Introduction to

# Information Retrieval

ΠΛΕ70: Ανάκτηση Πληροφορίας

*Διδάσκουσα: Ευαγγελία Πιτουρά*

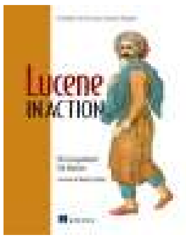
Διάλεξη 12: Εισαγωγή στο Lucene.

## Lucene: Τι είναι;

- *Open source Java library* for indexing and searching
  - Lets you add search to your application
  - Not a complete search system by itself
  - Written by Doug Cutting
- Used by LinkedIn, Twitter, …
  - …and many more (see http://wiki.apache.org/lucene-java/PoweredBy)
- Ports/integrations to other languages
  - C/C++, C#, Ruby, Perl, Python, PHP, …

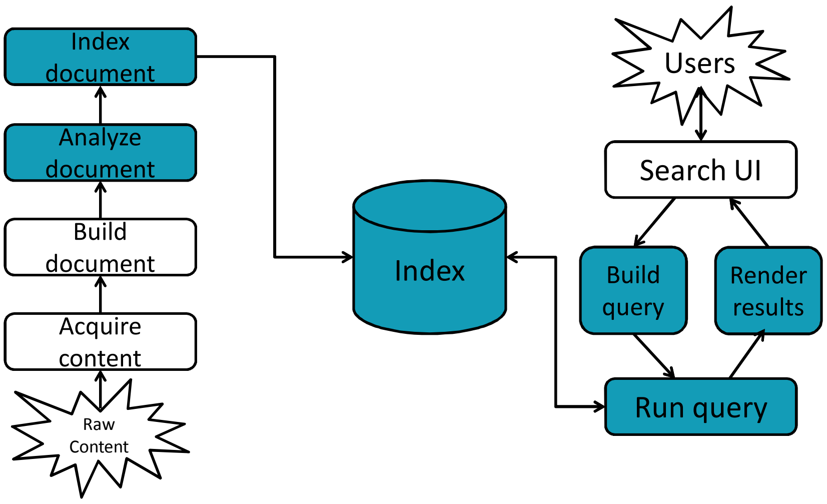
## Πηγές

- Lucene: http://lucene.apache.org/core/
- Lucene in Action: http://www.manning.com/hatcher3/
  - Code samples available for download



- Ant: http://ant.apache.org/
  - Java build system used by "Lucene in Action" code

## Lucene in a search system



## Lucene in action

- Command line **Indexer**
  - …/lia2e/src/lia/meetlucene/Indexer.java
- Command line **Searcher**
  - …/lia2e3/src/lia/meetlucene/Searcher.java

## How Lucene models content

- A **Document** is the atomic unit of indexing and searching
  - A Document contains Fields
- **Field**s have a **name** and a **value**
  - Examples: Title, author, date, abstract, body, URL, keywords, ..
  - Different documents can have different fields

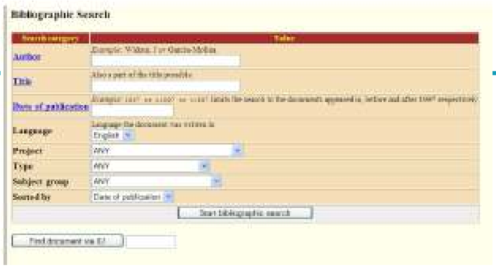
❖ You have to translate raw content into Fields

❖ Search a field using name:term, e.g., title:lucene

## Parametric and field indexes

- Documents often contain metadata: specific forms of data about a document, such as its author(s), title and date of publication.
- Metadata generally include fields such as the date of creation, format of the document, the author, title of the document, etc
- There is one parametric index for each field (e.g., one for title, one for date, etc)

## Parametric indexes



**Bibliographic Search**

| Search category | Value |
|---|---|
| Author | Example: Widom, J or Garcia-Molina |
| Title | Also a part of the title possible |
| Date of publication | Example: 1997 or <1997 or >1997 limits the search to the documents appeared in, before and after 1997 respectively |
| Language | Language the document was written in: English |
| Project | ANY |
| Type | ANY |
| Subject group | ANY |
| Sorted by | Date of publication |

Start bibliographic search

Find document via ID

Example query: *"find documents authored by William Shakespeare in 1601, containing the phrase alas poor Yorick".*

- Usual postings intersections, *except that we may merge postings from standard inverted as well as parametric indexes*.

