Use of Advanced Natural Language Processing Techniques for the Automatic Recommendation of Reinforcement Activities

INEDA Group: Teaching Innovation in Data Structure and Algorithms

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Motivation

- **Online distance learning** is gaining increasing attention, specially in higher education
- In e-Learning environments it may be **difficult for teachers to detect what are the specific needs of their students**, as the interaction is lower than in traditional settings
  - The discussion forum encourage dialogue and relations
- In contrast, e-learning systems **allow for a higher level of personalization** and adaptation

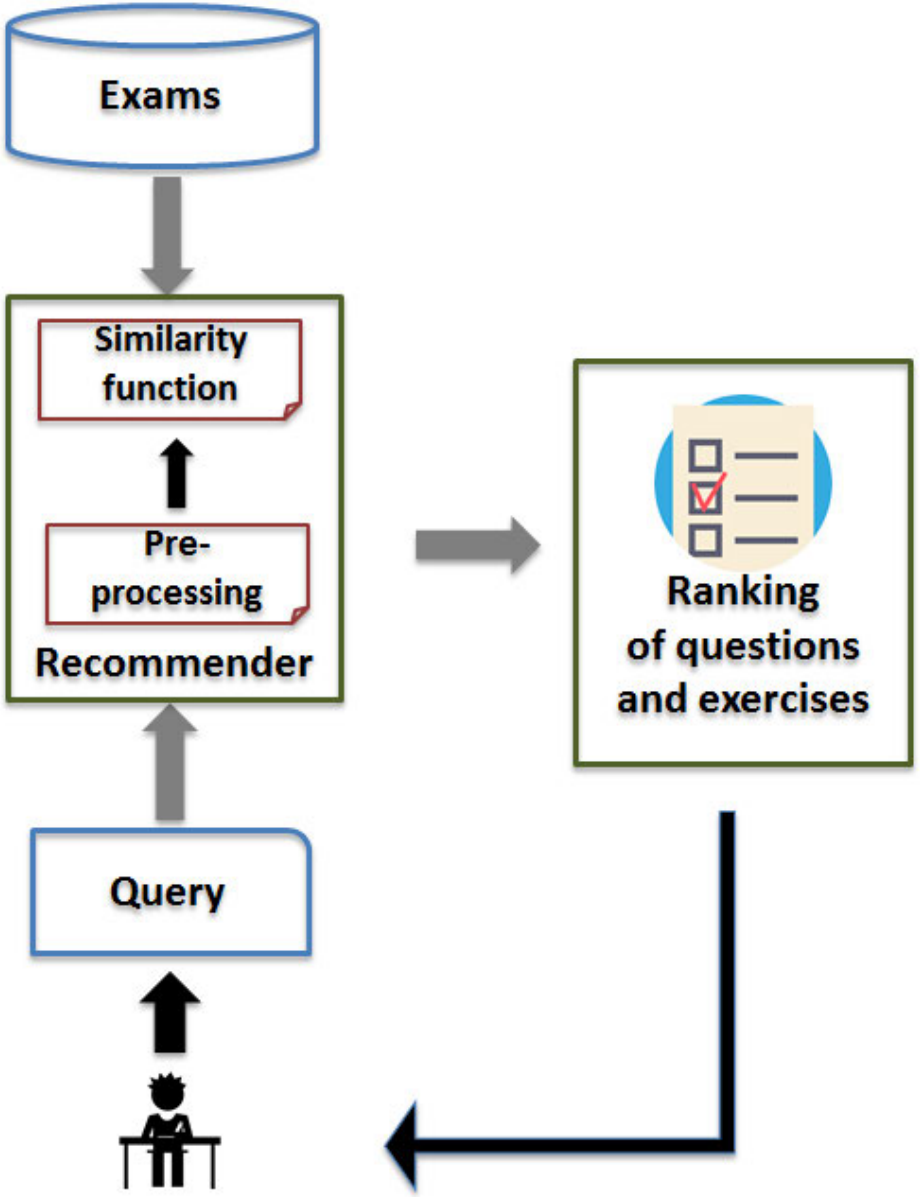
Motivation

- **Personalized learning** brings learners flexibility, adaptation, engagement and motivation
- **Recommendation systems** may be used to provide information to students according to their preferences, user profile and learning objectives
- We propose the use of a recommender that proposes **reinforcement activities to students based on their individual needs**, as expressed in their query posed in a discussion forum

