An XML-based Approach for Data Preprocessing of Multi-Label Classification Problems

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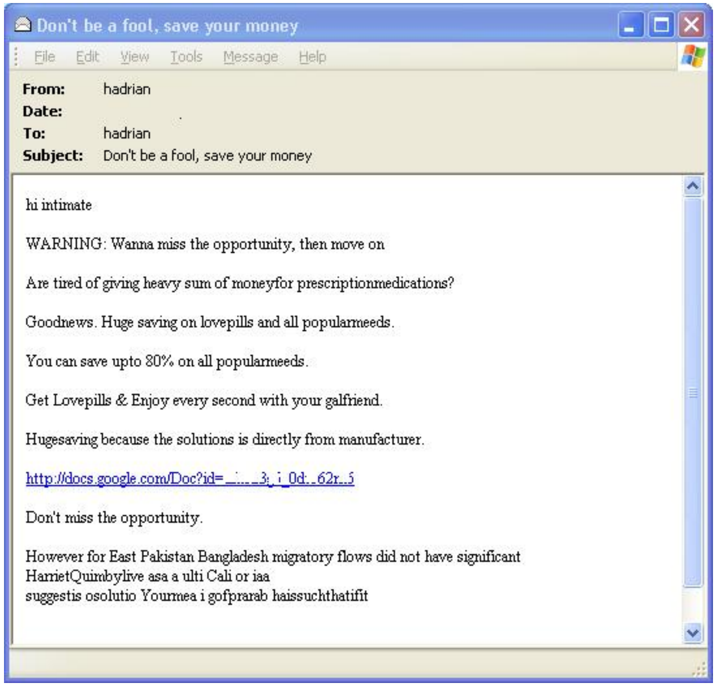
Outline

- Introduction
- Multi-Label Classification
- ARFF *versus* XML
- XML-based Preprocessing of the IMDb Dataset
    - The IMDb dataset
    - A Study on the Words
    - Data Transformation
- Conclusions and Future Work

Introduction (1/4)

- **Classification**
  - Active topic of research in the fields of A.I. and Data Mining.
  - Task of automatically assigning objects to **discrete classes** (known as “labels”) based on the features of the objects.
    - **I.e.**: **predicting** the category(ies) to which an object belongs.

    - **Example**: Spam detection



From: hadrian
Date:
To: hadrian
Subject: Don't be a fool, save your money

hi intimate

WARNING: Wanna miss the opportunity, then move on

Are tired of giving heavy sum of moneyfor prescriptionmedications?

Goodnews. Huge saving on lovepills and all popularmeeds.

You can save upto 80% on all popularmeeds.

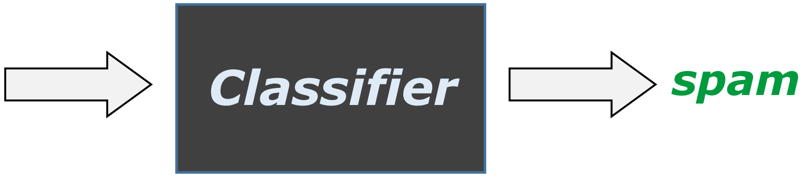
Get Lovepills & Enjoy every second with your galfriend.

Hugesaving because the solutions is directly from manufacturer.

http://docs.google.com/Doc?id=_i..._3;_i_0d:_62r_5

Don't miss the opportunity.

However for East Pakistan Bangladesh migratory flows did not have significant
HarrietQuimbylive asa a ulti Cali or iaa
suggestis osolutio Yourmea i gofprarab haissuchthatifit



object: *message*

label: *spam*

Introduction (2/4)

Single-Label Classification (SLC)

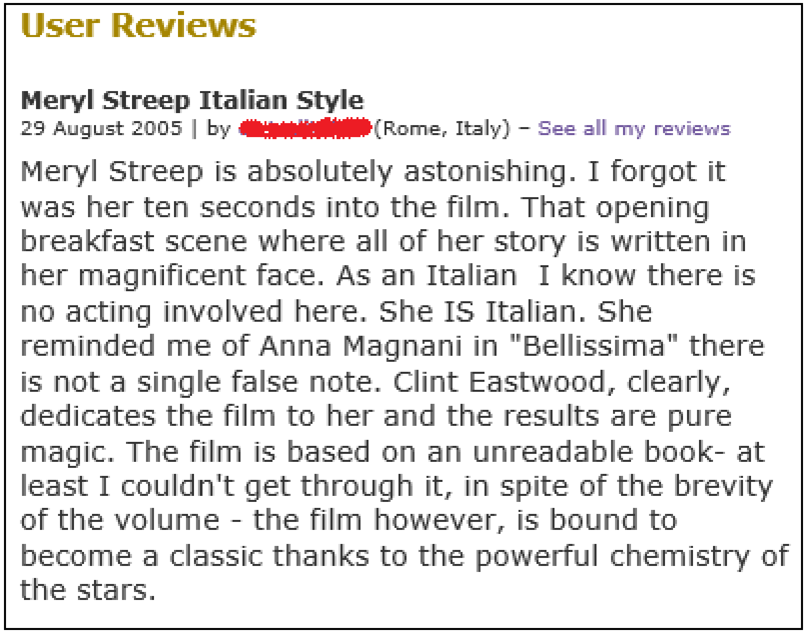
- Object must be associated to **one and only one** class label.
  - **Spam detection** – an incoming e-mail either belongs to the class "*spam*" or to the class "*normal*".
  - **Loan risk prediction** - a loan applicant can be classified as "*low*", "*medium*" or "*high*" credit risk.

Multi-Label Classification (MLC)

- Objects can be assigned to **various labels**.
  - **Text categorization** - A news article about the 2014 Football World Cup can be classified as "*Sports*", "*Politics*" and "*Brazil*".

Introduction (3/4)

- **Problem Statement**
  - It is well-known that a large (perhaps the largest) part of the available data in the world takes the form of **free text** on the Web.



User Reviews

Meryl Streep Italian Style

29 August 2005 | by [redacted] (Rome, Italy) – See all my reviews

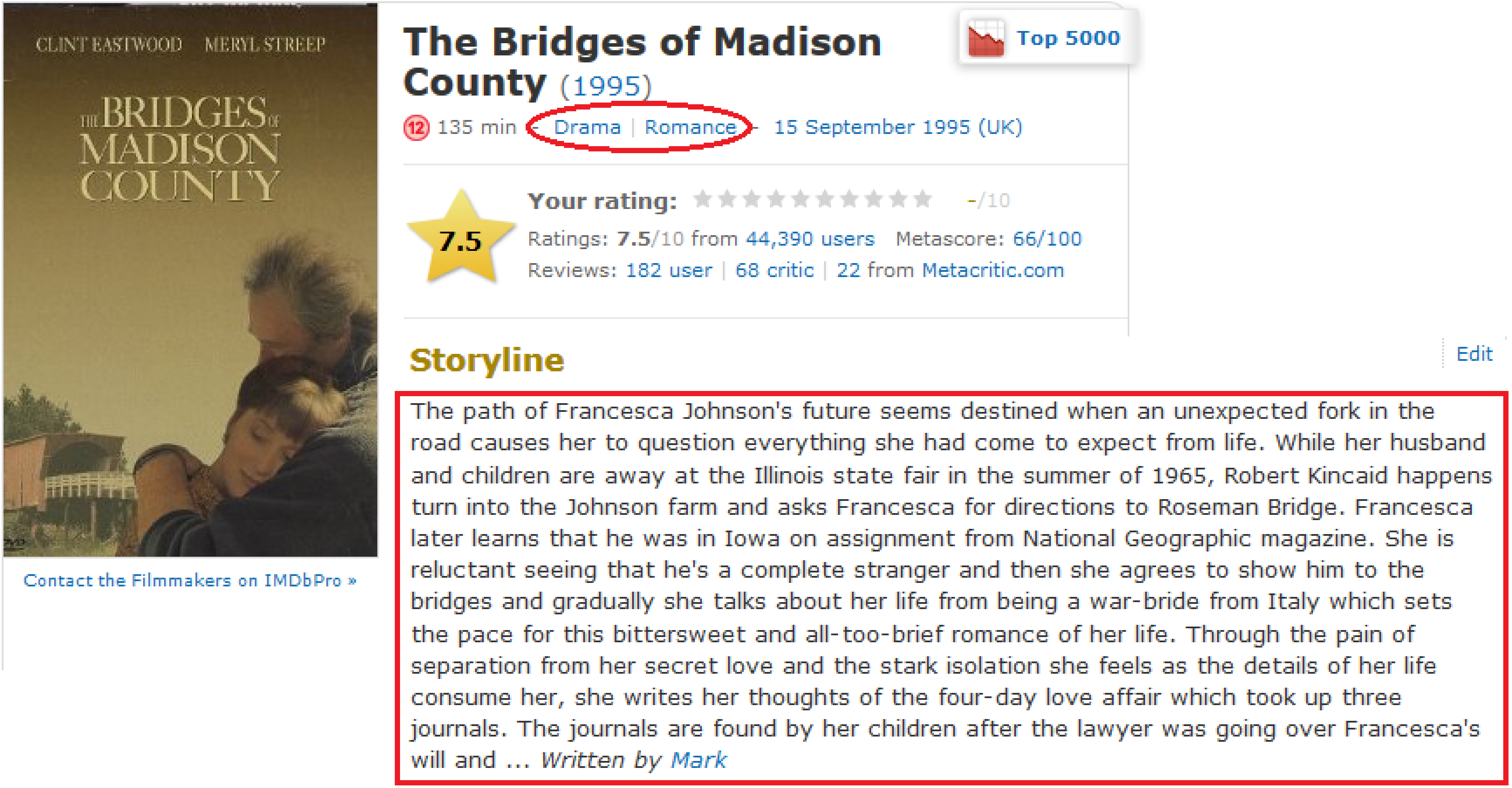
Meryl Streep is absolutely astonishing. I forgot it was her ten seconds into the film. That opening breakfast scene where all of her story is written in her magnificent face. As an Italian I know there is no acting involved here. She IS Italian. She reminded me of Anna Magnani in "Bellissima" there is not a single false note. Clint Eastwood, clearly, dedicates the film to her and the results are pure magic. The film is based on an unreadable book- at least I couldn't get through it, in spite of the brevity of the volume - the film however, is bound to become a classic thanks to the powerful chemistry of the stars.