- For ordered values (e.g., year) may support querying ranges -> use a structure like a B-tree for the dictionary of sucg fields

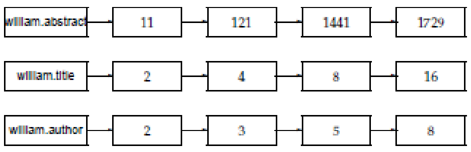
## Zone indexes

- Zones similar to fields, except *the contents of a zone can be arbitrary free text.*
  - example, document titles and abstracts

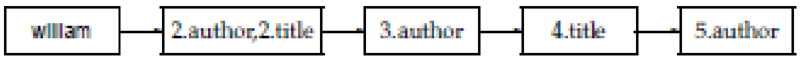
- We may build a separate inverted index for each zone of a document, to support queries such as
  *"find documents with merchant in the title and william in the author list and the phrase gentle rain in the body".*

- Whereas, the dictionary for a parametric index comes from a fixed vocabulary, the dictionary for a zone index whatever vocabulary stems from the text of that zone.

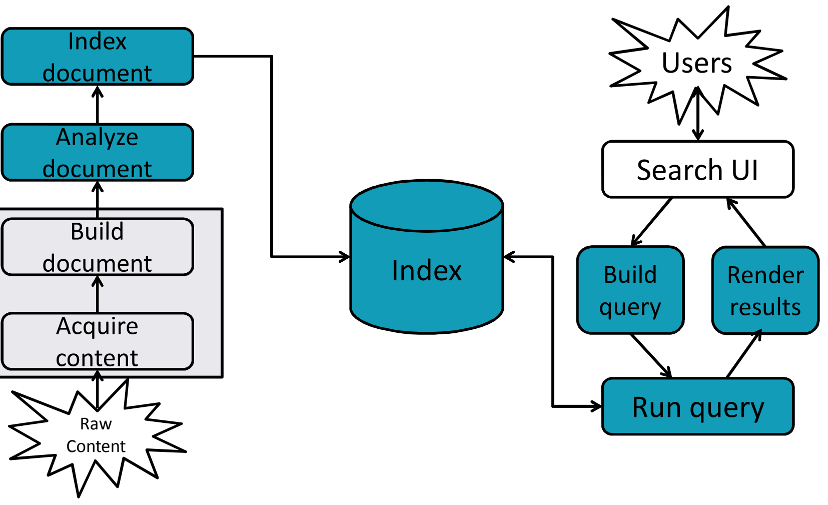
## Zone indexes



- we can reduce the size of the dictionary by encoding the zone in which a term occurs in the postings
- Also, supports weighted zone scoring



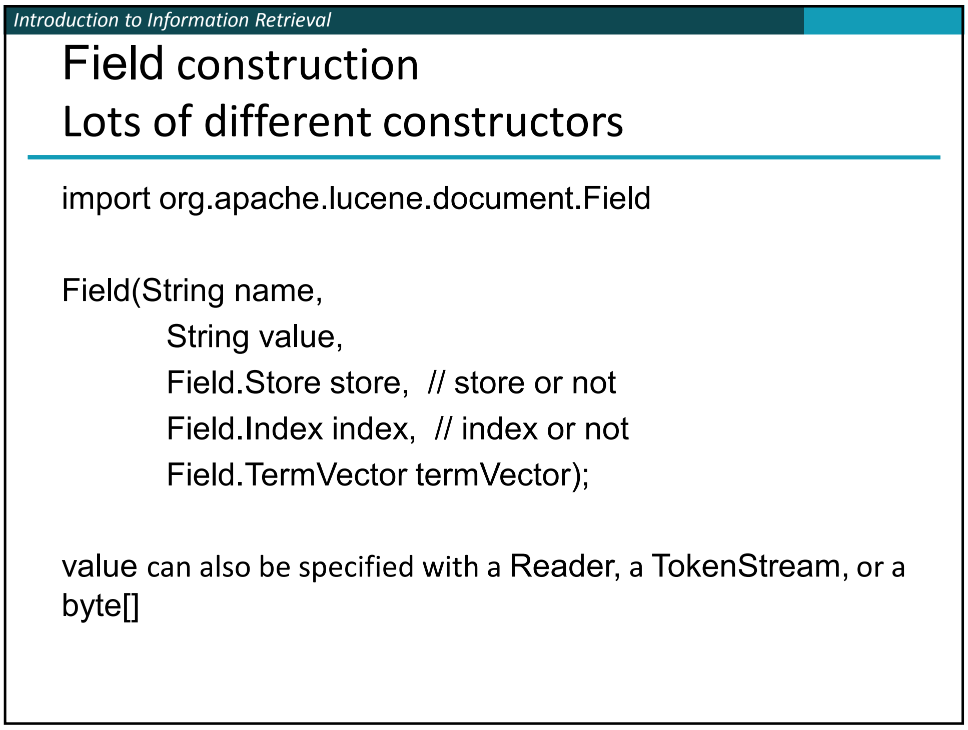
## Lucene in a search system



## Fields

Fields may

- Be indexed or not
  - Indexed fields may or may not be analyzed (i.e., tokenized with an Analyzer)
    - *Non-analyzed fields view the entire value as a single token* (useful for URLs, paths, dates, social security numbers, ...)
- Be stored or not
  - Useful for fields that you'd like to display to users
- Optionally store term vectors
  - Like a positional index on the Field's terms
  - Useful for highlighting, finding similar documents, categorization

