  - the same pre-processor must be used for indexing and search
- `org.apache.lucene.index`: it contains the classes needed to represent an index

Structure of the Lucene Project

- `org.apache.lucene.search`: it contains the classes implementing different search models and ranking functions
- `org.apache.lucene.store`: it contains the classes needed to read and write to/from an index

`analysis` package

- It contains all functionalities required to pre-process documents
- Main functionalities
  - Tokenization.
  - Stop words removal
  - Special character removal
  - Stemming
    - Porter Stemmer
    - Snowball Stemmer



`analysis` package (2)

- Pro:
  - We can customize the combination of pre-processing steps
  - We can customize and (re)implement each step
    - E.g. loading different stop word lists
- Cons:
  - Intrinsic structure of a document is ignored
    - A document can be divided in “title”, “abstract”, “author”
    - The implementation of such structure is left to the programmer and it must me always re-implemented

`search` package

- Several query implementations have been implemented in Lucene:
  - Term Query
  - Boolean Query
  - Wildcard Query
  - Phrase Query
  - Prefix Query
  - Fuzzy Query
  - Range Query
  - Span Query

Query syntax

- Generic Query
  - `pink panther`
- Phrase Query
  - `"pink panther"`
- Boolean Query
  - `"pink panther" AND return`
  - `"pink panther" +return`
- Field specific query
  - `title:"pink panther"`
- Wildcard
  - `pant?er`
  - `panther*`
- Fuzzy
  - `panther~`
  - `panther~0.8`
- Boosting of a query term
  - `pink panther^4`
- Range
  - `mod_date:[20070101 TO 20071001]`

Ranking Function

- The final ranking function is Lucene is based on a TF * IDF weghting schema
- Given a query q, the ranking score assigned to a document d is

$$\mathsf{sim}(q,d) = \mathsf{coord}(q,d) \cdot \mathsf{queryNorm}(q) \cdot \sum_{t \in q} \left(\mathsf{tf}(t,q) \cdot \mathsf{idf}(t)^2 \cdot \mathsf{boost}(t) \cdot \mathsf{norm}(t,d) \right)$$

A sort of similarity sim(. , .) between a query and a document in a Vector Space Model

Ranking Function (2)

$$\mathsf{sim}(q,d) = \mathsf{coord}(q,d) \cdot \mathsf{queryNorm}(q) \cdot \sum_{t \in q} \left(\mathsf{tf}(t,d) \cdot \mathsf{idf}(t)^2 \cdot \mathsf{boost}(t) \cdot \mathsf{norm}(t,d) \right)$$

$\mathsf{coord}(q,d)$ It counts the number of terms from q occurring in d

$\mathsf{boost}(t)$ The boost (weight) associated to each query term

$\mathsf{tf}(t,q)$ $\sqrt{\#t_d}$

$\mathsf{idf}(t)$ $1 + \log\left(\frac{\#D}{\mathsf{docFreq}(t)}\right)$

$\mathsf{queryNorm}(q)$ $\frac{1}{\mathsf{boost}(q) \cdot \sum_{t \in q} (\mathsf{idf}(t) \cdot \mathsf{boost}(t))}$

$\mathsf{norm}(t,d)$ Normalize the importance document/query in the collection, e.g. considering the document length

