Abstract.

We discuss two techniques used to characterize bibliographic records based on their similarity to and relationship with the contents of the NASA Astrophysics Data System (ADS) databases. The first method has been used to classify input text as being relevant to one or more subject areas based on an analysis of the frequency distribution of its individual words. The second method has been used to classify existing records as being relevant to one or more databases based on the distribution of the papers citing them. Both techniques have proven to be valuable tools in assigning new and existing bibliographic records to different disciplines within the ADS databases.

1. Overview

The NASA Astrophysics Data System (ADS; Kurtz et al 2000) maintains three main databases of scientific bibliographies: Astronomy, Physics, and the ArXiv e-prints. Over the past few years the ADS has created and maintained a separate “general” database containing records which do not readily fit in the three main databases. The use for the general database is twofold: it serves as a staging area for bibliographic records which may be later incorporated into one of the other databases and it provides a placeholder for those records which, while not being directly related to physics or astronomy, may be cited by or citing them. For instance, it is not unusual for physics papers to cite articles in chemistry or computer science and vice versa. The typical use of such a database is to store all records from inter-disciplinary journals such as Science and Nature. While some of the articles published in these journals will be entered in the Astronomy and Physics databases, their full table of contents will always be available in the general database.

When new records are provided to the ADS without any metadata enabling them to be reliably labeled as belonging to either physics or astronomy or physics, a decision has to be made in terms of which database they should be assigned to. Given the sheer amount of bibliographic data being handled by the ADS project (Grant et al 2000), this decision has to be made automatically most of the time. This paper describes how we have made use of two different tools to help us with the automatic classification of bibliographic records. The first tool is a text classifier which performs an analysis of textual data based on a
well-known Bayesian probabilistic model (McCollum and Nigam 1998). Classification of a document is performed by estimating the likelihood of its membership in a certain database based on the relative frequency of the words from the text in that database. The second tool is a citation classifier which assigns existing ADS records to one or more databases based on how frequently they have been cited by the records in those databases. The underlying assumption of the citation classifier is that any papers which have been frequently cited by papers in a particular subject area should be considered relevant to such subject area.

Both classifiers have been trained on a set of 400 articles published in the journal Nature during 1987. In this sample, 39 records were picked as being relevant to astronomy by a librarian. The classifiers were tested against the full set of articles published by Nature in 1997 (4033 records, 434 of which had citation data). These records consist of scientific research articles as well as short news, editorials, book reviews, and obituaries.

2. The Text Classifier

The problem of text classification can be summarized as follows: given a certain string of words from a document, which of a finite set of categories can this document be best assigned to? Following a probabilistic approach, we chose to implement a Multinomial Naive Bayesian Classifier which allows a straightforward computation of the category with the maximum likelihood based on the frequencies of the document’s words within each category. In our application, each category represents the set of documents in a particular database. Since the frequencies of the words in each database are readily available from the database-specific indexes that the ADS maintains, the computation of the probabilities can be carried out in real time from the index data.

The implementation of the classifier showed that it performed well in classifying documents for which at least 20 text words were available from either the title or the abstract. The challenge we were presented was trying to classify records for which only a title was available. In order to improve the classifier, a number of pre- and post-scoring steps were taken:

- The input text was pre-processed using the standard parsing rules used by the ADS search engine (Accomazzi et al 2000).
- All words consisting solely of digits were removed, as well as title words and phrases which had no relevance for classification (e.g. “obituary”).
- The likelihood score generated by the Bayesian classifier was normalized in order to limit the contribution of records consisting of few words, for which the highest rate of misclassification was found.
- To compensate for the previous step, a set of database-specific “trigger” keywords were defined which, when found, boosted the classification score of the input text.

The resulting classifier was implemented as a two-parameter function: $N_t$, the minimum number of words required for a document to be considered classifiable, and $S_t$, the minimum classification score necessary for a document to be considered belonging to a particular database. The results of the classification are displayed in Figure 1 where the performance of the classifier can be judged by looking at the Precision ($P$) and Recall ($R$) of the classification for each input
set of cutoff scores and minimum number of words. As one can see from the plot, the classifier has been designed to yield a high precision irregardless of the number of input words. This is a crucial issue for our application since we do not want to mistakenly assign non-relevant records to any of the ADS databases.

3. The Citation Classifier

The citation classifier was implemented to assign existing ADS records to one or more databases based on how frequently they have been cited by the records in those databases. The underlying assumption of the citation classifier is that any papers which have been frequently cited by papers in a particular subject area should be considered relevant to such subject area (Kurtz et al 2002). The scope and usefulness of this classifier is obviously limited by the availability of citation data for the records being considered: an article which has not been cited in any of the astronomy or physics journals for which the ADS has reference data cannot be categorized by the classifier. However, since the coverage of journal references from the core astronomy literature is quite thorough in the ADS, we can expect that important research articles will be cited with some frequency within astronomy.

Based on this premise, we implemented a citation classifier by considering, for each record for which citations are available, the ratio between the number of citations belonging to a particular database and the total number of citations. If the ratio is high enough we can conclude that since a significant portion of the papers citing the record in question come from a single database, the paper in question is relevant to that database. The citation classifier was implemented as a function taking as input two parameters: $N_c$, the minimum number of citations required for a record to be considered classifiable, and $R_c$, the ratio between the number of citations in a particular database and the total number of citations.

The performance of the citation classifier was tested against the set of 434 articles in the Nature sample which have citation data available. The results of the classifier are summarized in Figure 1. Once again we notice little variation in the performance of the classifier as a function of the total number of citations for a given paper, which is a desirable feature. On the other hand, given the limited number of citations for some of the records available, the recall is much lower than what was achieved with the text classifier.

4. Discussion

The text and citation classifiers described here have shown to be a valuable tool in categorizing records from scientific journals such as Nature and Science for the purpose of introducing them into the Astronomy or Physics databases. Further inspection of the results showed that misclassified papers are often borderline cases involving subjects such as Geophysics and Planetary Science which overlap the different databases. Additionally, a small number of records which were originally not selected as belonging to Astronomy by the librarian were later found to be relevant upon a subsequent review of the results by the classifiers.
Because the text and citation classifiers use different data when assigning articles to a database, we find that best overall results can be achieved by combining the output from both classifiers. By choosing conservative settings for the parameters controlling the classifiers ($S_t = 0.25, M_t = 5, R_c = 0.5, N_c = 4$), we were able to achieve a precision of 0.94 with a recall of 0.89 when classifying the sample against the astronomy database.

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