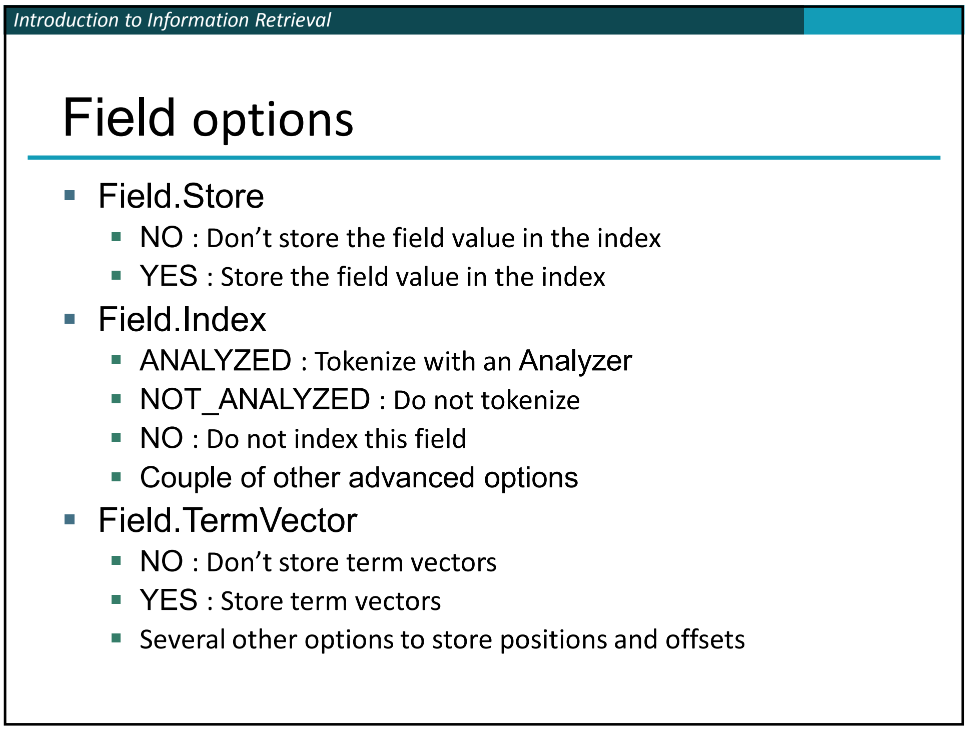


## Field construction
## Lots of different constructors

```
import org.apache.lucene.document.Field

Field(String name,
        String value,
        Field.Store store,  // store or not
        Field.Index index,  // index or not
        Field.TermVector termVector);
```

value can also be specified with a Reader, a TokenStream, or a byte[]



## Field options

- Field.Store
  - NO : Don’t store the field value in the index
  - YES : Store the field value in the index
- Field.Index
  - ANALYZED : Tokenize with an Analyzer
  - NOT_ANALYZED : Do not tokenize
  - NO : Do not index this field
  - Couple of other advanced options
- Field.TermVector
  - NO : Don’t store term vectors
  - YES : Store term vectors
  - Several other options to store positions and offsets

## Using Field options

| Index | Store | TermVector | Example usage |
|---|---|---|---|
| NOT_ANALYZED | YES | NO | Identifiers, telephone/SSNs, URLs, dates, ... |
| ANALYZED | YES | WITH_POSITIONS_OFFSETS | Title, abstract |
| ANALYZED | NO | WITH_POSITIONS_OFFSETS | Body |
| NO | YES | NO | Document type, DB keys (if not used for searching) |
| NOT_ANALYZED | NO | NO | Hidden keywords |

## Document

import org.apache.lucene.document.Field

- Constructor:
  - Document();
- Methods
  - void add(Fieldable field); // Field implements
    // Fieldable
  - String get(String name); // Returns value of
    // Field with given
    // name
  - Fieldable getFieldable(String name);
  - ... and many more