Indexing procedure

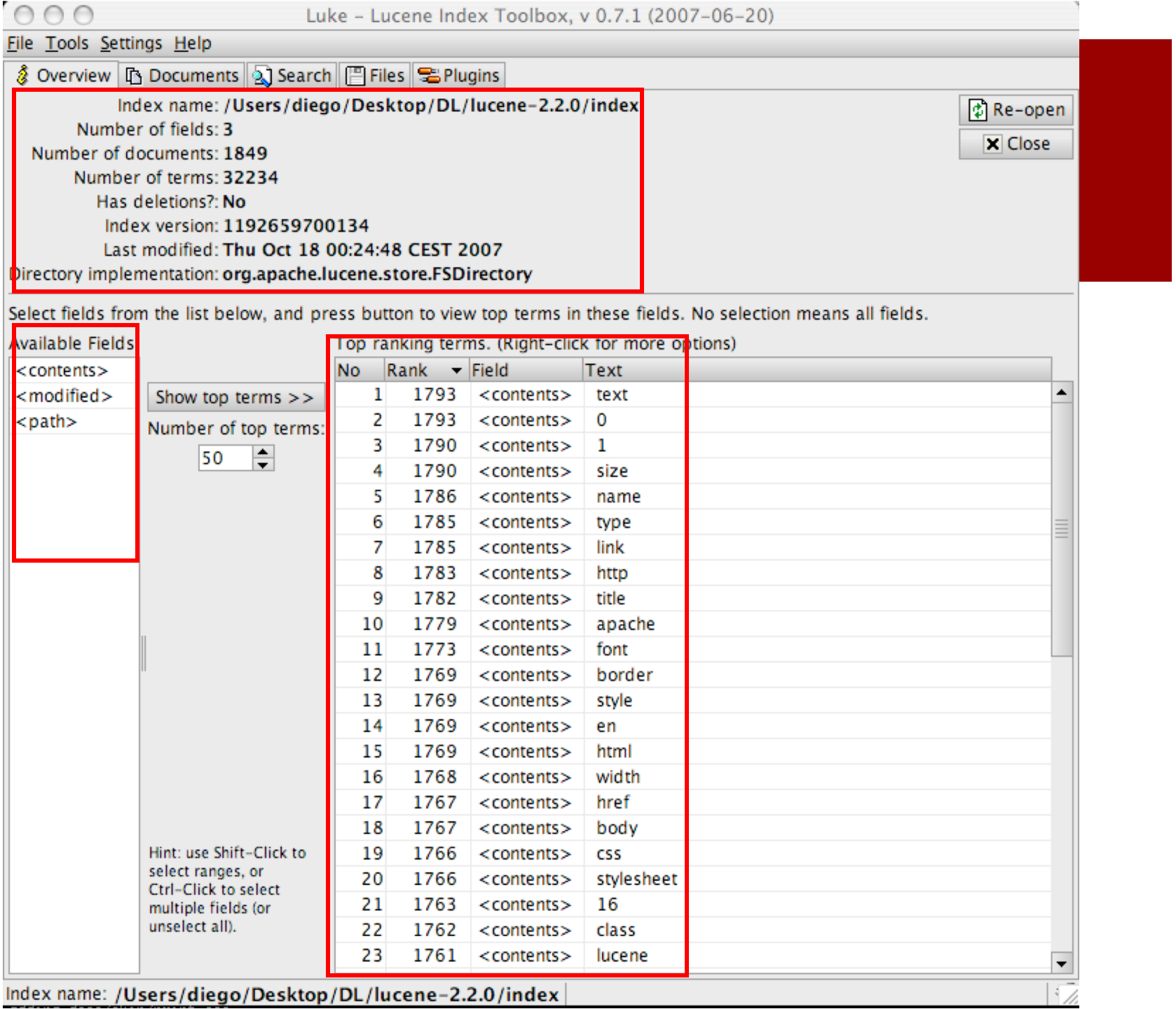
- Define a sequence of pre-processing steps, extending the `Analyzer` class
- For each document in the collection
  - Build a `Document` object populating its `Fields`
  - Define an `IndexWriter` and adding the document to the index by using the `addDocument()` method

