# Ontology-Based News Recommendation

Wouter IJntema    Frank Goossen
Flavius Frasincar*    Frederik Hogenboom

Erasmus University Rotterdam, the Netherlands

*frasincar@ese.eur.nl

# Outline

# Introduction
## Motivation

### Problem

- Stock prices are sensitive to news
- News overload (different sources, different topics)
- Difficult to find the news of interest
- ... need for an intelligent solution to support news-based decision processes

### Partial solution

- RSS feeds
- Broad categories (business, cars, entertainment, etc.)

### Solutions

- News querying systems (intrusive)
- News recommender systems (non-intrusive)

### Recommender systems:

- Content-based (Traditional)
- Collaborative filtering (Users-based)
- Semantics-based (Our focus here)
- Hybrid

# Introduction

## Related Work

- Content-based
  - Based on TF-IDF for representing articles and the user profile
  - Cosine similarity between new article and the user profile
  - Performance of cosine similarity decreases as the length of the article increases
  - Tools: YourNews, News Dude
- Semantics-based
  - Based on is-a relationships
  - Semantic relatedness as a similarity measure
    - Uses concepts instead of terms for the vector representation (improves precision)
    - Considers concepts related to the ones appearing in news items (improves recall)
    - Tools: PersoNews, (Getahun et al., 2009)

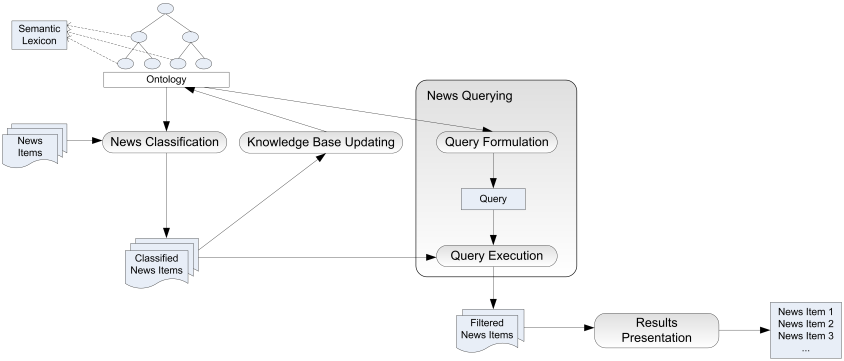
# Hermes: News Personalization Service
## Framework

- Input:
  - News items from RSS feeds
  - Domain ontology linked to a semantic lexicon (e.g., WordNet)
  - User query
- Output:
  - News items as answers to the user query

- Four phases:
  1. News Classification
     - Relate news items to ontology concepts
  2. Knowledge Base Updating
     - Update the knowledge base with news information
  3. News Querying
     - Allow the user to express his concepts of interest and the temporal constraints
  4. Results Presentation
     - Present the news items that match users query

# Hermes: News Personalization Service

## Architecture



# Athena: News Recommendation Service

## Framework

- Input:
  - News items from RSS feeds
  - Domain ontology linked to a semantic lexicon (e.g., WordNet)
  - User items of interest
- Output:
  - List of other news items of interest (possibly ranked)

- Five similarity measures (alternatives):
  - Concept Equivalence
  - Binary Cosine
  - Jaccard
  - Semantic Relatedness (adaptation of (Getahun et al., 2009))
  - Ranked Semantic Relatedness (our contribution)

# Athena: News Recommendation Service
## Preliminary Definitions

### Ontology

$$C = \{c_1, c_2, c_3, \cdots, c_n\} \ . \tag{1}$$

### User Profile

$$U = \left\{c_1^u, c_2^u, c_3^u, \cdots, c_p^u\right\}, \text{where } c_i^u \in C \ . \tag{2}$$

### News Article

$$A = \left\{c_1^a, c_2^a, c_3^a, \cdots, c_q^a\right\}, \text{where } c_j^a \in C \ . \tag{3}$$