## Multi-valued fields

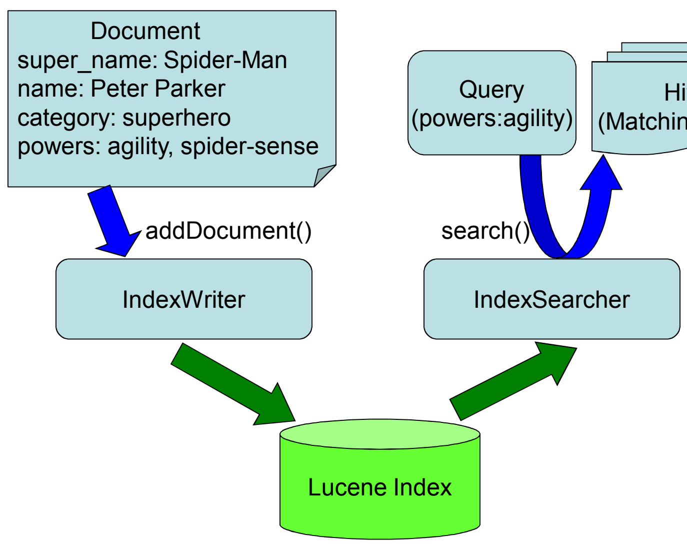
- You can add multiple Fields with the same name
  - Lucene simply concatenates the different values for that named Field

```
    Document doc = new Document();
doc.add(new Field("author",
                        "chris manning",
                        Field.Store.YES,
                        Field.Index.ANALYZED));
    doc.add(new Field("author",
                        "prabhakar raghavan",
                        Field.Store.YES,
                        Field.Index.ANALYZED));
    ...
```

## Core indexing classes

- *IndexWriter*
  - Central component that allows you to create a new index, open an existing one, and add, remove, or update documents in an index
- Directory
  - Abstract class that represents the location of an index
- *Analyzer*
  - Extracts tokens from a text stream

## Basic Application



1. Get Lucene jar file
2. Write indexing code to get data and create Document objects
3. Write code to create query objects
4. Write code to use/display results

## Basic Application: notes

Only a single IndexWriter may be open on an index
An IndexWriter is thread-safe, so multiple threads can add documents at the same time.

Multiple IndexSearchers may be opened on an index
- IndexSearchers are also thread safe, and can handle multiple searches concurrently
- an IndexSearcher instance has a static view of the index, it sees no updates after it has been opened

An index may be concurrently added to and searched, but new additions won’t show up until the IndexWriter is closed and a new IndexSearcher is opened.

## Analyzers

Tokenizes the input text

- Common Analyzers
  - WhitespaceAnalyzer
    *Splits tokens on whitespace*
  - SimpleAnalyzer
    *Splits tokens on non-letters, and then lowercases*
  - StopAnalyzer
    *Same as SimpleAnalyzer, but also removes stop words*
  - StandardAnalyzer
    *Most sophisticated analyzer that knows about certain token types, lowercases, removes stop words, ...*

## Analysis examples

“The quick brown fox jumped over the lazy dog”

- WhitespaceAnalyzer
  - [The] [quick] [brown] [fox] [jumped] [over] [the] [lazy] [dog]
- SimpleAnalyzer
  - [the] [quick] [brown] [fox] [jumped] [over] [the] [lazy] [dog]
- StopAnalyzer
  - [quick] [brown] [fox] [jumped] [over] [lazy] [dog]
- StandardAnalyzer
  - [quick] [brown] [fox] [jumped] [over] [lazy] [dog]

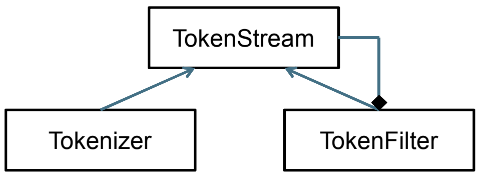
## More analysis examples

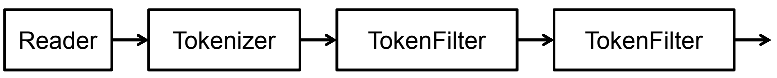
- "XY&Z Corporation – xyz@example.com"
- WhitespaceAnalyzer
  - [XY&Z] [Corporation] [-] [xyz@example.com]
- SimpleAnalyzer
  - [xy] [z] [corporation] [xyz] [example] [com]
- StopAnalyzer
  - [xy] [z] [corporation] [xyz] [example] [com]
- StandardAnalyzer
  - [xy&z] [corporation] [xyz@example.com]