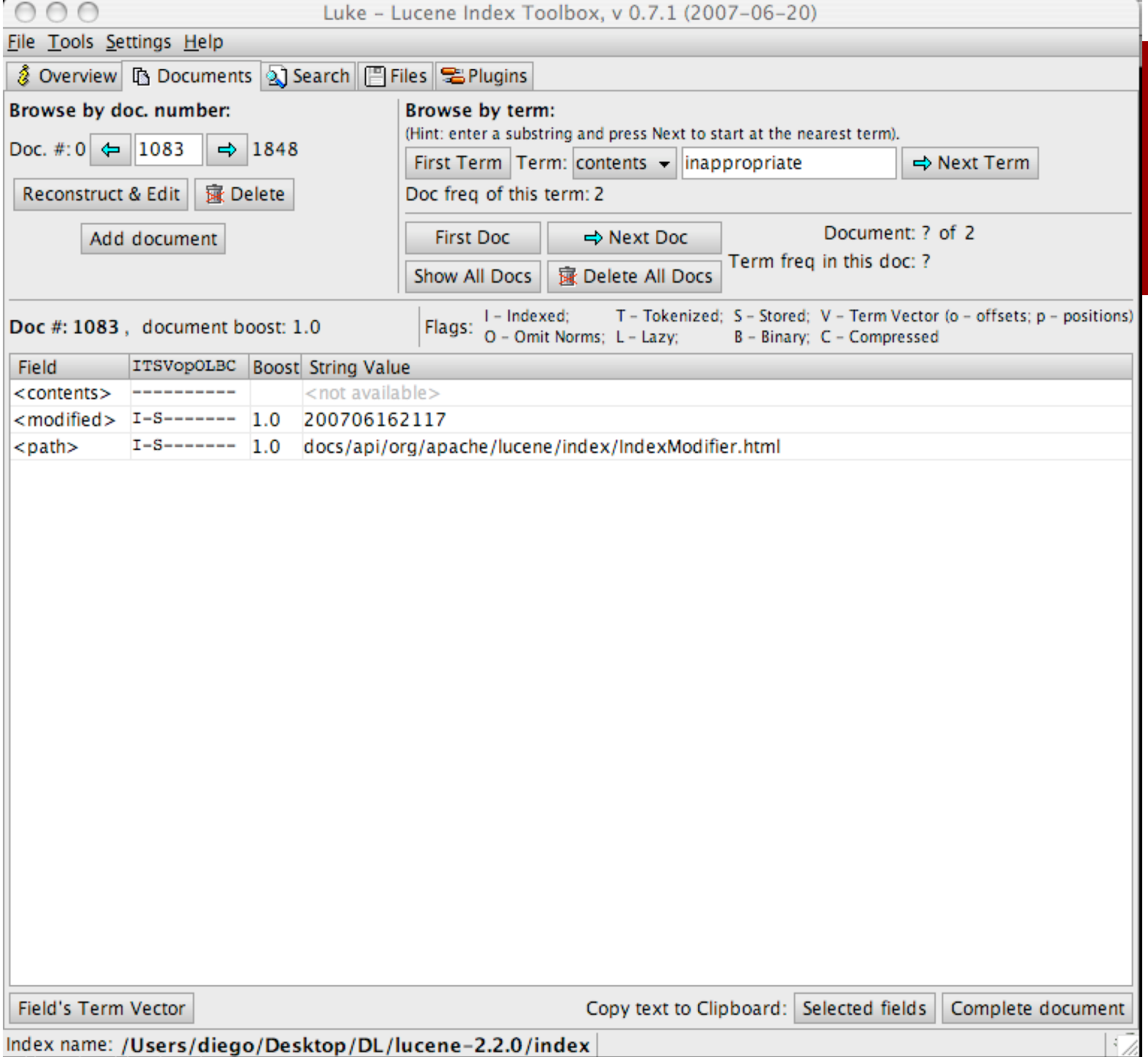
Search procedure

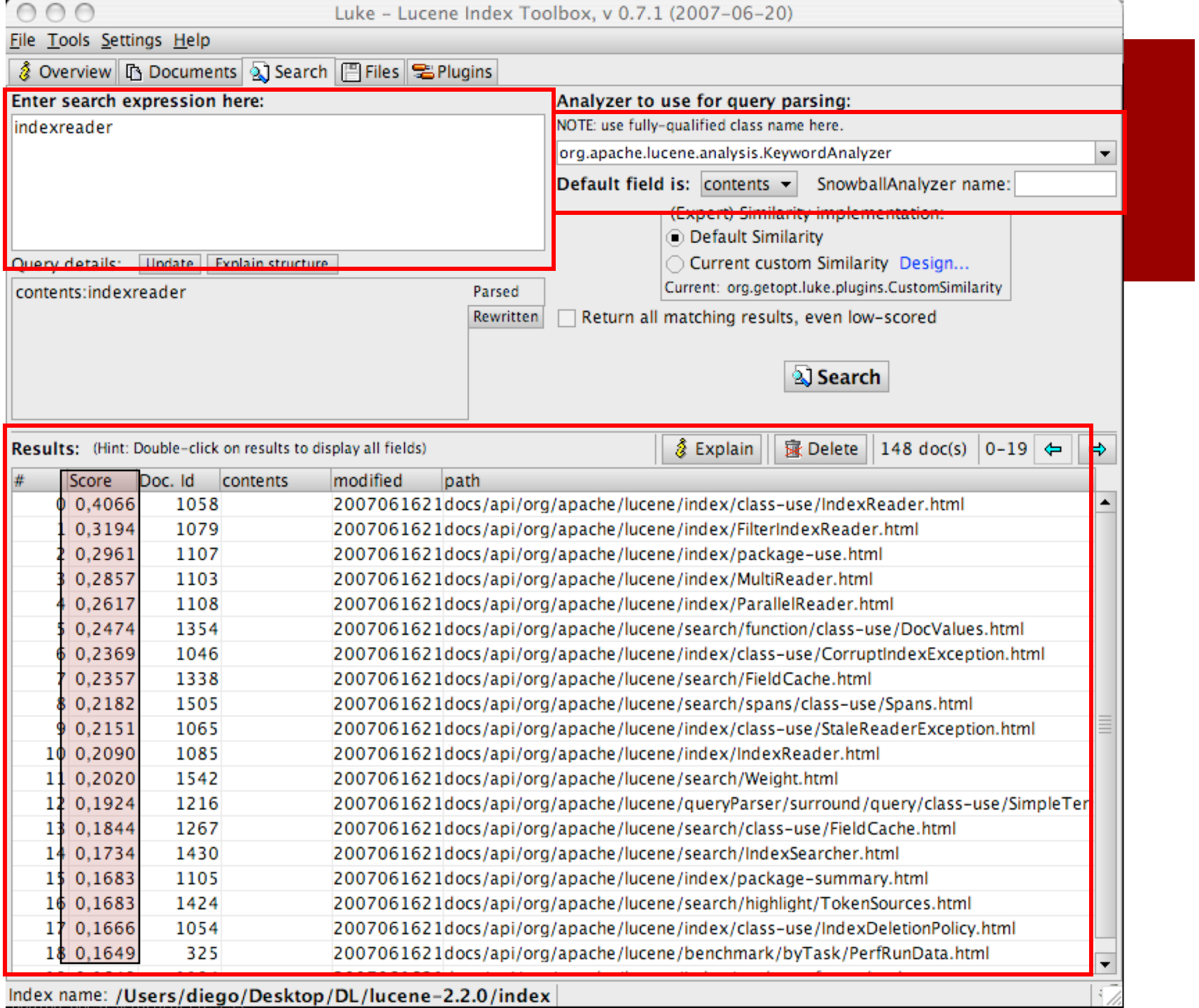
- Adopt the same pre-processing steps used in indexing
- Access the document index using the class `IndexSearcher`
- Define the module that analyze the query (`QueryParser`)
  - Define the `Query` model to be adopted
- Use the IndexSearcher to retrieve the documents