Problem statement

Given a query posed by a student in the **discussion forum** of the course, concerning a given learning concept, the recommender must be able to **propose exercises from a repository of past tests** to practice and improve understanding of such concept and other similar concepts that help the student in her final goal of being successful in the final test.

Methodology



Study case

A course on *Data Structures and Algorithms* taught in the second year of the Computer Science degree at a Spanish distance university

Step 1: Text pre-processing and key phrases extraction

- The text in the student query is processed to extract the following information: **query title** and **query body**
- **Key phrases** extraction, using natural language processing techniques, is performed on both the student query and the questions in the repository of past tests

Step 2: Similarity calculation

- Different similarities between the query and all the questions in the repository is calculated, using Jaccard coefficient:
  - Between the title of the query and the text of the question
  - Between the body and title of the query and the text of the question
  - Between the key phrases extracted from the body of the query and the key phrases extracted from the text of the question

Step 3: Ranking and presentation

- Questions are ranked according to their similarity to the student query, so that more similar questions are ranked first
- The top-5 ranked questions are presented to the student

Dataset

- A random set of 20 queries posed by students in the discussion forum of the course, from 2011 to 2020. Example:

  Title: *Quadratic probing in hash tables (page_52).*

  Body: *Hi. I'm not sure I have understood the quadratic probing. For example, if all the coefficients c_k are equal to 1, that means that if there is a collision then it searches the next position in the table, if the collision persists 4 more positions ahead, if it persists 9 more positions, ... Am I rigth? Greetings.*

- A repository of 312 questions from past tests

Evaluation methodology

- As the evaluation metric, we have used precision at 5 (P@5), the number of relevant documents among the 5 first documents in the ranking
- Evaluation is performed manually by an expert in data structures and algorithms
  - A question from a test is relevant to the student query if it refers to the same concept or problem regarding the same data structure or scheme

Evaluation results (I)