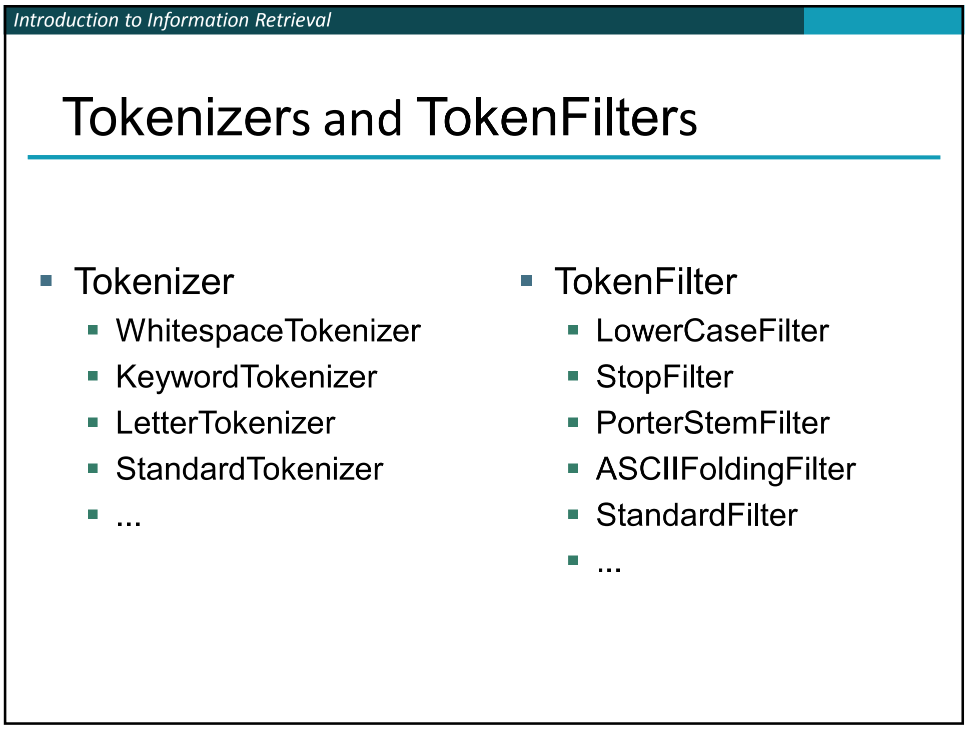
## What's inside an Analyzer?

- Analyzers need to return a TokenStream

```
public TokenStream tokenStream(String fieldName,
                               Reader reader)
```

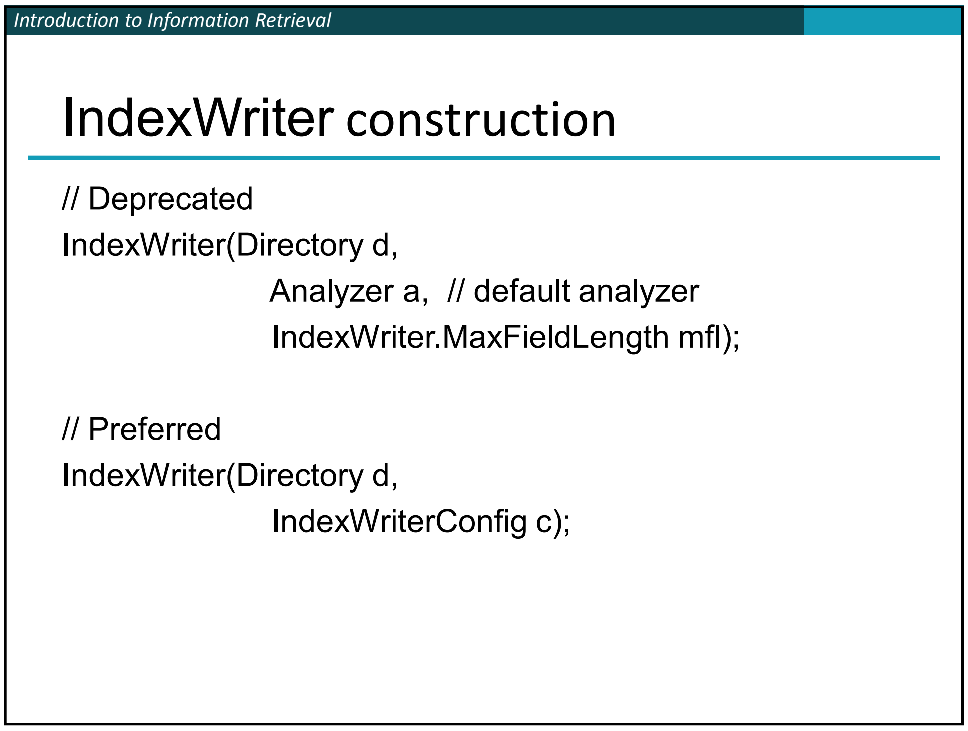






## Tokenizers and TokenFilters

- Tokenizer
  - WhitespaceTokenizer
  - KeywordTokenizer
  - LetterTokenizer
  - StandardTokenizer
  - ...
- TokenFilter
  - LowerCaseFilter
  - StopFilter
  - PorterStemFilter
  - ASCIIFoldingFilter
  - StandardFilter
  - ...