### Concept Equivalence

$$\text{Similarity}(U, A) = \begin{cases} 1 & \text{if } |U \cap A| > 0 \\ 0 & \text{otherwise} \end{cases} . \quad (4)$$

- Concept Equivalence does not consider consider the number of user profile concepts found in a news article

### Binary Cosine

$$B(U, A) = \frac{|U \cap A|}{|U| \times |A|} . \quad (5)$$

# Athena: News Recommendation Service
## Similarity Measures

### Jaccard

$$J(U, A) = \frac{|U \cap A|}{|U \cup A|} . \qquad (6)$$

- Binary Cosine and Jaccard do not consider the number of occurrences of a concept in an article
- Binary Cosine and Jaccard do not consider the concepts related to the ones found in an article

### Semantic Relatedness

#### Semantic Neighbourhood

$$N(c_i) = \left\{c_1^i, c_2^i, \cdots, c_n^i\right\} \ . \tag{7}$$

#### Vector Representation for 2 News Articles

$$V_l = (w_1^l, w_2^l \cdots, w_p^l) \ , \tag{8}$$

where

- $l \in \{i, j\}$, the two news articles $t_i$ and $t_j$
- $w_i$ represents the weight of $c_i$ (number of occurrences of $c_i$)
- $p = |CS_i \cup CS_j|$ is the number of distinct concepts in $CS_i$ and $CS_j$

### Semantic Relatedness

#### Vector Representation for 2 News Articles

$$w_i = \begin{cases} 1 & \text{if } \mathrm{freq}(c_i \text{ in } CS_j) > 0 \\ \max_j(\mathrm{ES}(c_i, c_j)) & \text{otherwise} \end{cases} \tag{9}$$

where the enclosure similarity is defined as

$$\mathrm{ES}(c_i, c_j) = \frac{|N(c_i) \cap N(c_j)|}{|N(c_i)|} \ . \tag{10}$$

$$\mathrm{SemRel}(t_i, t_j) = \cos(V_i, V_j) = \frac{V_i \cdot V_j}{||V_i|| \cdot ||V_j||} \in [0, 1] \ , \tag{11}$$

### Ranked Semantic Relatedness

### Extended User Profile

- The set of related concepts to concept $c_i$ is

$$r(c_i) = \left\{c_1^i, c_2^i, \cdots, c_k^i\right\} \ . \tag{12}$$

- The set of related concepts to the concepts in the user profile is

$$R = \bigcup_{u_i \in U} r(u_i) \ . \tag{13}$$

- The extended user profile is

$$U_R = U \cup R \ . \tag{14}$$

## Ranked Semantic Relatedness

## Rank Matrix

| | $e_1$ | $e_2$ | $\ldots$ | $e_q$ |
|---|---|---|---|---|
| $u_1$ | $r_{11}$ | $r_{12}$ | $\ldots$ | $r_{11}$ |
| $u_2$ | $r_{21}$ | $r_{22}$ | $\ldots$ | $r_{2q}$ |
| $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ |
| $u_m$ | $r_{m1}$ | $r_{m2}$ | $\ldots$ | $r_{mq}$ |

where the ranks from the rank matrix are:

$$r_{i,j} = w_i \times \begin{cases} +1.0 & \text{if } e_j = u_i \\ +0.5 & \text{if } e_j \neq u_i, e_j \in r(u_i) \\ -0.1 & \text{otherwise} \end{cases} \quad . \tag{15}$$

## Ranked Semantic Relatedness

## Rank Matrix

- The weight $w_i$ is the number of articles the user has read about concept $u_i$.
- The elements of the rank vector $V_U$ for the extended profile concepts are:

$$\mathrm{Rank}(e_j) = \sum_{i=1}^{m} r_{ij} \; . \tag{16}$$

- The normalization of the rank vector $V_U$ is:

$$V_U[v_i] = \frac{v_i - \min(v_u)}{\max(v_u) - \min(v_u)} \; . \tag{17}$$

# Athena: News Recommendation Service

## Similarity Measures

### Ranked Semantic Relatedness

- A new article is a set of concepts

$$A = \{a_1, a_2, \cdots, a_t\} \ . \tag{18}$$

- The rank vector of the article is

$$V_A = (s_1, s_2, \cdots, s_t) \ , \tag{19}$$

where

$$s_i = \begin{cases} \mathrm{Rank}(e_i) & \text{if } e_i \in A \\ 0 & \text{if } e_i \notin A \end{cases} \ . \tag{20}$$

