CS54701: Information Retrieval

Text Categorization
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Text Categorization (I)

- Outline
- Introduction to the task of text categorization
  - Manual vs. automatic text categorization
- Text categorization applications
- Evaluation of text categorization
- K nearest neighbor text categorization method

Text Categorization

- Tasks
  - Assign predefined categories to text documents /objects
- Motivation
  - Provide an organizational view of the data
- Large cost of manual text categorization
  - Millions of dollars spent for manual categorization in companies, governments, public libraries, hospitals
  - Manual categorization is almost impossible for some large scale application (Classification or Web pages)

Text Categorization

- Automatic text categorization
  - Learn algorithm to automatically assign predefined categories to text documents /objects
  - automatic or semi-automatic
- Procedures
  - Training: Given a set of categories and labeled document examples; learn a method to map a document to correct category (categories)
  - Testing: Predict the category (categories) of a new document
- Automatic or semi-automatic categorization can significantly reduce manual effort

Text Categorization: Examples

News Categories

Google News

Web Images Groups **News** Froogle Maps **more »** Advanced News Search

[Search News] [Search the Web]
Search and browse 4,500 news sources updated continuously.

Top Stories	**Sci/Tech**
World	
U.S.	
Business	
Sci/Tech	
Sports	
Entertainment	
Health	
Most Popular	

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Global warming has been a popular topic among scientists
DailyTech - **3 hours ago**
The Earth's average temperature over the past quarter century has been the hottest in four centuries -- and part of the world has been warmer during the past 25 years than any period in the past 1,000 years, according to the National Academy of Sciences **...**
National panel supports 98 global warming evidence Boston Globe
No More Dodging Global Temp Threat Detroit Free Press
Guardian Unlimited - Seattle Times - Reuters - Forbes - **all 441 related »**

Earthtimes.org

World's oldest bling: two tiny 100,000-year-old shells
Guardian Unlimited - **5 hours ago**
They may not compare with today's diamond-encrusted bling, but in their own way, they are of far greater value. Two tiny shells have been confirmed as the world's oldest known items of jewellery, probably used on a necklace about 100,000 years ago.
Tiny shells may be world's oldest beads MSNBC
Researchers Identify What May Be Oldest Known Jewelry Voice of America
BBC News - New York Times - People's Daily Online - Telegraph.co.uk - **all 79 related »**

Voice of America

Text Categorization: Examples

Categories

YAHOO! SEARCH Directory

Search: ⦿ the Web | ○ the Directory | ○ this category

[_____] [Search]

Computer Science > Human-Computer Interaction (HCI)   Email this page

Directory > Science > Computer Science > **Human-Computer Interaction (HCI)**

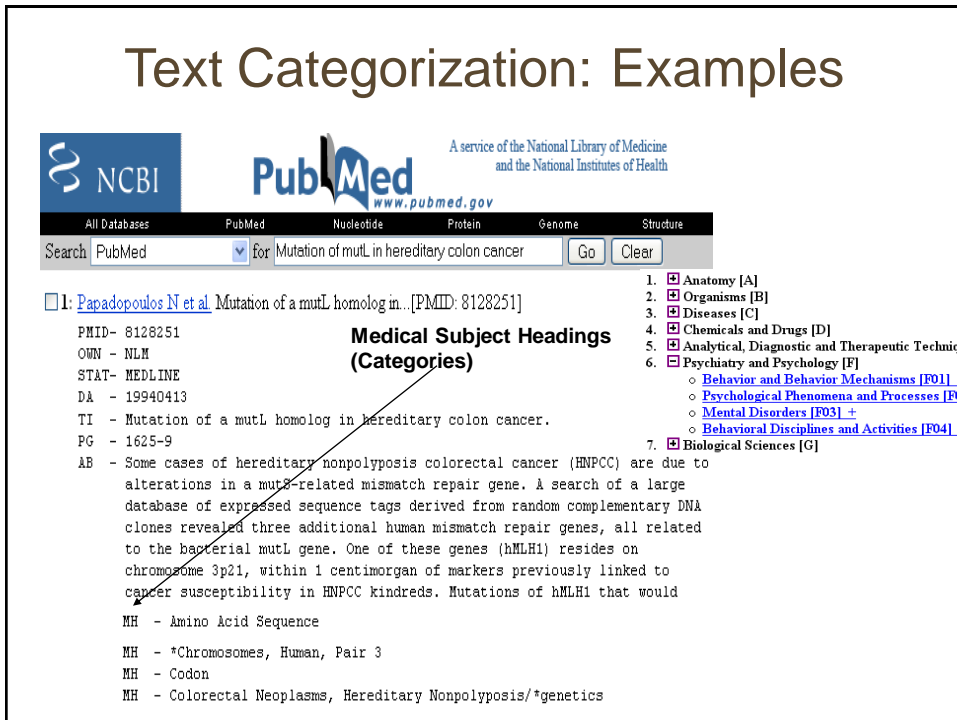**CATEGORIES** (What's This?)