## IndexWriter construction

```
// Deprecated
IndexWriter(Directory d,
                    Analyzer a,  // default analyzer
                    IndexWriter.MaxFieldLength mfl);

// Preferred
IndexWriter(Directory d,
                    IndexWriterConfig c);
```

## Creating an IndexWriter

```
import org.apache.lucene.index.IndexWriter;
import org.apache.lucene.store.Directory;
import org.apache.lucene.analysis.standard.StandardAnalyzer;
...
private IndexWriter writer;
...
public Indexer(String indexDir) throws IOException {
  Directory dir = FSDirectory.open(new File(indexDir));
  writer = new IndexWriter(
                              dir,
                          new StandardAnalyzer(Version.LUCENE_30),
                              true,
                              IndexWriter.MaxFieldLength.UNLIMITED);
}
```

## Core indexing classes

- Document
  - Represents a collection of named Fields.
  - Text in these Fields are indexed.
- Field
  - Note: Lucene Fields can represent both “fields” and “zones” as described in the textbook

## A Document contains Fields

```
import org.apache.lucene.document.Document;
import org.apache.lucene.document.Field;
...
protected Document getDocument(File f) throws Exception {
    Document doc = new Document();
    doc.add(new Field("contents", new FileReader(f)))
  doc.add(new Field("filename",
                          f.getName(),
                          Field.Store.YES,
                          Field.Index.NOT_ANALYZED));
  doc.add(new Field("fullpath",
                          f.getCanonicalPath(),
                          Field.Store.YES,
                          Field.Index.NOT_ANALYZED));
  return doc;
}
```

## Index a Document with IndexWriter

```
private IndexWriter writer;
...
private void indexFile(File f) throws
        Exception {
    Document doc = getDocument(f);
    writer.addDocument(doc);
}
```

## Indexing a directory

```
private IndexWriter writer;
...
public int index(String dataDir,
                     FileFilter filter)
        throws Exception {
    File[] files = new File(dataDir).listFiles();
    for (File f: files) {
        if (... &&
            (filter == null || filter.accept(f))) {
            indexFile(f);
        }
    }
    return writer.numDocs();
}
```

## Closing the IndexWriter

```
private IndexWriter writer;
...
public void close() throws IOException {
    writer.close();
}
```

## Adding/deleting Documents to/from an IndexWriter

```
void addDocument(Document d);
void addDocument(Document d, Analyzer a);
```

Important: Need to ensure that Analyzers used at indexing time are consistent with Analyzers used at searching time

```
// deletes docs containing term or matching
// query.  The term version is useful for
// deleting one document.
void deleteDocuments(Term term);
void deleteDocuments(Query query);
```

## Index format

- Each Lucene index consists of one or more segments
  - A segment is a standalone index for a subset of documents
  - All segments are searched
  - A segment is created whenever IndexWriter flushes adds/deletes
- Periodically, IndexWriter will merge a set of segments into a single segment
  - Policy specified by a MergePolicy
- You can explicitly invoke optimize() to merge segments

## Basic merge policy

- Segments are grouped into levels
- Segments within a group are roughly equal size (in log space)
- Once a level has enough segments, they are merged into a segment at the next level up

## Core searching classes

- IndexSearcher
  - Central class that exposes several search methods on an index
- Query
  - Abstract query class. Concrete subclasses represent specific types of queries, e.g., matching terms in fields, boolean queries, phrase queries, …
- QueryParser
  - Parses a textual representation of a query into a Query instance

## Creating an IndexSearcher

```
import org.apache.lucene.search.IndexSearcher;
...
public static void search(String indexDir,
                                          String q)
        throws IOException, ParseException {
    Directory dir = FSDirectory.open(
                                 new File(indexDir));
    IndexSearcher is = new IndexSearcher(dir);
    ...
}
```

## Query and QueryParser

```
import org.apache.lucene.search.Query;
import org.apache.lucene.queryParser.QueryParser;
...
public static void search(String indexDir, String q)
        throws IOException, ParseException
    ...
    QueryParser parser =
        new QueryParser(Version.LUCENE_30,
                        "contents”,
                        new StandardAnalyzer(
                                 Version.LUCENE_30));
    Query query = parser.parse(q);
    ...
}
```

## Core searching classes (contd.)

- TopDocs
  - Contains references to the top documents returned by a search
- ScoreDoc
  - Represents a single search result

## search() returns TopDocs

```
import org.apache.lucene.search.TopDocs;
...
public static void search(String indexDir,
                                          String q)
        throws IOException, ParseException
    ...
    IndexSearcher is = ...;
    ...
    Query query = ...;
    ...
    TopDocs hits = is.search(query, 10);
}
```

## TopDocs contain ScoreDocs

```
import org.apache.lucene.search.ScoreDoc;
...
public static void search(String indexDir, String q)
        throws IOException, ParseException
    ...
    IndexSearcher is = ...;
    ...
    TopDocs hits = ...;
    ...
    for(ScoreDoc scoreDoc : hits.scoreDocs) {
        Document doc = is.doc(scoreDoc.doc);
        System.out.println(doc.get("fullpath"));
    }
}
```

