Full Text Searching in the Astrophysics Data System

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Abstract. The Smithsonian/NASA Astrophysics Data System (ADS) provides a search system for the astronomy and physics scholarly literature. All major and many smaller astronomy journals that were published on paper have been scanned back to volume 1 and are available through the ADS free of charge. All scanned pages have been converted to text and can be searched through the ADS Full Text Search System. In addition, searches can be fanned out to several external search systems to include the literature published in electronic form. Results from the different search systems are combined into one results list.

The ADS Full Text Search System is available at:

http://adsabs.harvard.edu/fulltext_service.html

1. Introduction

The Smithsonian/NASA Astrophysics Data System (ADS) provides access to the astronomy and physics literature. As of September 2006 it provides a search system for almost 4.9 million records, covering most of the astronomical literature (including planetary sciences and solar physics) and a large part of the physics literature. The ADS has been described in detail in a series of articles in Astronomy and Astrophysics Supplements [Kurtz et al. 2000; Eichhorn et al. 2000; Accomazzi et al. 2000; Grant et al. 2000].

Since 1994, the Astrophysics Data System (ADS) has scanned the scholarly literature in astronomy. As of September 2006, we have scanned over 3.3 million pages. These articles are available free of charge world-wide.

In order to make this resource even more accessible, we have used Optical Character Recognition (OCR) software to obtain the text of all the scanned pages in ASCII form. This allows us to index the full text of all articles and make it searchable.

This search system covers the astronomical literature that was published only on paper. In order to search the literature published in electronic form, we developed a system that sends queries to the search systems of several publishers. The results of these queries are then combined with the results of the ADS internal queries to seamlessly cover the majority of the literature.

This article describes some of the features of the search system for the full text of the astronomical literature.
2. Current Data in the ADS

We have so far scanned about 3.3 million pages from 43 journals, 15 conference series and 67 individual conferences, as well as a significant number of historical observatory publications. The scanned pages as of September 2006 use about 600 GB of disk space, the OCRd text uses 72 GB. The OCRd text is so-called “dirty OCR” because it has not been checked manually and it contains significant numbers of errors. This means that this text cannot for instance be used to extract numerical data from tables, it would be inaccurate. However, for searching the text for specific words, this “dirty OCR” is good enough. Significant words are usually used more than once, so even if the OCR software made a mistake in recognizing a word once, it will still show up correctly in other places of the same article.

Indexing of the OCRd text proved to be challenging. The number of unique words from this text is large. One reason for the large number of words is the fact that mistakes during the OCR process create new misspelled words. To reduce this problem, we remove words that have spurious characters in them that are OCR errors. But even after removing such words, as well as other unusable words like numbers, there are 14 million unique words in the index. The files produced during indexing are large, the largest being about 3.7 GB, close to the limit of 32 bit addressing. There is still some room for growth, but eventually we will have to move to 64 bit addressing for the full text search system in the ADS.

3. Search Forms

There are two search forms available. The basic search form allows you to enter the search term(s) and select which search systems to query. The search terms are combined with AND, meaning that all search words must be present on a page in order to be selected. The system supports phrase searching when multiple words are enclosed in double quotes. By default, synonym replacement is enabled. This means that the system not only searches for a specified word but also for all other words that have the same meaning. Synonym replacement can be turned off for individual words by pre-pending a ‘=’. This will search for the exact spelling of the word, which can be useful for words that have synonyms that are very common and would produce many matches. For instance “galaxy” is a synonym for “extragalactic”. A search for “=extragalactic” will remove “galaxy” from the matches.

The advanced search form allows in addition the selection of a publication date range and a journal. It also allows the selection of several sort options. One important sort option is “oldest first”. This allows you to find the first occurrence of a word or phrase in the literature (see 6. Example Usage).

4. Returned Data

The search returns a list of articles that contain the search terms. Under each article it lists each page individually that contains the search terms. It includes a partial sentence around the search terms, with the search term highlighted in
red. For pages that are not in articles (cover pages, various other material, and pages from issues where we don’t have the pagination information), the pages are listed individually. The article information links back to the regular ADS abstract service, the page information links directly to the scanned page.

5. Combined Searches

In order to include the more recent literature that was published in electronic form, the user can select to include one or more external search systems in the query. The external search systems are queried in parallel. As results are returned from the external systems, they are displayed to the user. Once all results are available, a final combination of all the results is compiled and displayed. The search fan-out is still experimental. It is not yet very stable since none of the external systems provide a dedicated interface for such external queries. It was implemented by simulating regular user queries to these systems. This makes our fan-out system vulnerable to changes in the external search systems. If an API (Application Programming Interface) becomes available for any of the external systems, we will implement it to build a more stable system.

We currently query the systems listed in table 1.

| Search System                | Journals searched                                                                 |
|------------------------------|-----------------------------------------------------------------------------------|
| Google Scholar               | Monthly Notices of the Royal Astronomical Society                                   |
|                              | Annual Review in Astronomy and Astrophysics                                        |
|                              | Annual Review of Earth and Planetary Sciences                                      |
|                              | Applied Optics                                                                     |
|                              | Journal of the Optical Society of America                                           |
| University of Chicago Press  | Astronomical Journal                                                               |
|                              | Astrophysical Journal                                                             |
|                              | Astrophysical Journal Letters                                                     |
|                              | Astrophysical Journal Supplement                                                  |
|                              | Publications of the Astronomical Society                                           |
|                              | of the Pacific                                                                     |
| EDP Sciences                 | Astronomy and Astrophysics                                                         |
| Nature                       | Nature                                                                             |
|                              | Nature Physics                                                                     |
|                              | Nature Physical Science                                                           |
| National Academy of Science  | Proceedings of the National Academy of Science                                     |

6. Example Usage

Using the full text search system is different from using the abstract search system in the ADS. Since there are so many more words in the full text, there are usually many more matches. It is therefore generally advisable to use more unique words, more search terms, and/or phrases.
For instance if you are trying to find out when the concept of a critical mass was first described, searching for the words “critical mass” without the double quotes would not produce anything useful, but a search for the phrase “critical mass” with double quotes from the Advanced Search form, with “Oldest first” selected, quickly finds an article in PASP from 1919 that attributes this phrase to Professor Eddington.

Another interesting question is to find out when the name Pluto was first suggested for a planet. If you enter:

planet pluto

in the search field and select “Oldest first” under the sort options. One of the first matches will be of an article in “The Observatory” from 1898 that suggests using Pluto as the name for the recently discovered planet DQ. Incidentally, the name had to wait for another 30 years before it was actually used for a planet. This capability can be very useful for astronomy historians.

7. Conclusion

The ADS provides a search capability for the full text of a large part of the astronomical literature. This capability complements the regular abstract search system. It allows the in-depth analysis of the older literature and especially the historical observatory publications, a part of the astronomical literature that has not been accessible in any search system until now.

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References

Accomazzi, A., Eichhorn, G., Kurtz, M. J., Grant, C. S., & Murray, S. S. 2000, A&AS, 143, 85
Eichhorn, G., Kurtz, M. J., Accomazzi, A., Grant, C. S., & Murray, S. S. 2000, A&AS, 143, 61
Grant, C. S., Accomazzi, A., Eichhorn, G., Kurtz, M. J., & Murray, S. S. 2000, A&AS, 143, 111
Kurtz, M. J., Eichhorn, G., Accomazzi, A., Grant, C. S., Murray, S. S., & Watson, J. M. 2000, A&AS, 143, 41