- **Computer Supported Cooperative Work (CSCW)** (7)
- **Conferences** (7)
- **Courses** (2)
- **Ergonomics@**
- **Information Architecture and Design@**

- **Institutes** (19)
- **Journals** (1)
- **Organizations** (3)
- **Projects** (6)
- **Web Directories** (3)

SITE LISTINGS By Popularity | Alphabetical (What's This?)   Sites **1 - 14** of **14**

- HCI Bibliography
  Features abstracted validated bibliographic entries, along with a variety of reference materials.
  www.hcibib.org

Text Categorization: Examples

Example: U.S. Census in 1990

- Included 22 million responses
- Needed to be classified into industry categories (200+) and occupation categories (500+)
- Estimate $15 million if done by hand
- Two alternative automatic text categorization methods evaluated
  - Knowledge-Engineering (Expert System)
  - Machine Learning (K nearest neighbor method)

Example: U.S. Census in 1990

- Knowledge-Engineering Approach
  - Expert System (Designed by domain expert)
  - Hand-Coded rule
    (e.g., "Professor" and "Lecturer" ➔ "Education")
  - Development cost: 2 experts, 8 years (192 Person-months)
  - Accuracy = 47%
- Machine Learning Approach
  - K Nearest Neighbor (KNN) classification: details later; find your language by what language your neighbors speak
  - Fully automatic
  - Development cost: 4 Person-months
  - Accuracy = 60%

Many Applications!

- Web page classification (Yahoo-like category taxonomies)
- News article classification (more formal than most Web pages)
- Automatic email sorting (spam detection; into different folders)
- Word sense disambiguation (Java programming vs. Java in Indonesia)
- Gene function classification (find the functions of a gene from the articles talking about the gene)
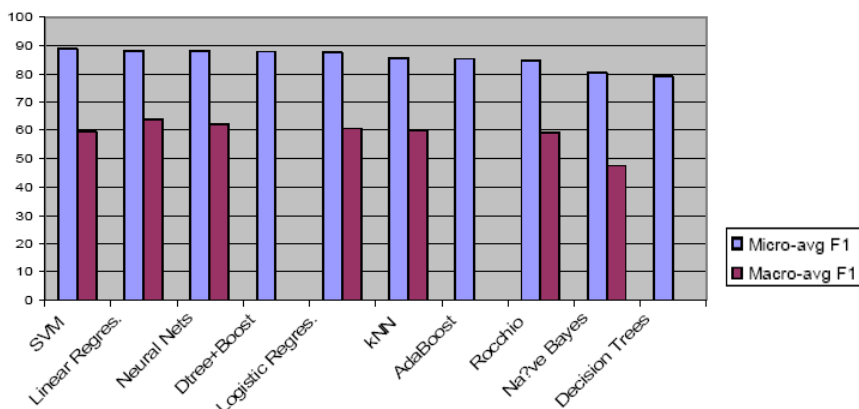- What is your favorite application?...