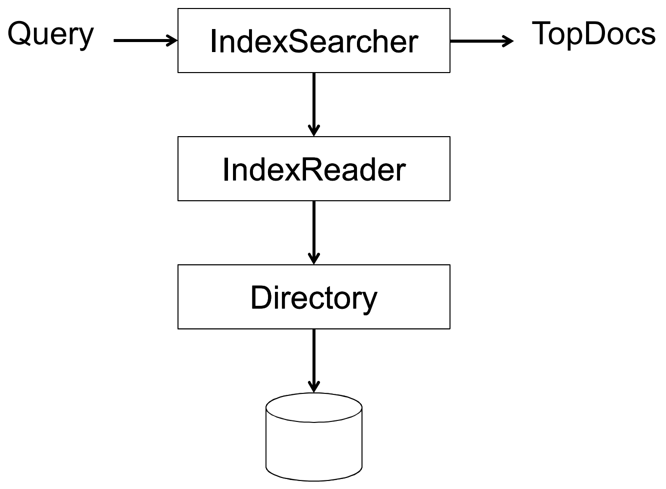
## Closing IndexSearcher

```
public static void search(String indexDir,
                                        String q)
        throws IOException, ParseException
    ...
    IndexSearcher is = ...;
    ...
    is.close();
}
```

## IndexSearcher

- Constructor:
  - IndexSearcher(Directory d);
    - deprecated

## IndexReader



## IndexSearcher

- Constructor:
  - IndexSearcher(Directory d);
    - deprecated
  - IndexSearcher(IndexReader r);
    - Construct an IndexReader with static method IndexReader.open(dir)

## Searching a changing index

```
Directory dir = FSDirectory.open(...);
IndexReader reader = IndexReader.open(dir);
IndexSearcher searcher = new IndexSearcher(reader);
```

Above reader does not reflect changes to the index unless you reopen it.
Reopening is more resource efficient than opening a new IndexReader.

```
IndexReader newReader = reader.reopen();
If (reader != newReader) {
    reader.close();
    reader = newReader;
    searcher = new IndexSearcher(reader);
}
```

## Near-real-time search

```
IndexWriter writer = ...;
IndexReader reader = writer.getReader();
IndexSearcher searcher = new IndexSearcher(reader);
```

Now let us say there's a change to the index using writer

```
// reopen() and getReader() force writer to flush
IndexReader newReader = reader.reopen();
if (reader != newReader) {
    reader.close();
    reader = newReader;
    searcher = new IndexSearcher(reader);
}
```

## IndexSearcher

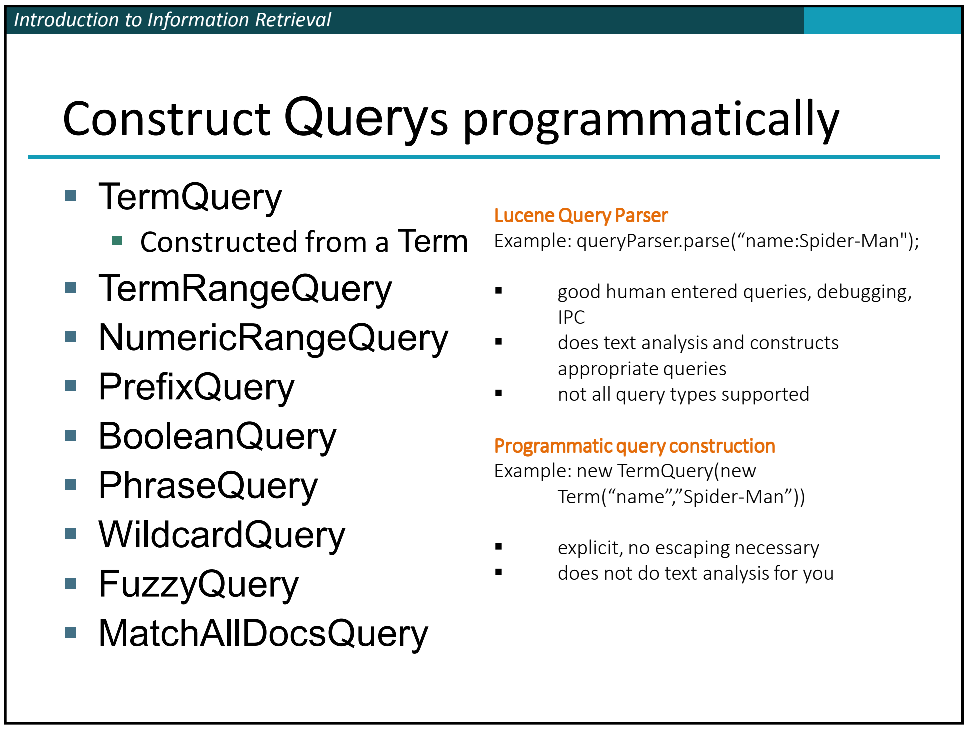
- Methods
  - TopDocs search(Query q, int n);
  - Document doc(int docID);