- There has been a increasing interest in the application of classification techniques to these data!
  - **E.g.**: **sentiment analysis**.
- **PROBLEM**: text data are tend to be more **difficult to clean** and **transform** (highly susceptible to **noisy**)
- **CONSEQUENCE**: low quality data → low quality classification.

- Our proposal:
  - The use of an XML-based approach for **data preprocessing** in **multi-label classification** of **text documents**.

Introduction (4/4)

- **Goal:** demonstrate that XML facilitates the major steps involved in preprocessing.
  - **Classification task**: associate movie summaries to genres.
  - **Data**: IMDb (Internet Movie Database - www.imdb.com)



The Bridges of Madison County (1995)

12 135 min - Drama | Romance - 15 September 1995 (UK)

7.5

Your rating: ★★★★★★★★★★ -/10

Ratings: **7.5**/10 from 44,390 users Metascore: 66/100

Reviews: 182 user | 68 critic | 22 from Metacritic.com

Storyline

The path of Francesca Johnson's future seems destined when an unexpected fork in the road causes her to question everything she had come to expect from life. While her husband and children are away at the Illinois state fair in the summer of 1965, Robert Kincaid happens turn into the Johnson farm and asks Francesca for directions to Roseman Bridge. Francesca later learns that he was in Iowa on assignment from National Geographic magazine. She is reluctant seeing that he's a complete stranger and then she agrees to show him to the bridges and gradually she talks about her life from being a war-bride from Italy which sets the pace for this bittersweet and all-too-brief romance of her life. Through the pain of separation from her secret love and the stark isolation she feels as the details of her life consume her, she writes her thoughts of the four-day love affair which took up three journals. The journals are found by her children after the lawyer was going over Francesca's will and ... *Written by Mark*

Contact the Filmmakers on IMDbPro »

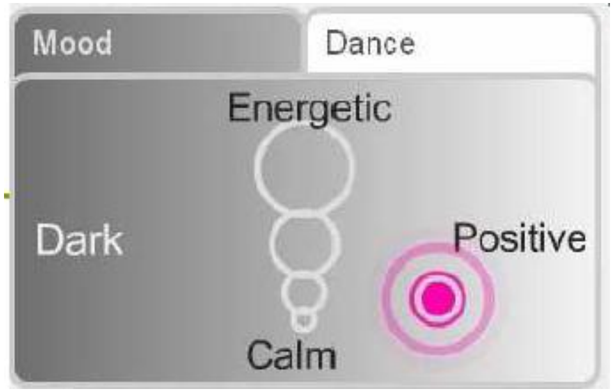
Multi-label Classification (1/5)

- Recently, several modern applications of MLC have emerged:

- **Scene Classification:**

mountains + trees

- **Music into Emotions:**



- **Functional Genomics:** predicting functional classes of genes and proteins

- **Text Classification:** documents into topics (*ex: sports, ecology, religion, …*)

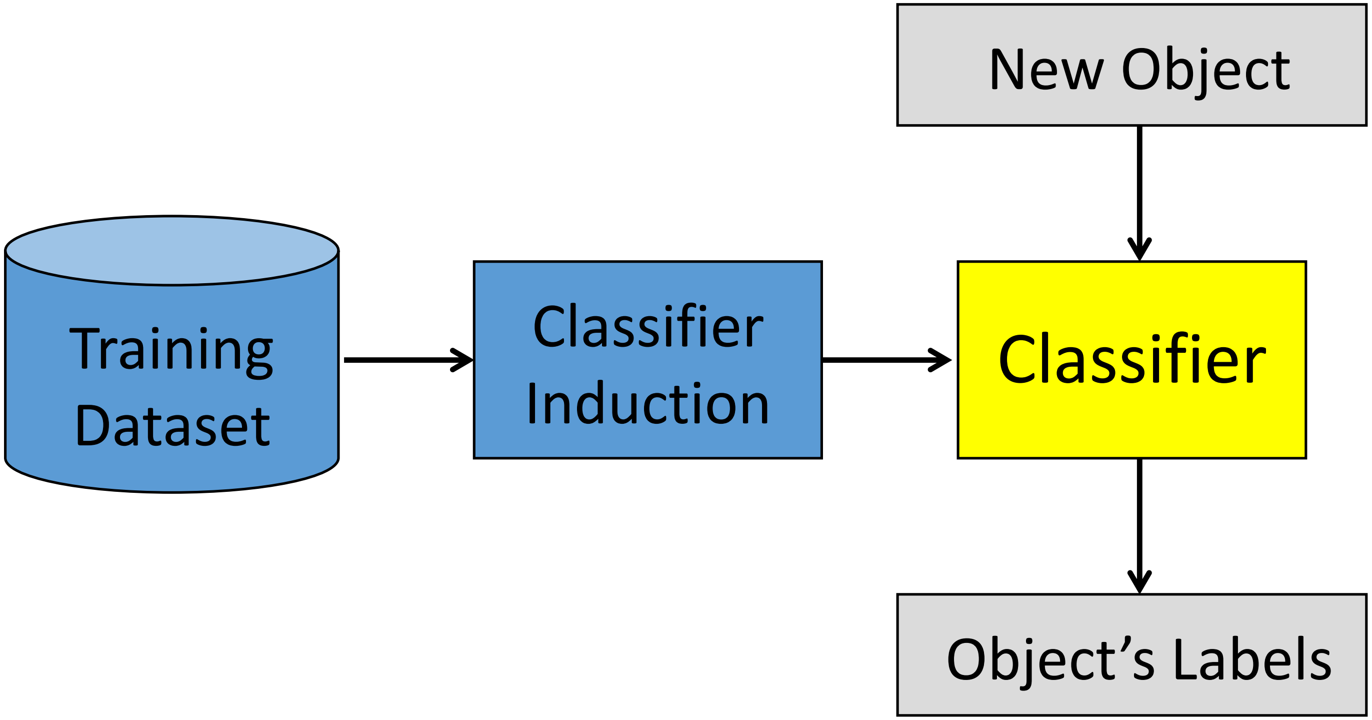
Multi-label Classification (2/5)

- **How to build a multi-label classifier (1/2)?**
  - MLC algorithms need to **learn** from a set objects whose classes are known:
    - The **training dataset**.
  - **Example**:
    - **MLC task**: associating movies to genres according to their summaries.
      - Four possible genres: “*drama*”, “*romance*”, “*horror*”, “*action*”.
      - Training dataset

Text Id	**Feature Vector** (words of the movie summary)	**Drama**	**Romance**	**Horror**	**Action**
1	x_1	●	●		
2	x_2			●	●
3	x_3		●		
4	x_4	●			
5	x_5	●	●		●

Multi-label Classification (3/5)

- **How to build a multi-label classifier (1/2)?**
  - From the training set, the MLC algorithm learns a **classifier**.