Techniques Explored in Text Categorization

- Rule-based Expert system (Hayes, 1990)
- Nearest Neighbor methods (Creecy'92; Yang'94)
- Decision symbolic rule induction (Apte'94)
- Naïve Bayes (Language Model) (Lewis'94; McCallum'98)
- Regression method (Furh'92; Yang'92)
- Support Vector Machines (Joachims'98)
- Boosting or Bagging (Schapier'98)
- Neural networks (Wiener'95)
- ......

Text Categorization: Evaluation

Performance of different algorithms on Reuters-21578 corpus: 90 categories, 7769 Training docs, 3019 test docs, (Yang, JIR 1999)

Text Categorization: Evaluation
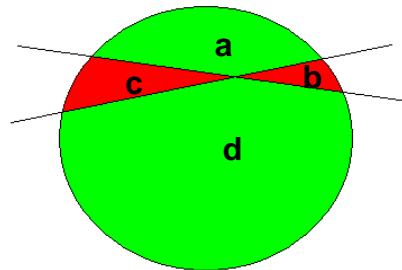
Contingency Table Per Category (for all docs)

	Truth: True	Truth: False	
Predicted Positive	a	b	a+b
Predicted Negative	c	d	c+d
	a+c	b+d	n=a+b+c+d

a: number of truly positive docs   b: number of false-positive docs

c: number of false negative docs d: number of truly-negative docs

n: total number of test documents

Text Categorization: Evaluation

Contingency Table Per Category (for all docs)
n: total number of docs

Sensitivity: a/(a+c)   truly-positive rate, the larger the better

Specificity: d/(b+d)   truly-negative rate, the larger the better

Depends on decision threshold, trade off between the values

Text Categorization: Evaluation

Recall: r=a/(a+c)   percentage of positive docs detected

Precision: p=a/(a+b)   how accurate are the predicted positive docs

Accuracy: (a+d)/n   how accurate are all the predicted docs

F-measure: $F_\beta = \dfrac{(\beta^2 + 1)pr}{\beta^2 p + r}$ $F_1 = \dfrac{2pr}{p + r}$

Harmonic average: $\dfrac{1}{\frac{1}{2}\left(\frac{1}{x_1} + \frac{1}{x_2}\right)}$

Error: (b+c)/n   error rate of predicted docs

Accuracy+Error=1

Text Categorization: Evaluation

- Micro F1-Measure
  - Calculate a single contingency table for all categories and calculate F1 measure
  - Treat each prediction with equal weight; better for algorithms that work well on large categories
- Macro F1-Measure
  - Calculate a single contingency table for every category calculate F1 measure separately and average the values
  - Treat each category with equal weight; better for algorithms that work well on many small categories

K-Nearest Neighbor Classifier

- Also called "Instance-based learning" or "lazy learning"
  - low/no cost in "training", high cost in online prediction
- Commonly used in pattern recognition (5 decades)
- Theoretical error bound analyzed by Duda & Hart (1957)
- Applied to text categorization in 1990's
- Among top-performing text categorization methods
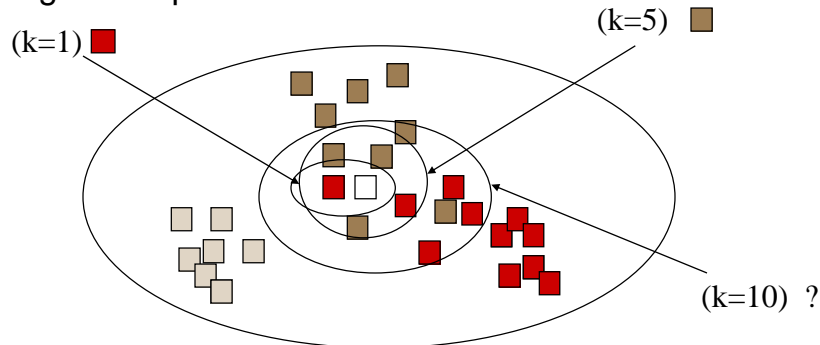
K-Nearest Neighbor Classifier

From all training examples:
- Find k examples that are most similar to the new document
  - "neighbor" documents
- Assign the category that is most common in these neighbor documents
  - neighbors vote for the category
- Can also consider the distance of a neighbor
  - a closer neighbor has more weight/influence

K-Nearest Neighbor Classifier

- Idea: find your language by what language your neighbors speak

(k=1) ■   (k=5) ■

(k=10) ?