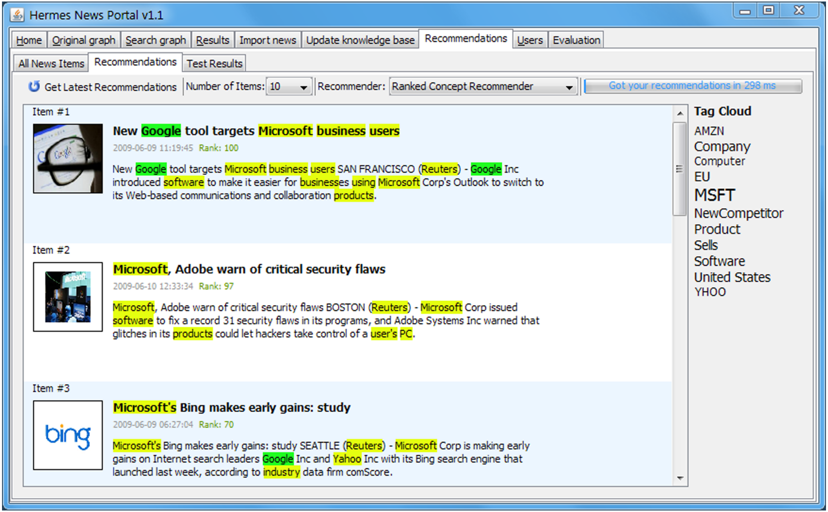
$$\mathrm{RankedSemanticSimilarity}(V_A, V_U) = \frac{\sum_{v_a \in V_A} v_a}{\sum_{v_u \in V_U} v_u} \ . \tag{21}$$

# Athena Implementation
## Athena as HNP Plugin

- Hermes News Portal (HNP) is the implementation of Hermes
- Athena is a plugin for HNP
- Athena has three tabs:
  - Browser for all news items
  - Recommendations
  - Evaluation
- Implements all five recommenders
- Double clicking means the news item is added to the profile

# Athena Implementation

## Athena Plugin



# Athena Implementation

## HNP/Athena Implementation Tools

- Programming Language: Java
- Ontology Language: OWL
- Query Language: tSPARQL
- Semantic Web Framework: Jena
- Semantic Lexicon: WordNet
- Natural Language Proceesing: GATE
- Visualization: Prefuse
- Stemmer: Krovetz

# Evaluation

## Evaluation Setup

- 300 news items
- 5 users
- Each user has different interests
- All news items are marked as interesting/non-interesting by the users
- News items randomly split into two different sets:
  - Training set (60% of news items)
  - Validation set (40% of news items)
  - Similarity cut-off value: 0.5

# Evaluation

## Evaluation Results

| Method | Accuracy | Precision |
|---|---|---|
| TF-IDF | 90% | 90% |
| Concept Equivalence | 44% | 22% |
| Binary Cosine | 47% | 23% |
| Jaccard | 93% | 92% |
| Semantic Relatedness | 57% | 26% |
| Ranked | 94% | 93% |

| Method | Recall | Specificity |
|---|---|---|
| TF-IDF | 45% | 99% |
| Concept Equivalence | 98% | 32% |
| Binary Cosine | 95% | 36% |
| Jaccard | 58% | 99% |
| Semantic Relatedness | 92% | 47% |
| Ranked | 62% | 99% |