- **Classifier**: function that receives the features of a new object as input and outputs its predicted label set

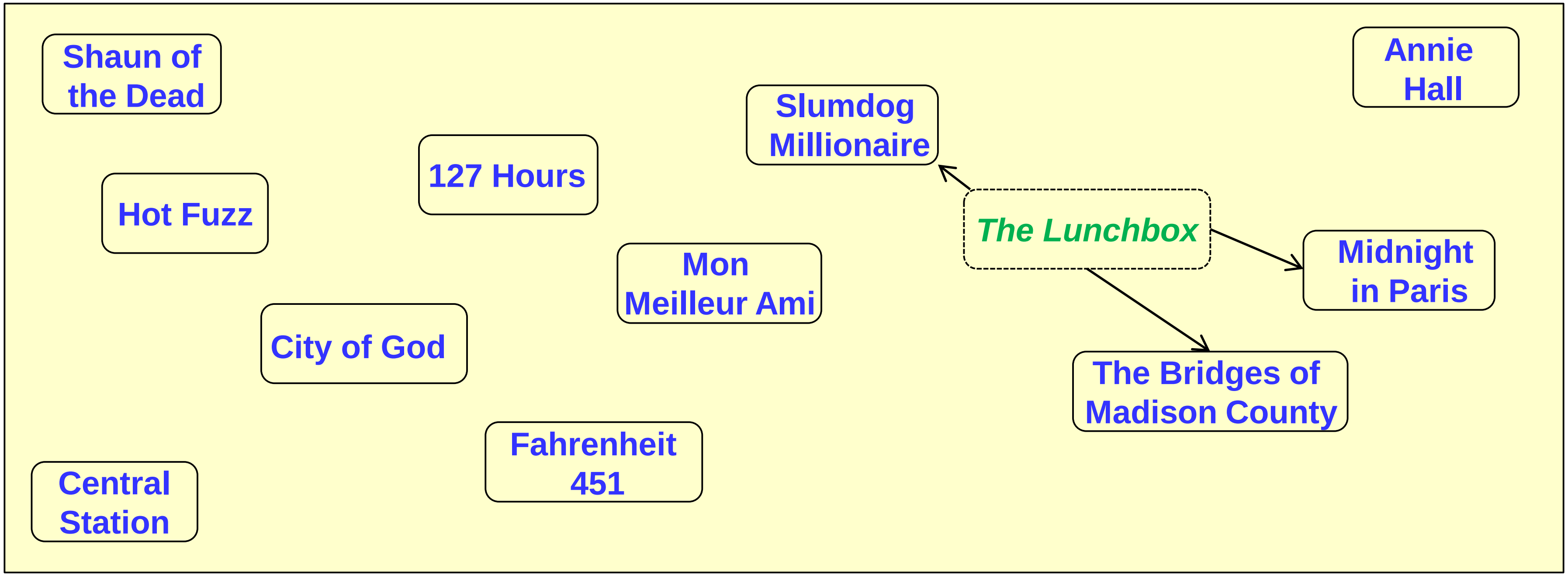
$h : X \to \{0,1\}^q$ where $\boldsymbol{q}$ = number of labels

Multi-label Classification (4/5)

- Several distinct techniques have been developed for building classifiers:
  - k-Nearest Neighbours (k-NN).
  - Decision trees.
  - Probabilistic classifiers.
  - Neural networks.
  - Support vector machines.
- They are based on different mathematical principles for addressing the classification task.
- In the next slide we give an example of classification with the k-NN technique.

Multi-label Classification (5/5)

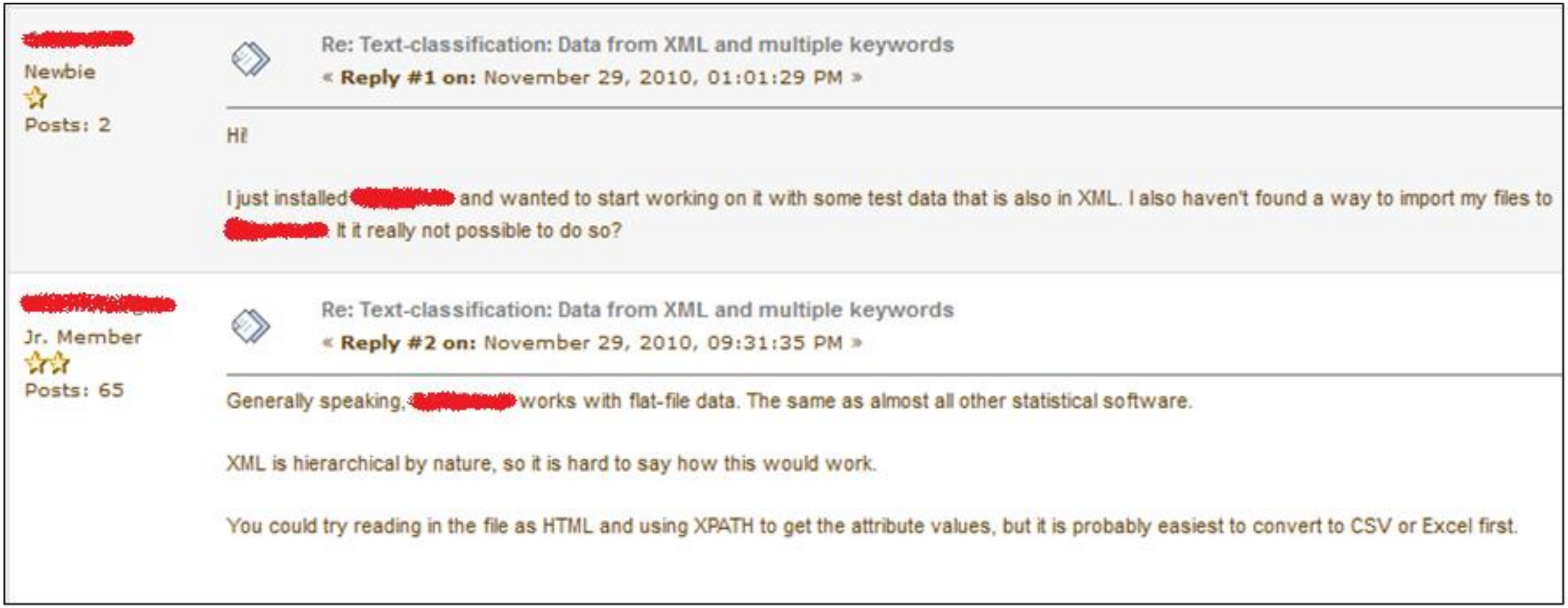
- **Example**: k-Nearest Neighbours.
  - A new object *x* is classified based on the *k* objects in the training set which are more similar to it.
  - **Example**: new object = "The Lunchbox"   *k*=3



- Neighbour$_1$– Slumdog Millionaire (class labels = *Action*, *Romance*, *Drama*)
- Neighbour$_2$ – Midnight in Paris (class labels = *Romance, Fantasy, Comedy*)
- Neighbour$_3$ – The Bridges of Madison County (class labels = *Romance*, *Drama*)
  - **The Lunchbox** is assigned the labels **Romance** and **Drama**

ARFF *versus* XML (1/7)

- Most classification tools work with training data either structured in:
  - Relational tables; or
  - Flat-files (one record per line).



[redacted]
Newbie
☆
Posts: 2

Re: Text-classification: Data from XML and multiple keywords
« **Reply #1 on:** November 29, 2010, 01:01:29 PM »

Hi!

I just installed [redacted] and wanted to start working on it with some test data that is also in XML. I also haven't found a way to import my files to [redacted]. It it really not possible to do so?

[redacted]
Jr. Member
☆☆
Posts: 65

Re: Text-classification: Data from XML and multiple keywords
« **Reply #2 on:** November 29, 2010, 09:31:35 PM »

Generally speaking, [redacted] works with flat-file data. The same as almost all other statistical software.

XML is hierarchical by nature, so it is hard to say how this would work.

You could try reading in the file as HTML and using XPATH to get the attribute values, but it is probably easiest to convert to CSV or Excel first.