- Use K nearest neighbors to vote

1-NN:Red; 5-NN:Brown; 10-NN:?; Weighted 10-NN:Brown

K Nearest Neighbor:
Technical Elements

- Document representation
- Document distance measure: closer documents should have similar labels; neighbors speak the same language
- Number of nearest neighbors (value of K)
- Decision threshold

K Nearest Neighbor: Framework

Training data $D = \{(x_i, y_i)\}, \quad x_i \in R^M, docs, \quad y_i \in \{0,1\}$

Test data $\quad x \in R^M \quad$ The neighborhood is $\quad D_k \in D$

Scoring Function $\quad \hat{y}(x) = \dfrac{1}{k} \sum\limits_{x_i \in D_k(x)} sim(x, x_i) y_i$

Classification: $\quad \begin{cases} 1 \text{ if } \hat{y}(x) - t > 0 \\ 0 \text{ otherwise} \end{cases}$

Document Representation: X_i uses tf.idf weighting for each dimension

Choices of Similarity Functions

Euclidean distance $\quad d(\vec{x}_1, \vec{x}_2) = \sqrt{\sum\limits_v (x_{1v} - x_{2v})^2}$

Kullback Leibler distance $\quad d(\vec{x}_1, \vec{x}_2) = \sum\limits_v x_{1v} \log \dfrac{x_{1v}}{x_{2v}}$

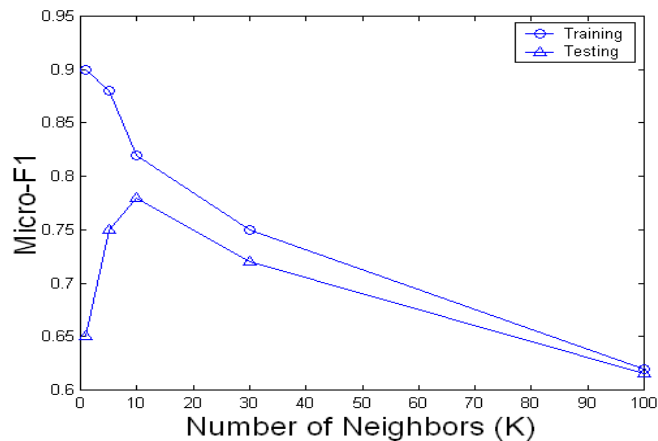Dot product $\quad \vec{x}_1 * \vec{x}_2 = \sum\limits_v x_{1v} * x_{2v}$

Cosine Similarity $\quad \cos(\vec{x}_1, \vec{x}_2) = \dfrac{\sum\limits_v x_{1v} * x_{2v}}{\sqrt{\sum\limits_v x_{1v}^2} \sqrt{\sum\limits_v x_{2v}^2}}$

Kernel functions $\quad k(\vec{x}_1, \vec{x}_2) = e^{-d(\vec{x}_1, \vec{x}_2)/2\sigma^2}$ (Gaussian Kernel)

Automatic learning of the metrics

Choices of Number of Neighbors (K)

Trade off between small number of neighbors and large number of neighbors

Choices of Number of Neighbors (K)

- Find desired number of neighbors by cross validation
  - Choose a subset of available data as training data, the rest as validation data
  - Find the desired number of neighbors on the validation data
  - The procedure can be repeated for different splits; find the consistent good number for the splits

Characteristics of KNN

Pros
- Simple and intuitive, based on local-continuity assumption
- Widely used and provide strong baseline in TC Evaluation
- No training needed, low training cost
- Easy to implement; can use standard IR techniques (e.g., tf.idf)

Cons
- Heuristic approach, no explicit objective function
- Difficult to determine the number of neighbors
- High online cost in testing; find nearest neighbors has high time complexity

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  - Local-continuity assumption: find your language by what language your neighbors speak