Analyzing Large Collections of Electronic Text Using OLAP

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Abstract

Computer-assisted reading and analysis of text has applications in the humanities and social sciences. Ever-larger electronic text archives have the advantage of allowing a more complete analysis but the disadvantage of forcing longer waits for results. On-Line Analytical Processing (OLAP) allows quick analysis of multidimensional data. By storing text-analysis information in an OLAP system, queries may be solved in seconds instead of minutes or hours. This analysis is user-driven, allowing users the freedom to pursue their own directions of research.

1 Introduction

Electronic text collections have existed for over half a century. In this time these archives have increased in both size and accuracy. Many tools have been created for searching, classifying, and retrieving information from these collections. Examples include Signature [Lee], Word Cruncher [ATL], Word Smith Tools [Sco], and Intext [InT]. Such tools tend not to be interactive. Also, analyzing a multi-gigabyte corpus tends to be slow.

We propose the creation of user-driven tools to interface with a *(Data) Warehouse of Words* (WoW) (see Fig. 1). A WoW is built by an *Extraction, Transformation, and Loading* (ETL) procedure, which processes the text and aggregates data from different sources.

A WoW stores its data in *data cubes* [GBLP96]. A data cube can be abstracted as a *k*-dimensional array with several predefined operations such as *slicing, dicing, rolling up* and *drilling down*. These operations allow the user to focus on just some subset of the data, at the desired granularity. While a data cube may have 15 dimensions or more, the user may be only interested in 2 or 3 dimensions at a time. See Fig. 2 for an example of a 3-dimensional data cube with two word dimensions and a book dimension. An example cell might record a count of 10 for (“cat”,“dog”) in *Ivanhoe,* and this cube could be used to study cooccurrences across several documents. Moreover, the attribute values of the example dimensions belong to a hierarchy: given the title of a book, we can “roll up” to the author of the book and finally to the author’s nationality.

On-Line Analytical Processing (OLAP) provides near constant-time answers to queries over large multidimensional data sets [Cod93]. For example, a user may be interested in comparing word or punctuation frequencies of two authors in the past 10 years. In a standard relational database system this type of query may be expensive. OLAP, however, seeks to solve queries in a matter of seconds before the user’s train of thought has been lost. Typically, fast results are at the expense of increased storage, by precomputing *summary* data cubes.

OLAP is especially applicable when many aggregate queries such as sum and average are of interest. Thus, data warehouses and OLAP have been used widely in business applications. Only recently have attempts been made to handle scientific information in an OLAP environment [WPR$^+$03]. If we exclude Information Retrieval (IR) [MLC$^+$00, MCDA03], this paper is the first attempt to apply OLAP to literature. OLAP has been used in conjunction with text mining [Sul01], informetrics/bibliomining [NHJ03], and to study literary titles [Ber95], however.

The main advantage a user-driven OLAP tool would provide is flexibility.