ARFF *versus* XML (2/7)

- **The ARFF format**
  - Flat-file format
  - Popularly used in the data mining field

```
@relation loan_risk_prediction

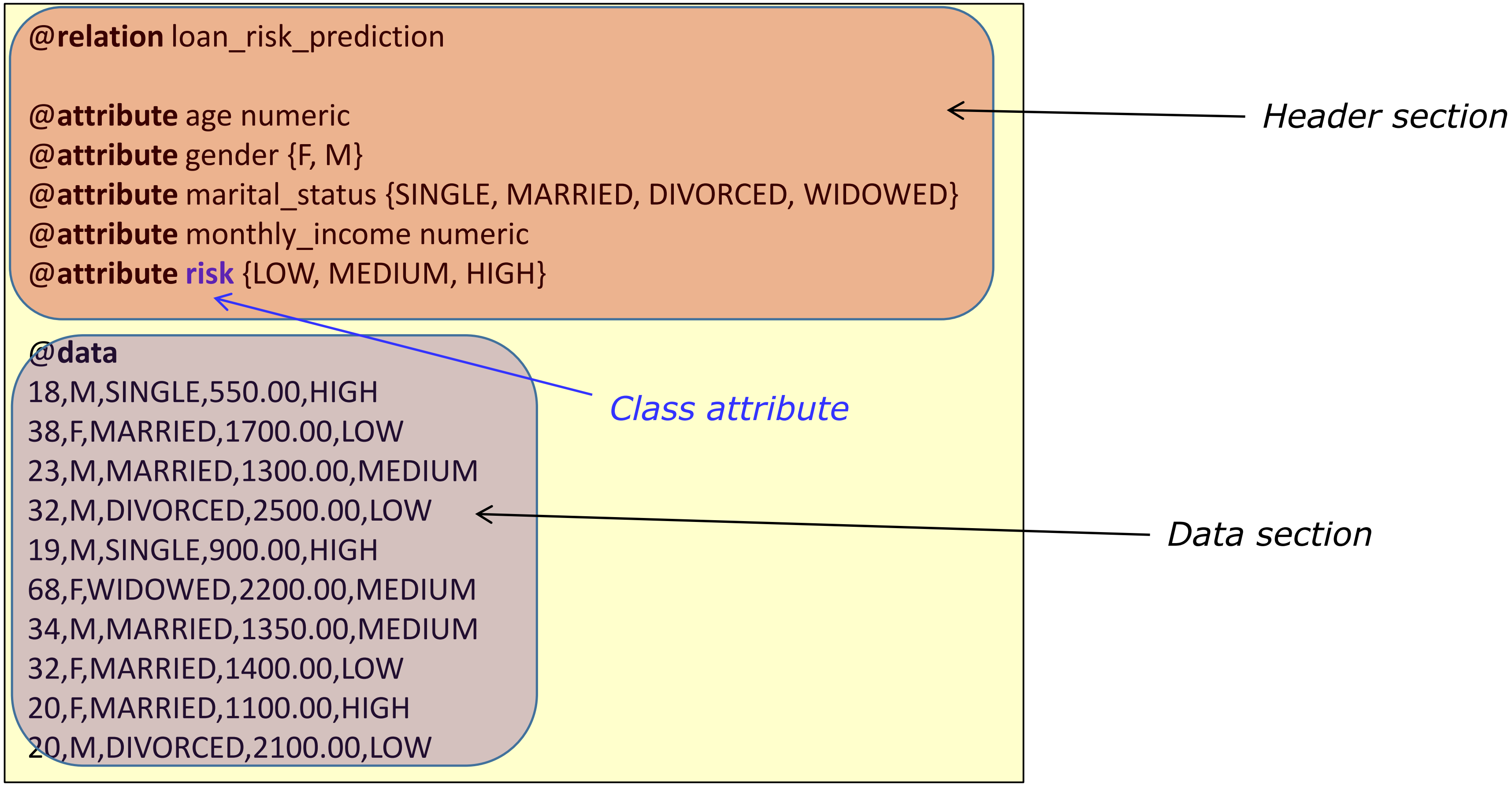
@attribute age numeric
@attribute gender {F, M}
@attribute marital_status {SINGLE, MARRIED, DIVORCED, WIDOWED}
@attribute monthly_income numeric
@attribute risk {LOW, MEDIUM, HIGH}

@data
18,M,SINGLE,550.00,HIGH
38,F,MARRIED,1700.00,LOW
23,M,MARRIED,1300.00,MEDIUM
32,M,DIVORCED,2500.00,LOW
19,M,SINGLE,900.00,HIGH
68,F,WIDOWED,2200.00,MEDIUM
34,M,MARRIED,1350.00,MEDIUM
32,F,MARRIED,1400.00,LOW
20,F,MARRIED,1100.00,HIGH
20,M,DIVORCED,2100.00,LOW
```

ARFF file for loan risk prediction

ARFF *versus* XML (3/7)

- **The ARFF format**
  - Flat-file format
  - Popularly used in the data mining field



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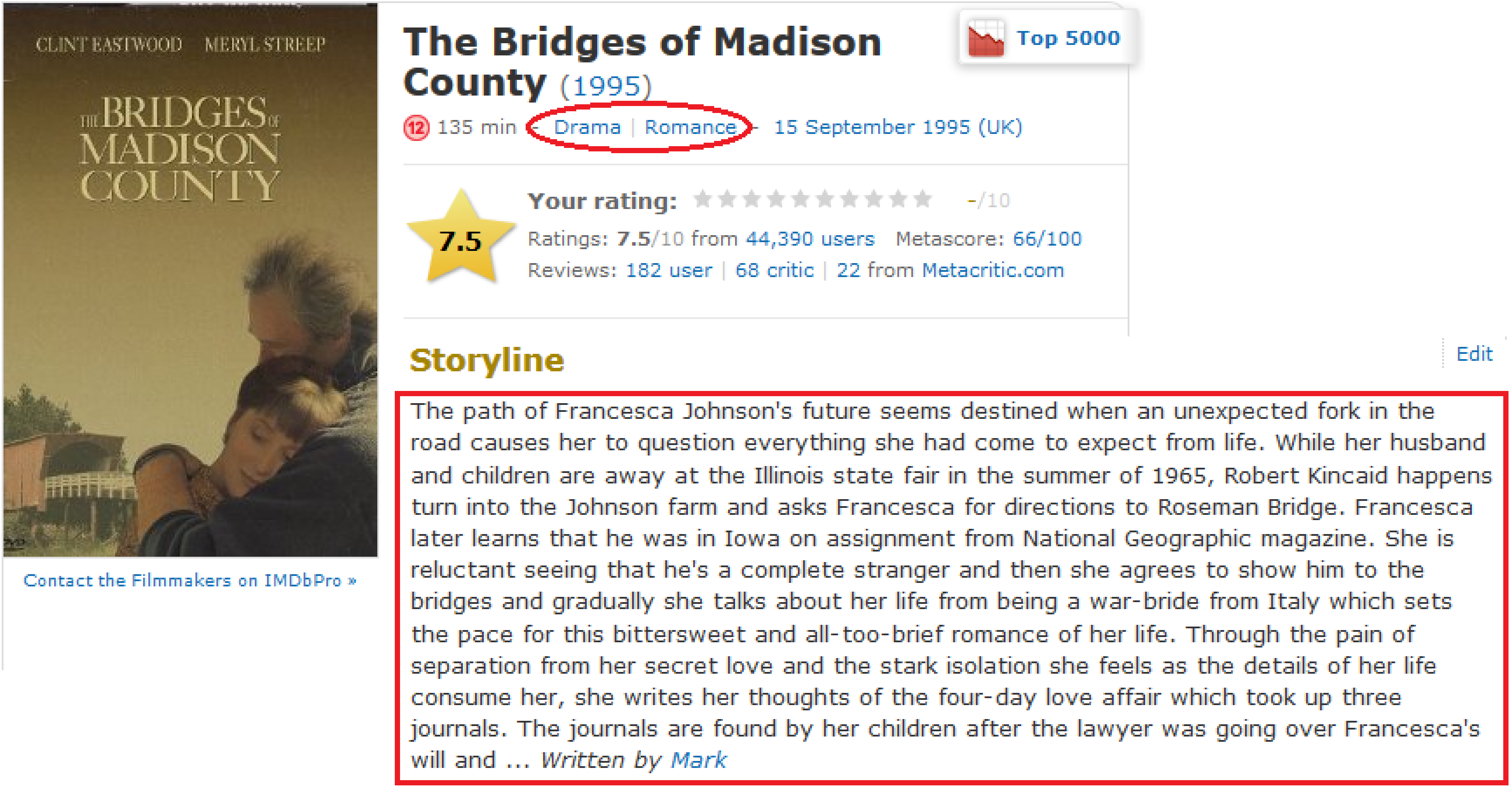
38,F,MARRIED,1700.00,LOW
23,M,MARRIED,1300.00,MEDIUM
32,M,DIVORCED,2500.00,LOW
19,M,SINGLE,900.00,HIGH
68,F,WIDOWED,2200.00,MEDIUM
34,M,MARRIED,1350.00,MEDIUM
32,F,MARRIED,1400.00,LOW
20,F,MARRIED,1100.00,HIGH
20,M,DIVORCED,2100.00,LOW
```

ARFF *versus* XML (4/7)

- **The ARFF format**
  - Simple and intuitive.
  - Sufficient for several classification tasks… as long as they involve:
    - Relational data (“one record per line”).
    - Conventional attributes (“age”, “salary”, “marital status”, …).
  - However ARFF is **not suitable** for **text classification**… this is because:
    - We normally have to deal with multiple labels.
    - We need to deal with a “less conventional” attribute:
      - The **words** that appear documents!

ARFF *versus* XML (5/7)

- **Remembering our classification task**:
  - Prediction of movie genres in function of their summaries.



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Contact the Filmmakers on IMDbPro »

ARFF *versus* XML (6/7)

- Example of ARFF file for movie genres classification.