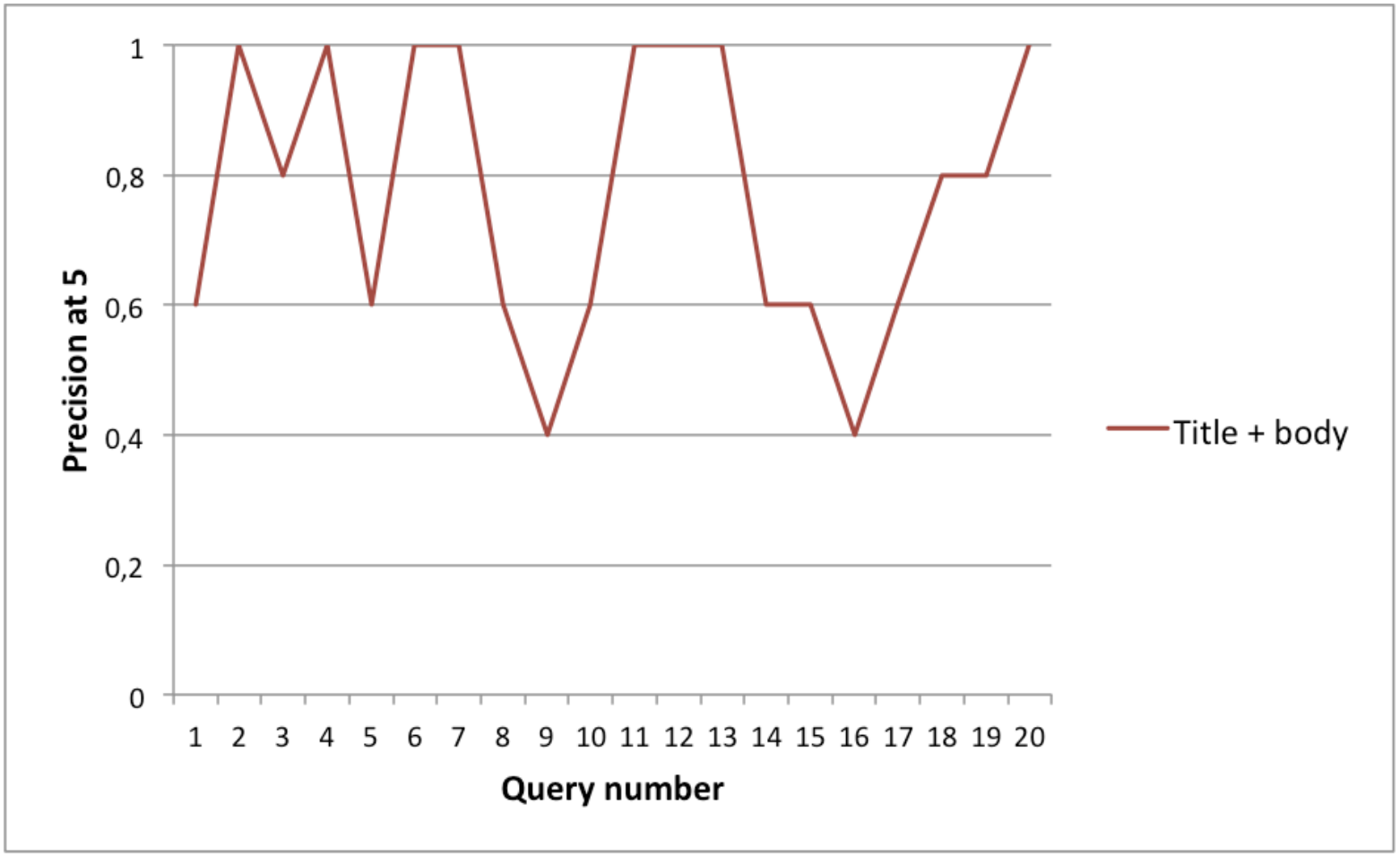


Figure 1 - *P@5 when the similarity between the title of the query and the text of the questions is computed*

Evaluation results (II)