Luke

- **Luke** is a graphical user interface (GUI) to access a Lucene index and execute the following operations:
  - Browse the indexed documents and their corresponding fields
  - Execute (complex) queries
  - Modify the index
    - E.g. deleting some documents
  - …
- It can be downloaded from
  - http://www.getopt.org/luke/


Luke - Lucene Index Toolbox, v 0.7.1 (2007-06-20)
File Tools Settings Help
Overview Documents Search Files Plugins
Index name: /Users/diego/Desktop/DL/lucene-2.2.0/index
Number of fields: 3
Number of documents: 1849
Number of terms: 32234
Has deletions?: No
Index version: 1192659700134
Last modified: Thu Oct 18 00:24:48 CEST 2007
Directory implementation: org.apache.lucene.store.FSDirectory
Re-open
Close
Select fields from the list below, and press button to view top terms in these fields. No selection means all fields.
Available Fields
<contents>
<modified>
<path>
Show top terms >>
Number of top terms:
50
Hint: use Shift-Click to select ranges, or Ctrl-Click to select multiple fields (or unselect all).
Top ranking terms. (Right-click for more options)
No Rank Field Text
1 1793 <contents> text
2 1793 <contents> 0
3 1790 <contents> 1
4 1790 <contents> size
5 1786 <contents> name
6 1785 <contents> type
7 1785 <contents> link
8 1783 <contents> http
9 1782 <contents> title
10 1779 <contents> apache
11 1773 <contents> font
12 1769 <contents> border
13 1769 <contents> style
14 1769 <contents> en
15 1769 <contents> html
16 1768 <contents> width
17 1767 <contents> href
18 1767 <contents> body
19 1766 <contents> css
20 1766 <contents> stylesheet
21 1763 <contents> 16
22 1762 <contents> class
23 1761 <contents> lucene
Index name: /Users/diego/Desktop/DL/lucene-2.2.0/index