```
@relation movies

@attribute a {0,1}
@attribute abandon {0,1}
@attribute about {0,1}
…
@attribute zero {0,1}
@attribute zoology {0,1}
@attribute genre_action{0,1}
@attribute genre_comedy{0,1}
@attribute genre_drama {0,1}
…
@attribute genre_romance {0,1}

@data
0,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,1,…
1,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,1,…
0,0,1,0,0,0,0,0,0,0,1,0,0,0,1,0,0,0,0,1,0,0,0,…
…
```

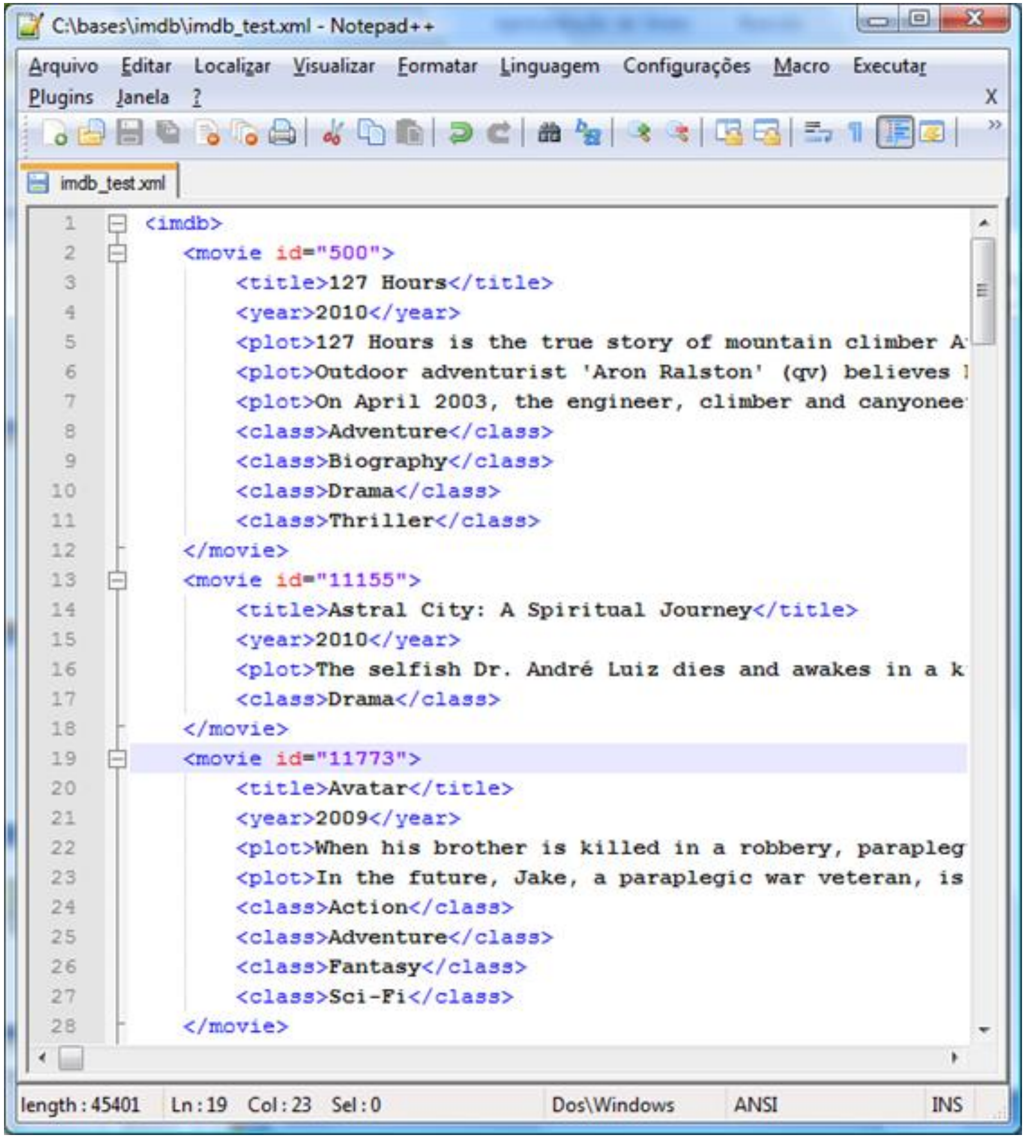
- **Problems**:
  - Each word must be declared as a binary attribute in the header (bag of words)

    IMDb: ≈190,000 words
    ≈ 154,000 movies

  - Cumbersome to query, explore and transform.
  - Highly sparse.
  - Does not support the specification of multi-valued attributes:
    - Movies with multiple genres or plots.

ARFF *versus* XML (7/7)

- **So… Why not to use XML?**


C:\bases\imdb\imdb_test.xml - Notepad++
Arquivo Editar Localizar Visualizar Formatar Linguagem Configurações Macro Executar
Plugins Janela ?
imdb_test.xml
length : 45401 Ln : 19 Col : 23 Sel : 0 Dos\Windows ANSI INS