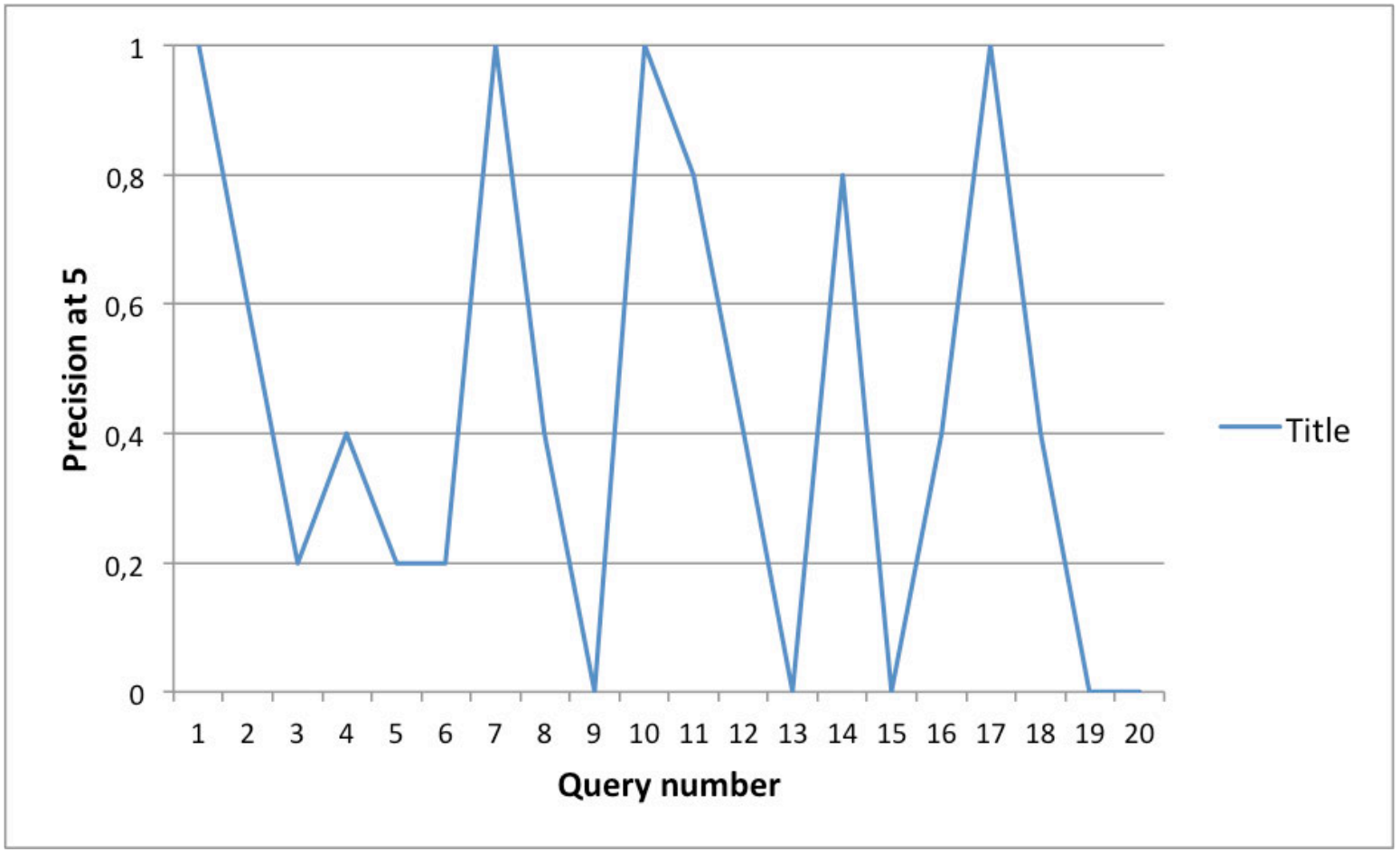


Figure 2 - *P@5 when the similarity between the title of the query and the text of the questions is computed*

Evaluation results (III)