Luke - Lucene Index Toolbox, v 0.7.1 (2007-06-20)
File Tools Settings Help
Overview Documents Search Files Plugins
Browse by doc. number:
Doc. #: 0 1083 1848
Reconstruct & Edit Delete
Add document
Browse by term:
(Hint: enter a substring and press Next to start at the nearest term).
First Term Term: contents inappropriate Next Term
Doc freq of this term: 2
First Doc Next Doc
Show All Docs Delete All Docs
Document: ? of 2
Term freq in this doc: ?
Doc #: 1083 , document boost: 1.0
Flags: I - Indexed; T - Tokenized; S - Stored; V - Term Vector (o - offsets; p - positions)
O - Omit Norms; L - Lazy; B - Binary; C - Compressed
Field ITSVopOLBC Boost String Value
<contents> ---------- <not available>
<modified> I-S------- 1.0 200706162117
<path> I-S------- 1.0 docs/api/org/apache/lucene/index/IndexModifier.html
Field's Term Vector
Copy text to Clipboard: Selected fields Complete document
Index name: /Users/diego/Desktop/DL/lucene-2.2.0/index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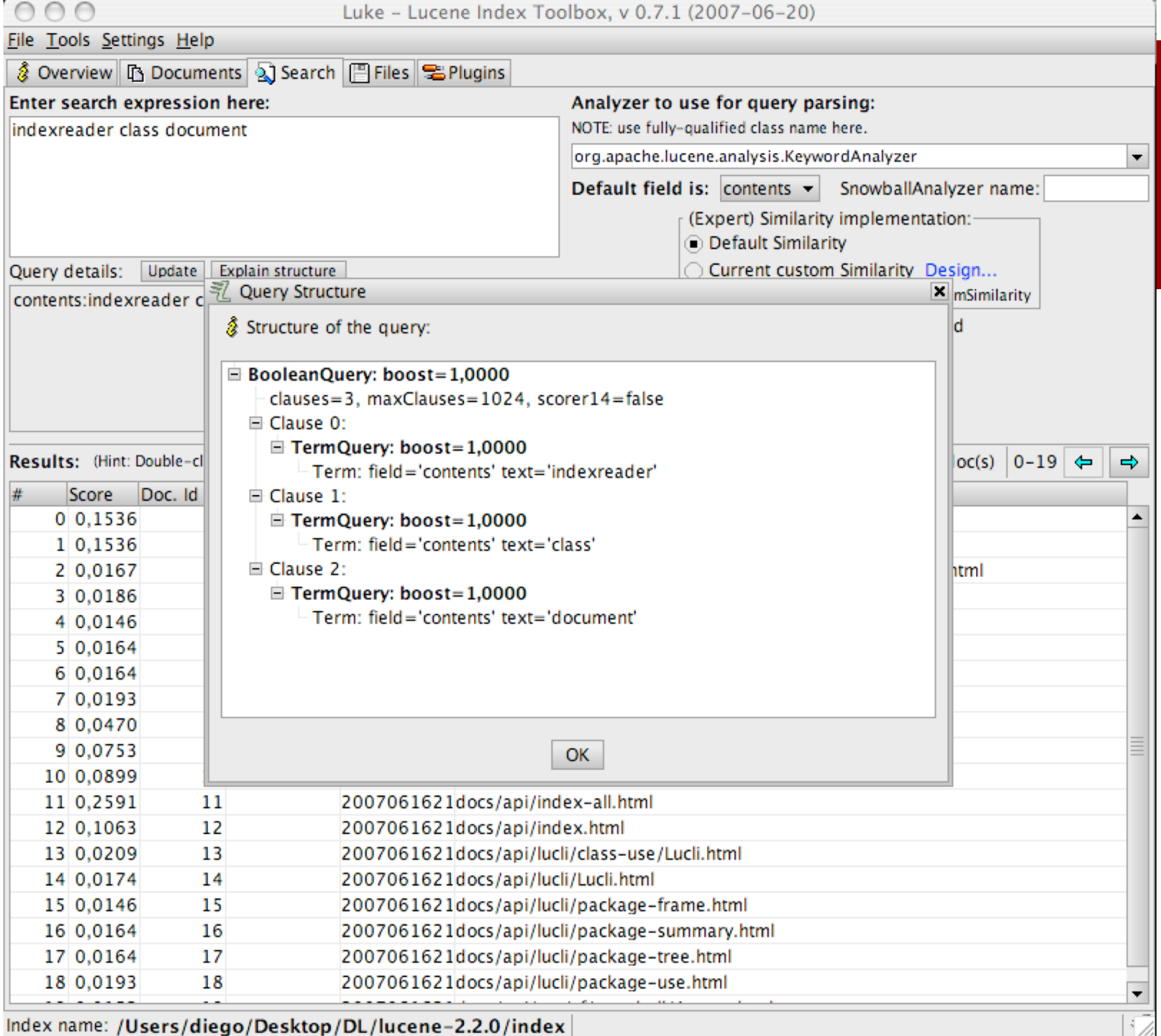
File Tools Settings Help
Overview Documents Search Files Plugins
Enter search expression here:
indexreader
Query details: Update Explain structure
contents:indexreader
Parsed
Rewritten
Analyzer to use for query parsing:
NOTE: use fully-qualified class name here.
org.apache.lucene.analysis.KeywordAnalyzer
Default field is: contents
SnowballAnalyzer name:
(Expert) Similarity implementation:
Default Similarity
Current custom Similarity Design...
Current: org.getopt.luke.plugins.CustomSimilarity
Return all matching results, even low-scored
Search
Results: (Hint: Double-click on results to display all fields)
Explain
Delete
148 doc(s)
0-19
Score Doc. Id contents modified path
0 0,4066 1058 2007061621 docs/api/org/apache/lucene/index/class-use/IndexReader.html
1 0,3194 1079 2007061621 docs/api/org/apache/lucene/index/FilterIndexReader.html
2 0,2961 1107 2007061621 docs/api/org/apache/lucene/index/package-use.html
3 0,2857 1103 2007061621 docs/api/org/apache/lucene/index/MultiReader.html
4 0,2617 1108 2007061621 docs/api/org/apache/lucene/index/ParallelReader.html
5 0,2474 1354 2007061621 docs/api/org/apache/lucene/search/function/class-use/DocValues.html