# Evaluation

## Evaluation Results

- Ranked Semantic Recommender scores better than TF-IDF for accuracy, precision, and recall, and the same for specificity
- Ranked Semantic Recommender scores best for accuracy and precision (closely followed by Jaccard)
- Ranked Semantic Recommender has a lower recall than Concept Equivalence, Binary Cosine, and Semantic Relatedness
- Concept Equivalence scores the best for recall

# Conclusions and Future Work

## Conclusions

- Athena: News Recommendation Service
- Athena implementation: HNP plugin
- Semantic recommenders are superior to traditional recommenders
- Ranked Semantic Recommender performs best for accuracy and precision

# Conclusions and Future Work
## Future Work

- Perform statistical significance tests
- Improve the recall of the Ranked Semantic Recommender by considering also the concepts related to the ones found in a new article
- Consider the indirect concepts in the semantic neighbourhood of a concept
- Refine the concept importance in an article: consider also the place appearance (title or/and body) in addition to number of occurrences

# Ranked Semantic Recommender

## Example

- The user profile is:

$$U = \{\text{Yahoo!}, \text{Obama}, \text{China}\} \ .$$

- The weights $W$ (number of articles) for the corresponding user profile concepts are:

$$W = (4, 3, 2) \ .$$

- The sets of related concepts for each concept in the profile are as follows:

$$\begin{aligned} r(\text{Yahoo!}) &= \{\text{Google}, \text{Apple}\} \,, \\ r(\text{Obama}) &= \{\text{USA}\} \,, \\ r(\text{China}) &= \{\text{USA}\} \,. \end{aligned}$$

# Ranked Semantic Recommender

## Example

- The set of related concepts to the user profile concepts is:

$$\begin{aligned} R &= r(\text{Yahoo!}) \cup r(\text{Obama}) \cup r(\text{China}) \\ &= \{\text{Google}, \text{Apple}, \text{USA}\}\,. \end{aligned}$$

- The extended user profile is:

$$U_R = \{\text{Yahoo!}, \text{Obama}, \text{China}, \text{Google}, \text{Apple}, \text{USA}\}\ .$$

- The rank matrix is:

| | Yahoo! | Obama | China | Google | Apple | USA |
|---|---|---|---|---|---|---|
| Yahoo! | 4 | -0.4 | -0.4 | 2 | 2 | -0.4 |
| Obama | -0.3 | 3 | -0.3 | -0.3 | -0.3 | 1.5 |
| China | -0.2 | -0.2 | 2 | -0.2 | -0.2 | 1 |
| Rank | 3.5 | 2.4 | 1.3 | 1.5 | 1.5 | 2.1 |

# Ranked Semantic Recommender

## Example

- The normalized rank vector $V_U$ is:

$$V_U = (1, 0.5, 0, 0.091, 0.091, 0.364) \ .$$

- Two new news articles:

$$\begin{aligned} A_1 &= \{\text{Google}, \text{USA}, \text{Vitamins}\} \\ A_2 &= \{\text{Yahoo!}, \text{USA}\} \,. \end{aligned}$$

- The vector representations of these two articles:

$$\begin{aligned} V_{A_1} &= (0.091, 0.364, 0.0) \\ V_{A_2} &= (1, 0.364) \,. \end{aligned}$$

# Ranked Semantic Recommender

## Example

- The ranked semantic similarities of these two news items to the extended user profile:

$$\begin{aligned}
RankedSemSim_{A_1} &= \frac{0.091 + 0.364}{1 + 0.5 + 0 + 0.091 + 0.091 + 0.364} \\
&= 0.222 \\
RankedSemSim_{A_2} &= \frac{1 + 0.364}{1 + 0.5 + 0 + 0.091 + 0.091 + 0.364} \\
&= 0.667.
\end{aligned}$$

- For a cut-off value of 0.5 only $A_2$ is recommended
- NB: Both $A_1$ and $A_2$ share only 1 concept with the user profile

# Key Issues

- How to improve the recall for the Ranked Semantic Recommender?
- How to compute the importance of a concept in an article?