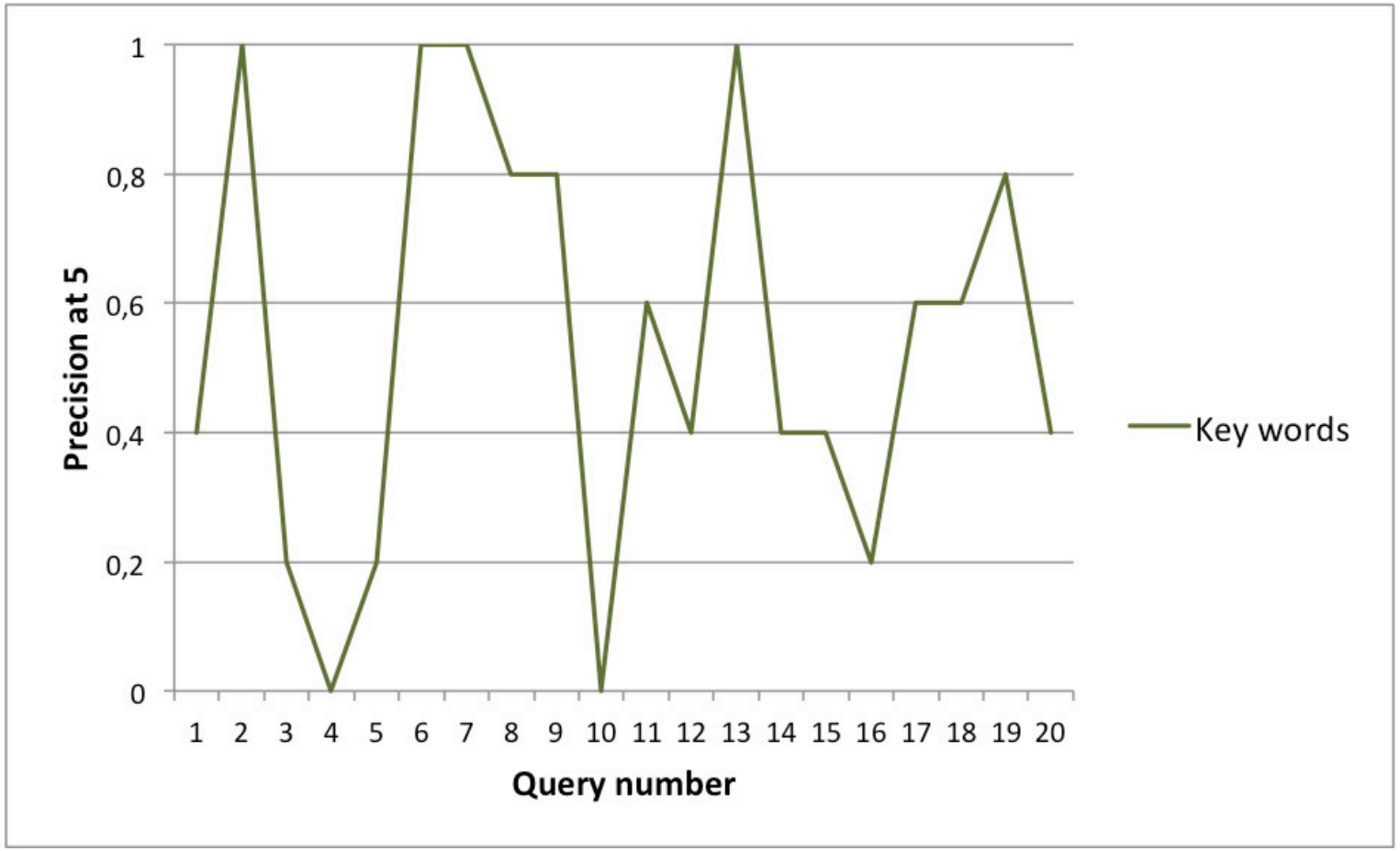


***Figure 3**- P@5 when the similarity between the key phrases in the query and the key phrases in the questions is computed*

Discussion

- The best results are obtained when a combination of the text in the title and the body of the query is used to compute the similarity with the tests' questions (Figure 1)
- For most of the queries in the dataset, a precision above 0.6 is obtained
  - Note that the criterion for considering a question as relevant to a query is very strict, since only exercises on the same algorithms are considered as valid, and not other exercises regarding other algorithms that also implement the same scheme or use the same data structure

Discussion

- The worst results are obtained for queries #9 and #16, which are both about the Dijkstra algorithm
  - The reason is that both queries are described using a very general vocabulary from the graph domain
- When only the text in the title of the query is used, the results are poor (Figure 2)
  - The reason is that, frequently, the title of the query refers to an activity in the course book by stating its page number (e.g. “Exercise 4.3 in page 176”). No information about the concept studied in the activity is given in the title

Discussion

- When we compute the similarity between key phrases automatically extracted from both the query and the questions, the results are not as good as expected
  - Students do not always use the standard vocabulary that is usually employed both in the reference book of the course and in the questions of the tests, and thus, the phrases extracted do not match

Conclusions and future work

- We have presented a content-based method for recommending reinforcement activities to students according to their queries in the discussion forum
- We have applied our methodology to a subject devoted to data structure and algorithms
- The results show that, for a given query, the recommender is able to propose related activities with high precision (above 75% on average)
- In future work, we plan to extend the method to the recommendation of threads in past discussion forums