6 0,2369 1046 2007061621 docs/api/org/apache/lucene/index/class-use/CorruptIndexException.html
7 0,2357 1338 2007061621 docs/api/org/apache/lucene/search/FieldCache.html
8 0,2182 1505 2007061621 docs/api/org/apache/lucene/search/spans/class-use/Spans.html
9 0,2151 1065 2007061621 docs/api/org/apache/lucene/index/class-use/StaleReaderException.html
10 0,2090 1085 2007061621 docs/api/org/apache/lucene/index/IndexReader.html
11 0,2020 1542 2007061621 docs/api/org/apache/lucene/search/Weight.html
12 0,1924 1216 2007061621 docs/api/org/apache/lucene/queryParser/surround/query/class-use/SimpleTer
13 0,1844 1267 2007061621 docs/api/org/apache/lucene/search/class-use/FieldCache.html
14 0,1734 1430 2007061621 docs/api/org/apache/lucene/search/IndexSearcher.html
15 0,1683 1105 2007061621 docs/api/org/apache/lucene/index/package-summary.html
16 0,1683 1424 2007061621 docs/api/org/apache/lucene/search/highlight/TokenSources.html
17 0,1666 1054 2007061621 docs/api/org/apache/lucene/index/class-use/IndexDeletionPolicy.html
18 0,1649 325 2007061621 docs/api/org/apache/lucene/benchmark/byTask/PerfRunData.html
Index name: /Users/diego/Desktop/DL/lucene-2.2.0/index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Overview Documents Search Files Plugins
Enter search expression here:
indexreader class document
Analyzer to use for query parsing:
NOTE: use fully-qualified class name here.
org.apache.lucene.analysis.KeywordAnalyzer
Default field is: contents
SnowballAnalyzer name:
(Expert) Similarity implementation:
Default Similarity
Current custom Similarity
Design...
Query details:
Update
Explain structure
contents:indexreader c
Query Structure
Structure of the query:
BooleanQuery: boost=1,0000
clauses=3, maxClauses=1024, scorer14=false
Clause 0:
TermQuery: boost=1,0000
Term: field='contents' text='indexreader'
Clause 1:
TermQuery: boost=1,0000
Term: field='contents' text='class'
Clause 2:
TermQuery: boost=1,0000
Term: field='contents' text='document'
OK
Results:
0-19
Score Doc. Id
0 0,1536
1 0,1536
2 0,0167
3 0,0186
4 0,0146
5 0,0164
6 0,0164
7 0,0193
8 0,0470
9 0,0753
10 0,0899
11 0,2591 11 2007061621docs/api/index-all.html