```
<imdb>
    <movie id="500">
        <title>127 Hours</title>
        <year>2010</year>
        <plot>127 Hours is the true story of mountain climber A
        <plot>Outdoor adventurist 'Aron Ralston' (qv) believes I
        <plot>On April 2003, the engineer, climber and canyonee
        <class>Adventure</class>
        <class>Biography</class>
        <class>Drama</class>
        <class>Thriller</class>
    </movie>
    <movie id="11155">
        <title>Astral City: A Spiritual Journey</title>
        <year>2010</year>
        <plot>The selfish Dr. André Luiz dies and awakes in a k
        <class>Drama</class>
    </movie>
    <movie id="11773">
        <title>Avatar</title>
        <year>2009</year>
        <plot>When his brother is killed in a robbery, parapleg
        <plot>In the future, Jake, a paraplegic war veteran, is
        <class>Action</class>
        <class>Adventure</class>
        <class>Fantasy</class>
        <class>Sci-Fi</class>
    </movie>
```

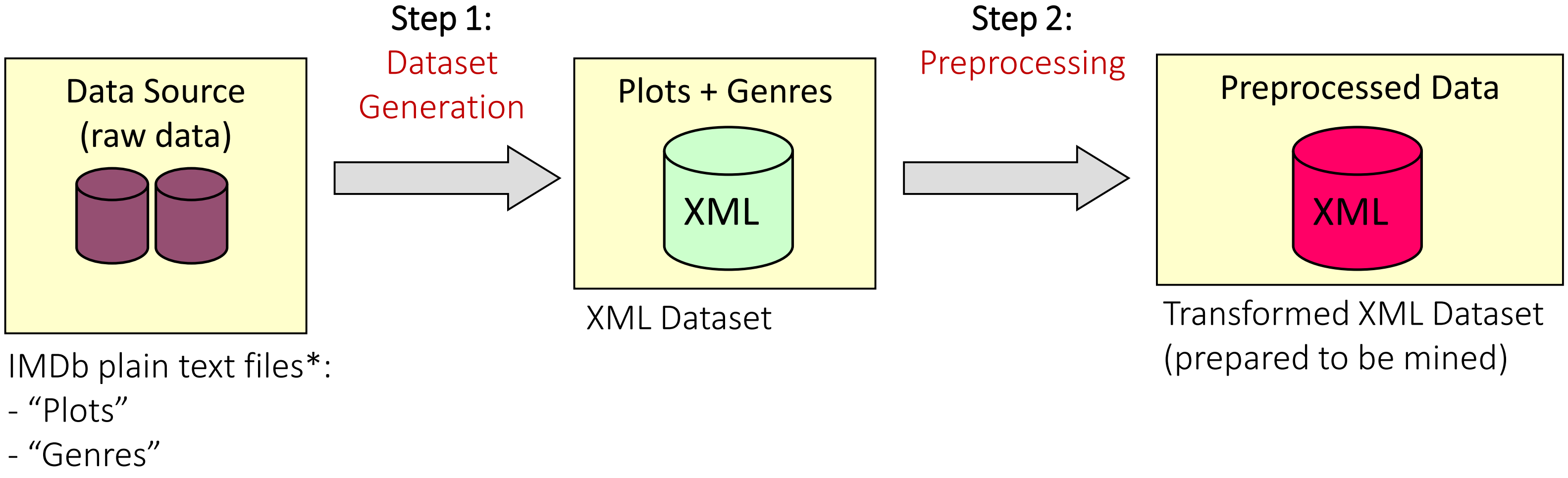
- Text represented in a natural way.

- Easy to query, explore and transform:
  - SAX
  - XQuery
  - XSLT

- Definition of multi-valued attributes is straightforward (movies with multiple plots and genres).

Experiment (1/10)

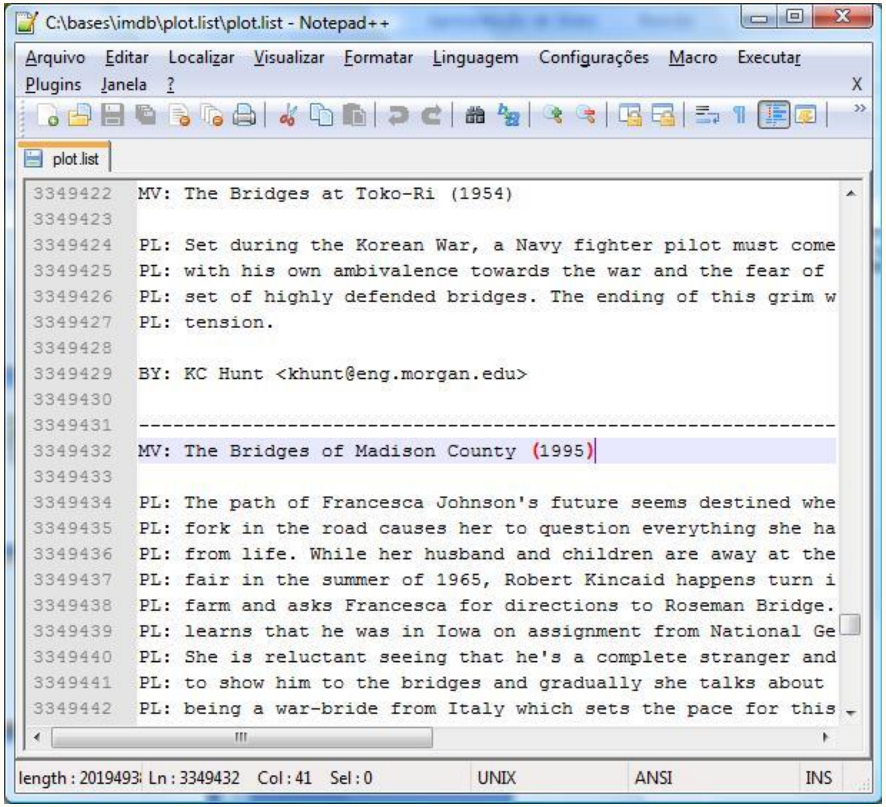
- **Goal:**
  - Transform the original IMDb data* (plain text files) into a XML database.
  - Study and preprocess this database.
    - As a result, we will obtain a dataset, ready to be mined.
      - high quality data → high quality classification.



*The IMDb plain text files can be download: www.imdb.com/interfaces

Experiment (2/10)

- **Step 1 – Generation of the "raw" XML dataset**


C:\bases\imdb\plot.list\plot.list - Notepad++
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Plugins Janela ?
plot.list
length : 2019493 Ln : 3349432 Col : 41 Sel : 0 UNIX ANSI INS

```
MV: The Bridges at Toko-Ri (1954)

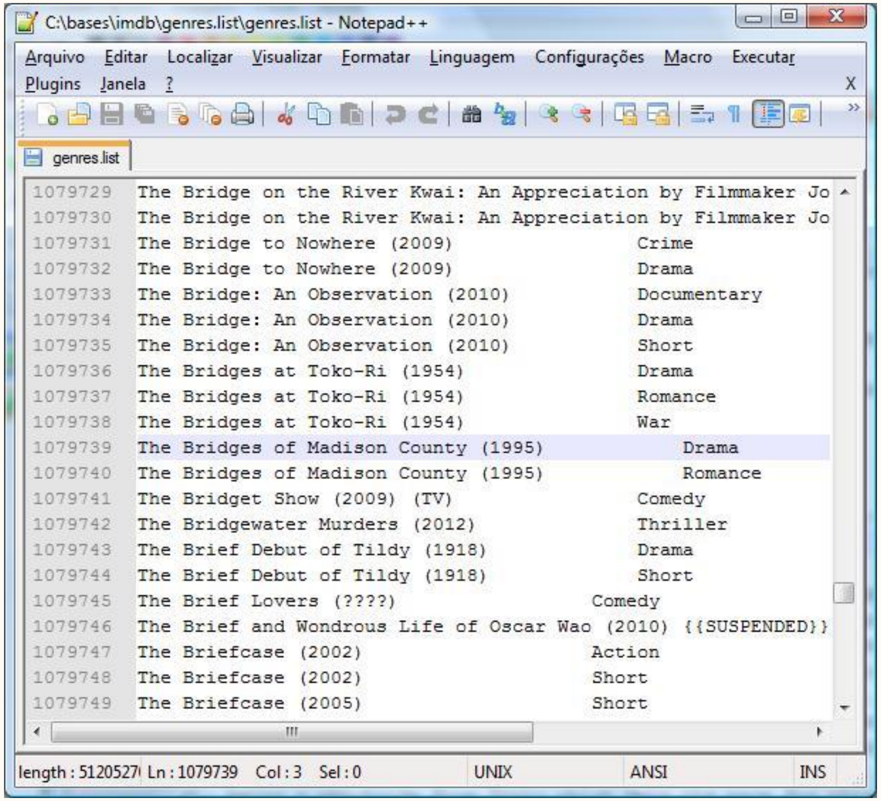
PL: Set during the Korean War, a Navy fighter pilot must come
PL: with his own ambivalence towards the war and the fear of
PL: set of highly defended bridges. The ending of this grim w
PL: tension.

BY: KC Hunt <khunt@eng.morgan.edu>

-------------------------------------------------------------
MV: The Bridges of Madison County (1995)

