Full Text Search (FTS)
- More formally known as Information Retrieval (IR)
- Search LARGE amount of textual data

Database Query
- Find the posts regarding “SSHD login errors”.
  ```sql
  select * from posts
  where content like '%SSHD login errors%';
  ```
  Here are the steps to take to fix the SSHD login errors:
  ```SQL```...
  ```plaintext```
  Please help! I got SSHD login errors!

Search Text
- Web search
- Desktop search
- Applications
  - Search posts in a bulletin board
  - Search product descriptions at an online retailer
  - ...

Problems with Database Queries
- Please help! I got an error when I tried to login through SSHD!
- There a problem recently discovered regarding SSHD and login. The error message is usually ...
- The solution for sshd/login errors: ...
- And how about performance??

Characteristics of FTS
- Vs. Databases
  - Relevancy ranking
  - "Fuzzy" query processing
Accuracy of FTS

\[
\text{Precision} = \frac{\text{# of relevant documents retrieved}}{\text{# of documents retrieved}}
\]

\[
\text{Recall} = \frac{\text{# of relevant documents retrieved}}{\text{# of relevant documents}}
\]

Journey of a Document

1. Stripping non-textual data
2. Tokenizing
3. Removing stop words
4. Stemming
5. Indexing

Document

- Original
  - <html>
  - <body>
    - <p>The solution for sshd/login errors: ...
    - <html>
  - </body>
  - </html>

- Text-only
  - The solution for sshd/login errors: ...

Tokenizing

- [the] [solution] [for] [sshd] [login] [errors]
- ...

Chinese Text Example

- Text: 今天天气不错。
- Unigram:
  - [今] [天] [天] [气] [不] [错]
- Bigram:
  - [今天] [天天] [天气] [气不] [不错]
- Grammar-based:
  - [今天] [天气] [不错]

Stop Words

- Words that do not help in search and retrieval
  - Function words: a, an, and, the, of, for ...
- After stop words removal:
  - [the] [solution] [for] [sshd] [login] [errors]
- Problem of stop word removal??
Stemming
- Reduce a word to its stem or root form.
- Examples:
  - connection, connections → connect
  - connected, connecting → connect
  - [solution] [sshd] [login] [errors] → [solve] [sshd] [login] [error]

Inverted Index
- cat
- dog
- keywords
- buckets

Query Processing
- Query
  - tokenizing
  - Removing stop words
  - Stemming
  - Searching
  - results
  - Ranking

Ranking
- How well the document matches the query
  - E.g. weighted vector distance
- How “important” the document is
  - E.g. based on ratings, citations, and links

FTS Implementations
- Databases
  - MySQL: MyISAM tables only
  - PostgreSQL (since 8.3)
  - Oracle, DB2, MS SQL Server, ...
- Standard-alone IR libraries
  - Lucene, Egothor, Xapian, MG4J, ...

FTS from the Perspective of Application Developers
- Prepare data
- Create query
- Display result
- (Index)
- (Ranking)
Lucene Overview

- http://lucene.apache.org/
- Originally developed by Doug Cutting
- THE full text search solution for Java applications
- Handles text only – needs external converters to convert other document types to text
- Java API - http://lucene.apache.org/java/3_4_0/api/core/index.html

Example 1: Index Text Files

- Directory
- Document and Field
- Analyzer
- IndexWriter

Directory

- A place where the index files will be stored
- FSDirectory – file system directory
- RAMDirectory – virtual directory in memory

Analyzer

- Pre-processing the document or query text –
  tokenization, stop words removal, stemming
- Lucene built-in analyzers
  - WhitespaceAnalyzer, SimpleAnalyzer, StopAnalyzer
  - StandardAnalyzer
    - Grammar-based
    - Recognize special tokens such as email addresses
    - Handle CJK text

IndexWriter

- addDocument( Document )
- close()
- optimize()

Document

- A document consists of a number of user-defined fields

Title: FTS with Lucene
Author: Chengyu Sun
Content:
  lots of words ...
  lots of words ...