## QueryParser

- Constructor
  - QueryParser(Version matchVersion,
    String defaultField,
    Analyzer analyzer);
- Parsing methods
  - Query parse(String query) throws
    ParseException;
  - ... and many more

## QueryParser syntax examples

| Query expression | Document matches if… |
|---|---|
| java | Contains the term *java* in the default field |
| java junit<br>java OR junit | Contains the term *java* or *junit* or both in the default field (*the default operator can be changed to* AND) |
| +java +junit<br>java AND junit | Contains both *java* and *junit* in the default field |
| title:ant | Contains the term *ant* in the title field |
| title:extreme –subject:sports | Contains *extreme* in the title and not *sports* in subject |
| (agile OR extreme) AND java | Boolean expression matches |
| title:”junit in action” | Phrase matches in title |
| title:”junit action”~5 | Proximity matches (within 5) in title |
| java* | Wildcard matches |
| java~ | Fuzzy matches |
| lastmodified:[1/1/09 TO 12/31/09] | Range matches |



## Construct Querys programmatically

- TermQuery
  - Constructed from a Term
- TermRangeQuery
- NumericRangeQuery
- PrefixQuery
- BooleanQuery
- PhraseQuery
- WildcardQuery
- FuzzyQuery
- MatchAllDocsQuery

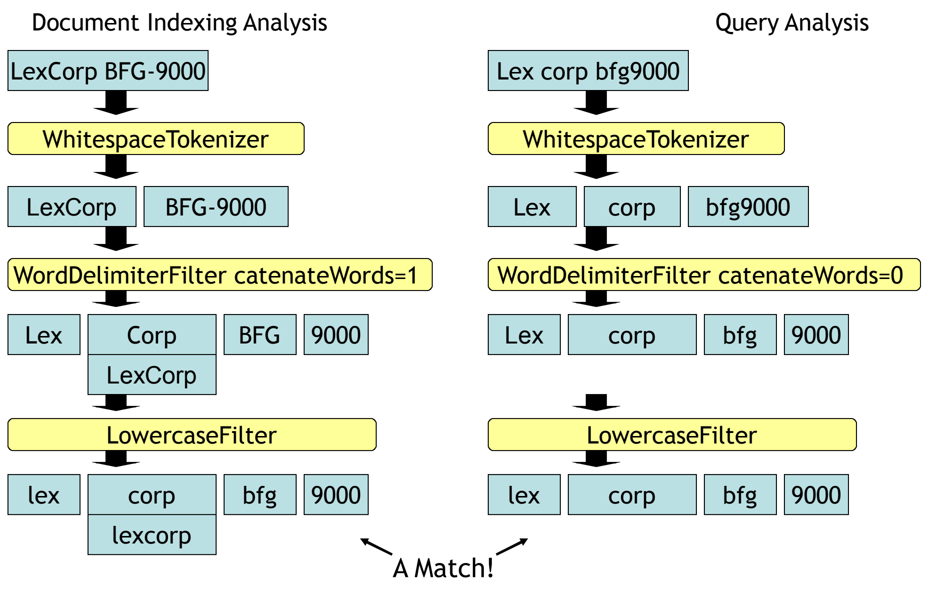
**Lucene Query Parser**
Example: queryParser.parse(“name:Spider-Man");

- good human entered queries, debugging, IPC
- does text analysis and constructs appropriate queries
- not all query types supported

**Programmatic query construction**
Example: new TermQuery(new Term(“name”,”Spider-Man”))

- explicit, no escaping necessary
- does not do text analysis for you

## Analysis & Search Relevancy



## TopDocs and ScoreDoc

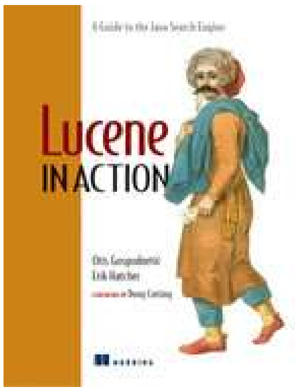
- TopDocs methods
  - Number of documents that matched the search
    totalHits
  - Array of ScoreDoc instances containing results
    scoreDocs
  - Returns best score of all matches
    getMaxScore()
- ScoreDoc methods
  - Document id
    doc
  - Document score
    score

## Scoring

- Scoring function uses basic tf-idf scoring with
  - Programmable boost values for certain fields in documents
  - Length normalization
  - Boosts for documents containing more of the query terms
- IndexSearcher provides an explain() method that explains the scoring of a document

## Based on “Lucene in Action”

- By Michael McCandless, Erik Hatcher, Otis Gospodnetic



ΤΕΛΟΣ 12$^{ου}$ Μαθήματος

Ερωτήσεις?

*Υλικό των:*
*✓Pandu Nayak and Prabhakar Raghavan, CS276:Information Retrieval and Web Search (Stanford)*