PL: The path of Francesca Johnson's future seems destined whe
PL: fork in the road causes her to question everything she ha
PL: from life. While her husband and children are away at the
PL: fair in the summer of 1965, Robert Kincaid happens turn i
PL: farm and asks Francesca for directions to Roseman Bridge.
PL: learns that he was in Iowa on assignment from National Ge
PL: She is reluctant seeing that he's a complete stranger and
PL: to show him to the bridges and gradually she talks about
PL: being a war-bride from Italy which sets the pace for this
```

plot.list: **256,486** movies
3.88M lines


C:\bases\imdb\genres.list\genres.list - Notepad++
Arquivo Editar Localizar Visualizar Formatar Linguagem Configurações Macro Executar
Plugins Janela ?
genres.list
length : 5120527 Ln : 1079739 Col : 3 Sel : 0 UNIX ANSI INS

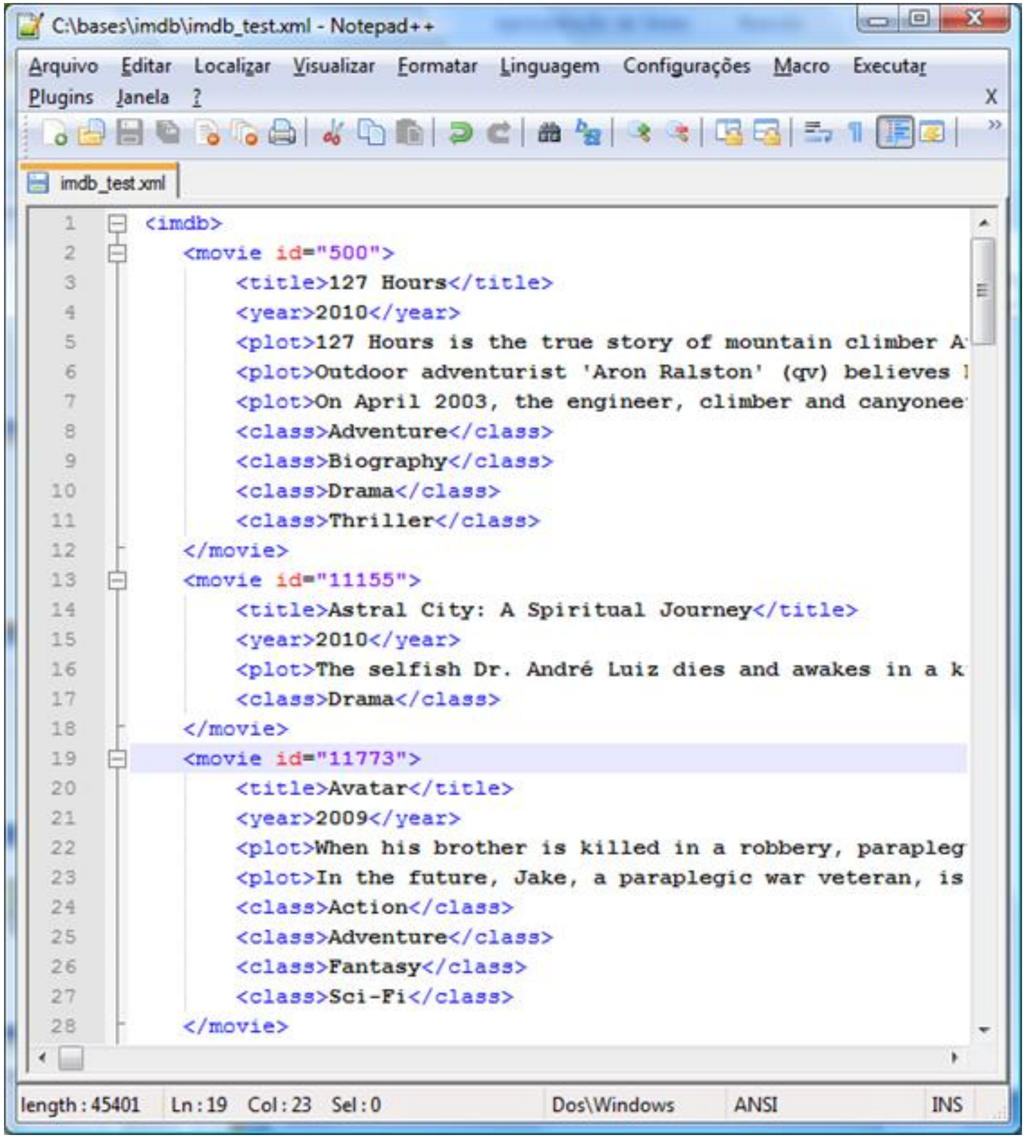
```
The Bridge on the River Kwai: An Appreciation by Filmmaker Jo
The Bridge on the River Kwai: An Appreciation by Filmmaker Jo
The Bridge to Nowhere (2009)                      Crime
The Bridge to Nowhere (2009)                      Drama
The Bridge: An Observation (2010)                 Documentary
The Bridge: An Observation (2010)                 Drama
The Bridge: An Observation (2010)                 Short
The Bridges at Toko-Ri (1954)                     Drama
The Bridges at Toko-Ri (1954)                     Romance
The Bridges at Toko-Ri (1954)                     War
The Bridges of Madison County (1995)                    Drama
The Bridges of Madison County (1995)                    Romance
The Bridget Show (2009) (TV)                      Comedy
The Bridgewater Murders (2012)                    Thriller
The Brief Debut of Tildy (1918)                   Drama
The Brief Debut of Tildy (1918)                   Short
The Brief Lovers (????)                     Comedy
The Brief and Wondrous Life of Oscar Wao (2010) {{SUSPENDED}}
The Briefcase (2002)                        Action
The Briefcase (2002)                        Short
The Briefcase (2005)                        Short
```

genres.list: **778,676** movies
1.33M lines

- Merging of the two plain IMDb files into a single XML dataset.
- **Result**: XML file containing 153,499 movies.

Experiment (3/10)

- **Step 1 – Generation of the “raw” XML dataset**


C:\bases\imdb\imdb_test.xml - Notepad++
Arquivo Editar Localizar Visualizar Formatar Linguagem Configurações Macro Executar
Plugins Janela ?
imdb_test.xml
length : 45401 Ln : 19 Col : 23 Sel : 0 Dos\Windows ANSI INS

```
<imdb>
    <movie id="500">
        <title>127 Hours</title>
        <year>2010</year>
        <plot>127 Hours is the true story of mountain climber A
        <plot>Outdoor adventurist 'Aron Ralston' (qv) believes I
        <plot>On April 2003, the engineer, climber and canyonee
        <class>Adventure</class>
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        <title>Astral City: A Spiritual Journey</title>
        <year>2010</year>
        <plot>The selfish Dr. André Luiz dies and awakes in a k
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    </movie>
    <movie id="11773">
        <title>Avatar</title>
        <year>2009</year>
        <plot>When his brother is killed in a robbery, parapleg
        <plot>In the future, Jake, a paraplegic war veteran, is
        <class>Action</class>
        <class>Adventure</class>
        <class>Fantasy</class>
        <class>Sci-Fi</class>
    </movie>
```

- Nice file!!!
  - But **not yet ready** to be mined!
  - The reasons are presented in the next slides
    - *Let’s go to the Step 2 of the experiment*.

Experiment (4/10)

- **Step 2 – Preprocessing**
  - Two sub-steps:

    1. STUDY:

    - The XQuery Language and the SAX API were used to querying and exploring the XML dataset.

    2. TRANSFORMATION:

    - According to the results of the study, we clean and transform the XML dataset.

Experiment (5/10)

- **Step 2.1 – Preprocessing / Study**
  - XQuery was used to generate frequency tables

```
<freq_genres>
{
for $u in distinct-values(doc("imdb.xml")//movie/class)
let $b := doc("imdb.xml")//movie[class=$u]
return
<row>
<genre>{$u}</genre>
<count>{count($b)}</count>
</row>
}
</freq_genres>
```

```
<freq_genres>
 <row>
  <genre>Drama</genre>
  <count>59177</count>
 </row>
 <row>
  <genre>Action</genre>
  <count>14416</count>
 </row>
 <row>
  <genre>Comedy</genre>
  <count>38373</count>
 </row>
 <row>
  <genre>Crime</genre>
  <count>10875</count>
 </row>
 <row>
  <genre>Adult</genre>
  <count>1625</count>
 </row>
 <row>
  <genre>Adventure</genre>
  <count>9596</count>
 </row>
 ...
</freq_genres>
```

Experiment (6/10)

- **Step 2.1 – Preprocessing / Study**
  - SAX was used to perform a study on the words.
  - Some results:

Description	Result
Total number of words	16.305.677
Number of distinct words	187.718
About half of the words occur only once	“*agnosticism*”, “*polyvision*”
Several misspelled words and typos	“*marjuana*”, “*caracters*”, “*theforce*”, ...
Several proper names	“*Robert*” (freq=3,053), “*Rosemary*” (229), “*Carlos*” (1,363), “*Marquinhos*” (5), “*Aleksandrov*” (2)
Synonyms, multiple languages	“*Brazil*” (741), “*Brasil*” (49), ...

Experiment (7/10)

- **Step 2.2** **– Preprocessing /** **Transformations**
  - From the results of our study we could do:
    - **Data reduction**:
      - Words that appeared only once were removed.
      - Removal of stop words (*details soon*)
      - Stemming (*details soon*)
    - It would also be possible to perform **data cleaning**
      - E.g: correction of typos.

Experiment (8/10)

- **Step 2.2 – Preprocessing –Transformations**
  - **Stop Words**.
    - Words that tend to be very frequent, but do not help on discriminating the movie genres.
      - articles, prepositions, adverbs, …
      - **E.g.**: "the" occurs in 100% of the movies...
      - On the IMDb domain, there are also specific words that can be regarded as useless: "movie", "film", the *proper names*.