Fields
Types of Fields

- Indexed – whether the field is indexed
  - Analyzed
  - Not analyzed
- Stored – whether the original text is stored together with the index

Common Usage of Field Types

<table>
<thead>
<tr>
<th>Field</th>
<th>Indexed</th>
<th>Analyzed</th>
<th>Stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>String</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Large text file</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>ID, people’s name, date</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Non-searchable data</td>
<td>Y</td>
<td></td>
<td>Y</td>
</tr>
</tbody>
</table>

Example 2: Search

- Query and QueryParser
- IndexSearcher
- TopDocs and ScoreDoc
- Document (again)

Queries

- full text search
- +full +text search
- +full +text -search
- +title:"text search"
- +(title:full title:text) -author:"john doe"

IndexSearcher

- search( Query, int n ) – returns the top n results for the query

TopDocs and ScoreDoc

- TopDocs contains an array of ScoreDoc, which has a document id and the relevancy score of the document
Factors in Lucene Score

- # of times a term appears in a document
- # of documents that contain the term
- # of query terms found
- length of a field
- boost factor - field and/or document
- query normalizing factor – does not affect ranking

See the API documentation for the Similarity class.

Document (again)

- Methods to retrieve data stored in the document
  - String get( String fieldName )

Handle Rich Text Documents

- HTML
  - NekoHTML
- PDF
  - PDFBox
- MS Word
  - POI

Further Readings

- Lucene in Action (2ed Ed) by Michael McCandless, Erik Hatcher and Otis Gospodnetic

FTS in PostgreSQL

- Since 8.3
  - tsearch/tsearch2 module before 8.3

Text Search Configuration

- Specify the options to transform a document to a tsvector – tokenization, stop words removal, stemming etc.
- psql commands
  - \dF
  - show default_text_search_config;
  - set default_text_search_config=english;
- Change default text search configuration in $DATA/postgresql.conf
Sample Schema

```sql
create table messages (  
  id       serial primary key,  
  subject  varchar(4092),  
  content  text,  
  author   varchar(255)  
);
```

Basic Data Types and Functions

- **Data types**
  - tsvector
  - tsquery
- **Functions**
  - to_tsvector
  - to_tsquery
  - plainto_tsquery

Query Syntax

- `plainto_tsquery` to_tsquery
  - full text search full & text & search
  - full & text | search full & !text | search
  - (! full | text ) & search

The Match Operator `@@`

- `tsvector @@ tsquery`
- `tsquery @@ tsvector`
- `text @@ tsquery`
- `to_tsvector(text) @@ tsquery`
- `to_tsvector(text) @@ plainto_tsquery(text)`

*Note that there is no tsquery @@ text.*

Query Examples

- Find the messages that contain "computer programs" in the content
- Find the messages that contain "computer programs" in either the content or the subject

Create an Index on Text Column(s)

```sql
create index messages_content_index  
  on messages  
  using gin(to_tsvector('english',content));
```

- **Expression (function) index**
- *The language parameter is required in both index construction and query*
Use a Separate Column for Text Search

- Create a tsvector column
- Use a trigger to update the column

Create an Index on the tsvector Column

```sql
create index messages_tsv_index on messages using gin(tsv);
```

- The `language` parameter is no longer required

More Functions

- `setweight(tsvector, "char")`
  - A: 1.0
  - B: 0.4
  - C: 0.2
  - D: 0.1
- `ts_rank(tsvector, tsquery)`
- `ts_headline(text, tsquery)`

Function Examples

- Set the weight of `subject` to be "A" and the weight of `content` to be "D"
- List the results by their relevancy scores and highlight the query terms in the results

Using Native SQL in JPA

```java
String sql = "select * from employees where id = ?";
entityManager.createQuery(sql, Employee.class)
    .setParameter(1, employeeId)
    .getResultList();
```

Named Query in Entity Class

```java
@NamedQueries({
    @NamedQuery( name="employee.findById",
        query="from Employee where id = :id" ),
    @NamedQuery( name="employee.findAll",
        query="select * from employees" )
})
public class Employee { .... }
```

A named query can be JPQL or SQL.
Named Query in Hibernate Mapping File

```xml
<sql-query name="message.search">
  <return class="Message" />
  <![[CDATA[
    select * from messages
    where tsv @@ plainto_tsquery(?)
  ]]]>
</sql-query>
```

Using Named Query in DAO

```java
entityManager
  .createNamedQuery("employee.findAll", Employee.class)
  .getResultList();

entityManager
  .createNamedQuery("employee.findById", Employee.class)
  .setParameter("id", employeeId)
  .getSingleResult();
```

Search for Courses in CSNS2

- Course.java
- csns-create.sql
- NamedQueries.hbm.xml
  - Hibernate automatically searches under classpath for *.hbm.xml files
- CourseDaoImpl.java
- CourseDaoTests.java

FTS in Databases vs. Standalone Libraries

- Pros??
- Cons??