12 0,1063 12 2007061621docs/api/index.html
13 0,0209 13 2007061621docs/api/lucli/class-use/Lucli.html
14 0,0174 14 2007061621docs/api/lucli/Lucli.html
15 0,0146 15 2007061621docs/api/lucli/package-frame.html
16 0,0164 16 2007061621docs/api/lucli/package-summary.html
17 0,0164 17 2007061621docs/api/lucli/package-tree.html
18 0,0193 18 2007061621docs/api/lucli/package-use.html
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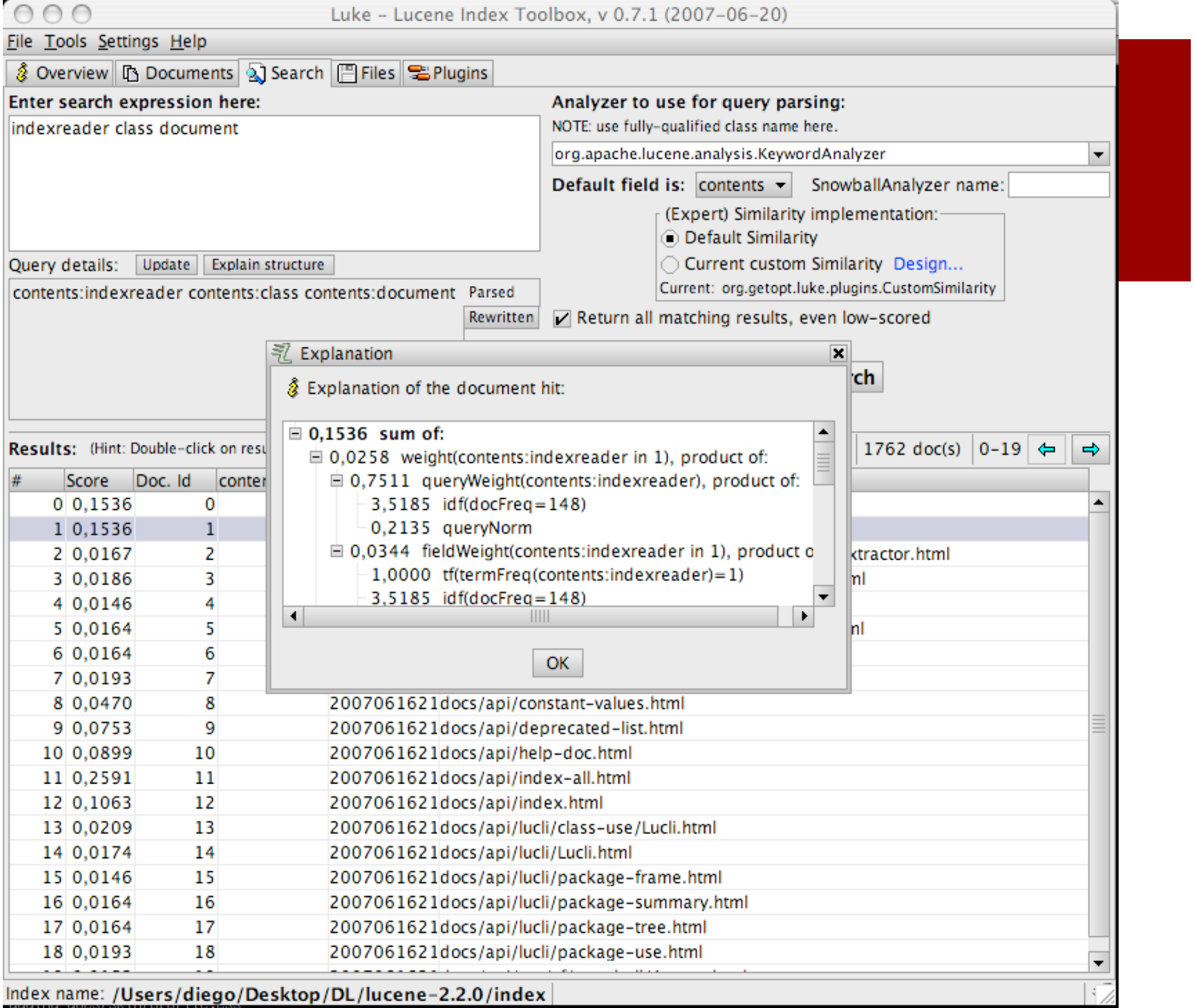
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indexreader class document
Analyzer to use for query parsing:
NOTE: use fully-qualified class name here.
org.apache.lucene.analysis.KeywordAnalyzer
Default field is: contents
SnowballAnalyzer name:
(Expert) Similarity implementation:
Default Similarity
Current custom Similarity Design...
Current: org.getopt.luke.plugins.CustomSimilarity
Query details: Update Explain structure
contents:indexreader contents:class contents:document Parsed
Rewritten
Return all matching results, even low-scored
Explanation
Explanation of the document hit:
0,1536 sum of:
0,0258 weight(contents:indexreader in 1), product of:
0,7511 queryWeight(contents:indexreader), product of:
3,5185 idf(docFreq=148)
0,2135 queryNorm
0,0344 fieldWeight(contents:indexreader in 1), product o
1,0000 tf(termFreq(contents:indexreader)=1)
3,5185 idf(docFreq=148)
OK
Results: (Hint: Double-click on resu
1762 doc(s) 0-19
Score Doc. Id conter
0 0,1536 0
1 0,1536 1
2 0,0167 2 xtractor.html
3 0,0186 3 ml
4 0,0146 4
5 0,0164 5 ml
6 0,0164 6
7 0,0193 7
8 0,0470 8 2007061621docs/api/constant-values.html
9 0,0753 9 2007061621docs/api/deprecated-list.html
10 0,0899 10 2007061621docs/api/help-doc.html
11 0,2591 11 2007061621docs/api/index-all.html
12 0,1063 12 2007061621docs/api/index.html
13 0,0209 13 2007061621docs/api/lucli/class-use/Lucli.html
14 0,0174 14 2007061621docs/api/lucli/Lucli.html
15 0,0146 15 2007061621docs/api/lucli/package-frame.html
16 0,0164 16 2007061621docs/api/lucli/package-summary.html
17 0,0164 17 2007061621docs/api/lucli/package-tree.html
18 0,0193 18 2007061621docs/api/lucli/package-use.html
Index name: /Users/diego/Desktop/DL/lucene-2.2.0/index