```
<?xml version="1.0" encoding="UTF-8"?>
<stopwords>
   <stopword>the</stopword>
   <stopword>and</stopword>
   <stopword>to</stopword>
   <stopword>mr</stopword>
   <stopword>that</stopword>
   <stopword>from</stopword>
   <stopword>movie</stopword>
        ...
</stopwords>
```

Experiment (9/10)

- **Step 2.2 – Preprocessing –Transformations**
- **Stemming**
  - The process of conflating the variant forms of a word into a compact representation: the **stem**.
  - **Intuition**: morphological variants of words typically have similar interpretations and can be considered as equivalent for the purpose of data mining analysis.
  - **Example**:
    - The words "educate", "educational", "education" and "educating" could all be reduced to the stem "educ".
  - In this work we used the **Porter Algorithm*** (*JAVA implementation*).

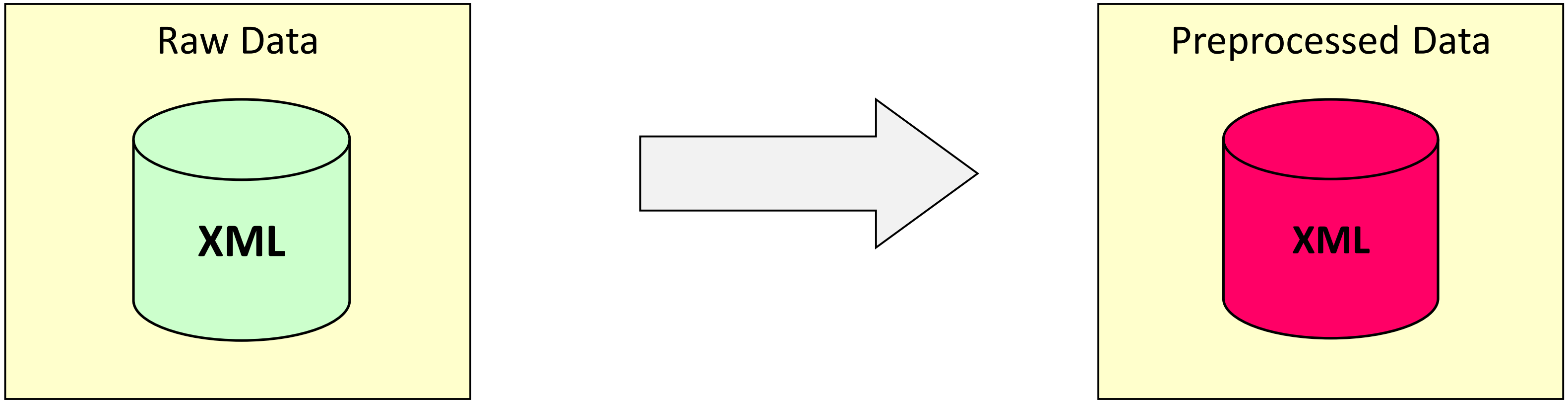
*The specification of the Porter Algorithm can be found at: http://tartarus.org/martin/PorterStemmer/

Experiment (10/10)

- **Summary**

Original XML Dataset

Transformed XML Dataset
(prepared to be mined)



Raw Data

XML

Preprocessed Data

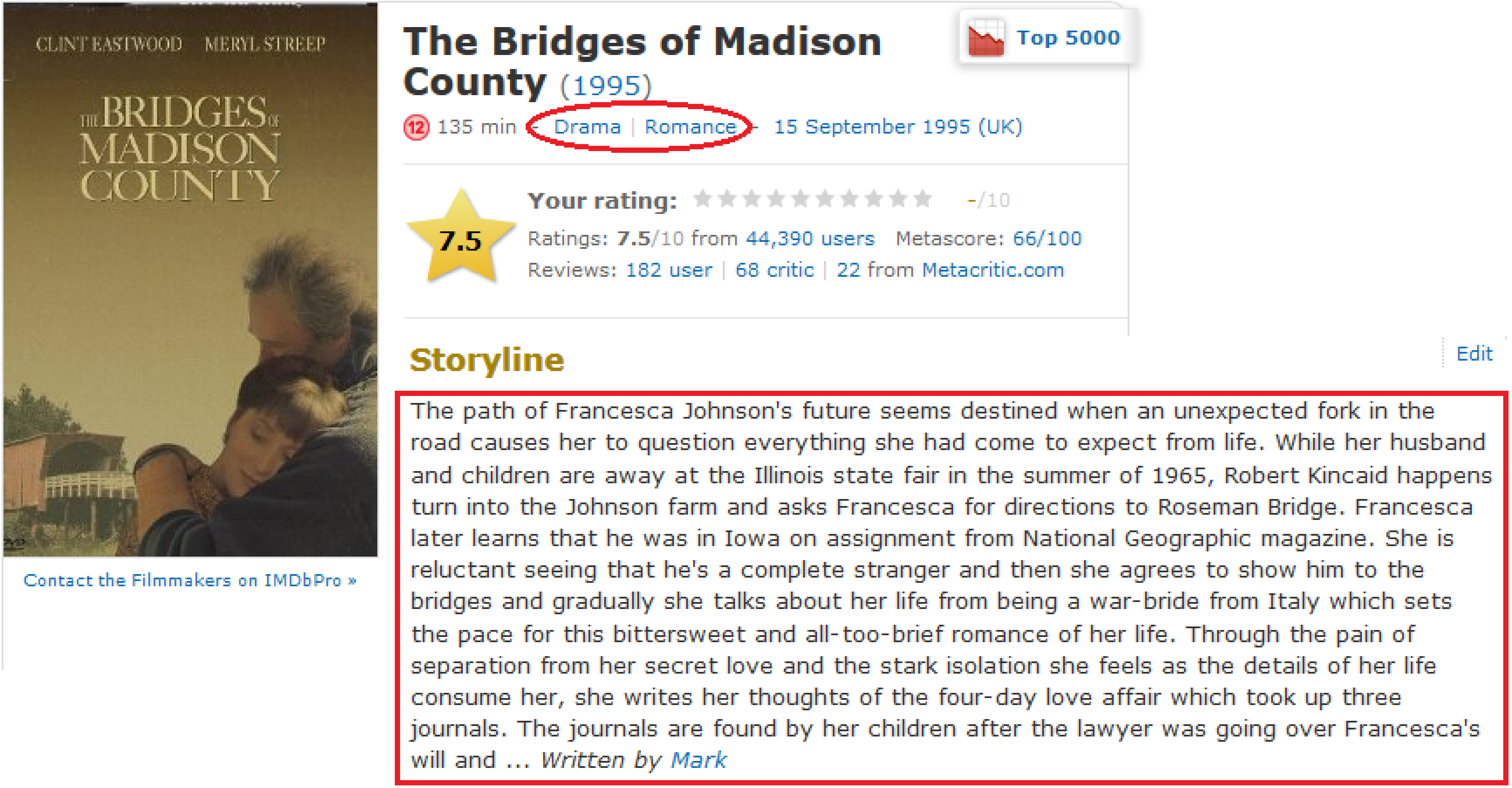
XML

187,817 words

79,753 stems

Conclusions

- XML facilitates the major steps involved in data preprocessing of text data.
- With the use of the SAX and XQuery, we could easily:
  - Querying, exploring and transforming the IMDb dataset.



Contact the Filmmakers on IMDbPro »

The Bridges of Madison County (1995)

12 135 min - Drama | Romance - 15 September 1995 (UK)

7.5 **Your rating:** ★★★★★★★★★★ -/10

Ratings: **7.5**/10 from 44,390 users Metascore: 66/100

Reviews: 182 user | 68 critic | 22 from Metacritic.com

Storyline

The path of Francesca Johnson's future seems destined when an unexpected fork in the road causes her to question everything she had come to expect from life. While her husband and children are away at the Illinois state fair in the summer of 1965, Robert Kincaid happens turn into the Johnson farm and asks Francesca for directions to Roseman Bridge. Francesca later learns that he was in Iowa on assignment from National Geographic magazine. She is reluctant seeing that he's a complete stranger and then she agrees to show him to the bridges and gradually she talks about her life from being a war-bride from Italy which sets the pace for this bittersweet and all-too-brief romance of her life. Through the pain of separation from her secret love and the stark isolation she feels as the details of her life consume her, she writes her thoughts of the four-day love affair which took up three journals. The journals are found by her children after the lawyer was going over Francesca's will and ... *Written by Mark*

Future Work (1/2)

- Define the final format of the preprocessed XML dataset.
- Develop an algorithm to direct mining this dataset.

```
<?xml version="1.0" encoding="UTF-8"?>
<imdb>
<movie id=1>
   <term>
      <stem>comput</stem>
      <weigth>0.8730</weigth>
   </term>
   <term>
      <stem>hyper</stem>
      <weigth>0.3020</weigth>
   </term>
        ...
   <class>drama</class>
   <class>suspense</class>
</movie>
        ...

</imdb>
```

Future Work (2/2)

- Evaluating the feasibility of developing an **XSLT version** of the Porter Stemming Algorithm.
  - This algorithm relies on the idea that the suffixes in English language are mostly made up of a combination of **smaller** and **simpler suffixes**.
  - It works in 5 steps:
    - Within each step the word is tested against a few set of **suffix transformation rules**.
      - If a test results in TRUE, the word suffix is removed or transformed; The control moves to the next step.
      - Otherwise, the next rule in the step is tested.

RELATION -> RELATE -> RELAT