Solr

- Solr is a standalone enterprise search server implemented from Apache
  - Solr is built using the API provided by Lucene
- Solr implements REST-like API
- It supports different standard to represent query and retrieve documents
  - JSON and XML are the more used
- It implements a Web-based Amministration console
- It allow to distribute and replicate indexes on different machines
- `http://lucene.apache.org/solr/`

Lemur

- Lemur is another framework for the development of IR systems
- It is the result of a collaboration between
  - *Computer Science Department at the University of Massachusetts*
  - *School of Computer Science at Carnegie Mellon University*.
- The core of Lemur is implemented in C++
- http://www.lemurproject.org/
- http://sourceforge.net/p/lemur/wiki/Home/

Exercise Objectives

- Development of a simple IR system, based on Lucene that supports
  - the indexing of documents
  - the retrieval of documents
- Evaluation of the resulting system

You will be provided with…

- A small dataset, the Cranfield collection, made of 1398 abstracts
  - `http://ir.dcs.gla.ac.uk/resources/test_collections/cran/`
- In the folder `resources/cranfield_collection_splitted` you can find the documents separated in different files
- Eeach document has the following format

```
.T
Document_title
.A
Authors
.B
Bibliographic_References
.W
Text
```

An example of document

.T
experimental investigation of the aerodynamics of a
wing in a slipstream .
.A
brenckman,m.
.B
j. ae. scs. 25, 1958, 324.
.W
experimental investigation of the aerodynamics of a
wing in a slipstream .
  an experimental study of a wing in a propeller slipstream
was made in order to determine the spanwise distribution of
the lift increase due to slipstream at different angles of
attack of the wing and at different free stream to
slipstream velocity ratios .
…

How to evaluate the IR system

- The file `resources/cranfield_query/cran_query.text` contains 225 query for the system
- The file `resources/cranfield_query/qrels.text` contains, for each query, the set of relevant document that the system is expected to retrieve
- For example, the query 1:
  - "*what similarity laws must be obeyed when constructing aeroelastic models of heated high speed aircraft .*"
- should retrieve the following document
  - `184, 29, 31, 12, 51, 102, 13, 14, 15, 57, 378, 859, 185, 30, 37, 52, 142, 195, 875, 56, 66, 95, 462, 497, 858, 876, 879, 880, 486`

Exercise

- Create two indexes from the Cranfield corpus by considering two different pre-processors
- You are provided of the JAVA code implementing the indexing and retrieval phase
- For each query in the dataset, retrieve the document from each system and measure
  - Precision
  - Recall
  - F1

Exercise facilities

- In the folder `code`
- To compile the search engine based on lucene
  - `bash compile.sh`
- To index the Cranfield corpus
  - `bash build_index.sh`
- To execute Luke
  - `bash launch_luke.sh`
- To retrieve documents
  - `python evaluate_search.py`

Exercise

- You can find a set of queries in the file

  `code/resources/cranfield_query/cran_query.text`

  - For each query the set of document to be retrieved is reported in

    `code/resources/cranfield_query/qrels.text`

- If you are not expert with JAVA, you are also provided with a python script to evaluate Input queries
- Measure
  - precision, recall and F1 by using the gold standard
  - MAP
- Modify the indexing process to improve F1