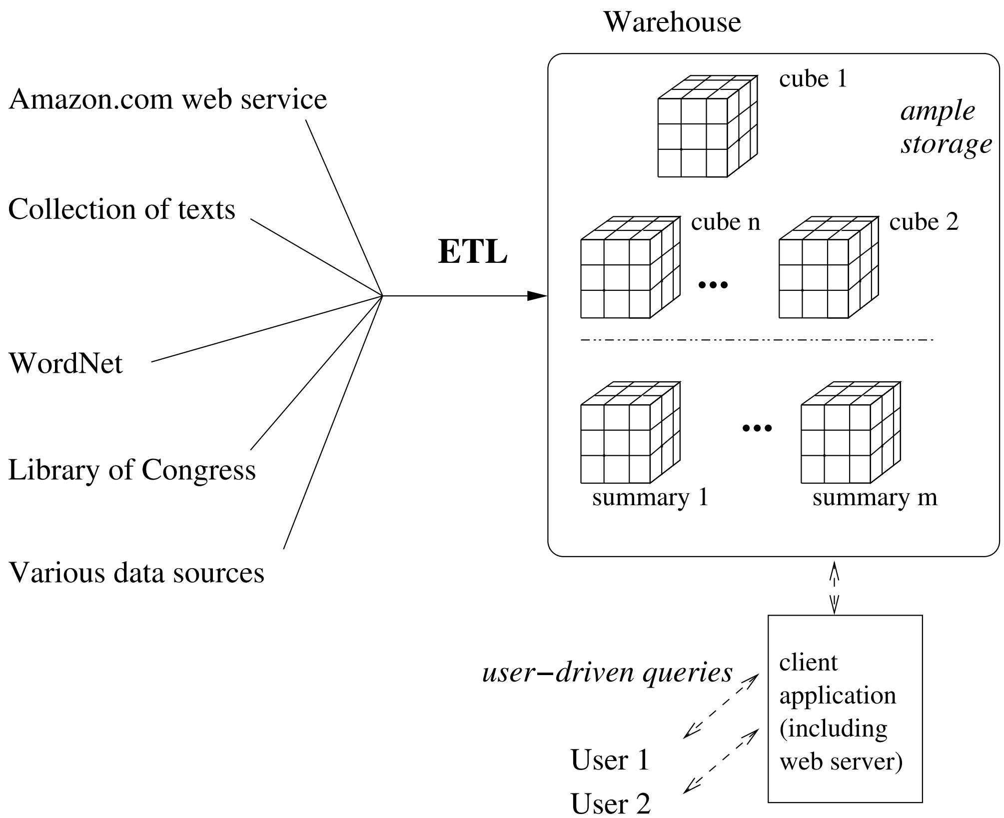


Figure 1: WoW architecture.

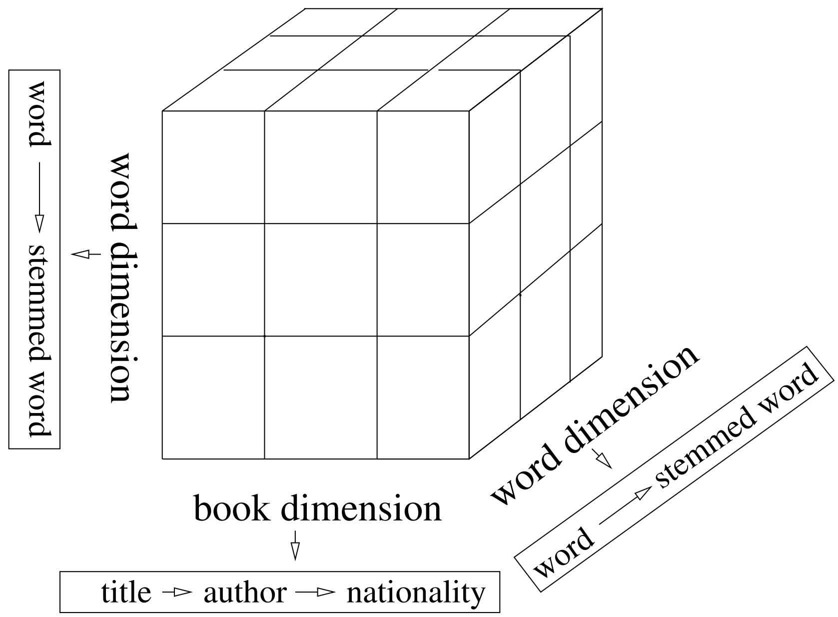


Figure 2: A simple data cube with three dimensions.

While IR and Artificial Intelligence tools are well suited to their single function, a user-driven tool gives a wide variety of users the freedom to pursue their individual research.

The end users of this OLAP system in most cases would be similar to the existent business users in their lack of database query skills. Most users would be unwilling to learn a multidimensional query language like MDX [HQ05]. Unlike business executives, academics are usually unable to finance technical assistants: they must be able to issue the queries themselves. A simple user-driven application is the most reasonable solution for those users not already accustomed to writing their own MDX or SQL queries.

Section 2 provides justification for this problem by presenting several research areas where a user-driven tool would be of benefit. Section 3 provides an overview of the ETL required to build the WoW. Section 4 concludes with the schema of the WoW and a description of queries the tool will support. Though there currently exist literary analysis tools, these types of applications do not take advantage of the hierarchical structure of literary data. Exploiting hierarchy is a key notion in OLAP.

2 Practical Applications

User-driven analytical tools are used in the humanities for author attribution, lexical analysis, and stylometric analysis. We review here some of the applications a WoW could support.

Author attribution is determining the authorship of an anonymous piece of writing through various stylistic and statistical methods. Mendenhall was the pioneer of this area with his study of word lengths [Men87]. This field was made famous in the 1990's by Foster's work [Fos00, Fos89] in attributing the authorship of *A Funeral Elegy* to Shakespeare. Foster was also responsible for determining the author of *Primary Colors* and has testified in a number of criminal court cases such as the trial of Theodore Kaczynski (The Unabomber). Though automatic author attribution has been implemented with reasonable measures of success [DKLP03, SFK01, BvHNT02], the complexity of language and stylistic analysis, as well as the fact that language is forever evolving, makes it difficult to automate the process reliably over an extended period of time.

Lexical analysis includes many measurements of vocabulary usage such as *Type-Token Ratio, Number of Different Words* and *Mean Word Frequency* [TB98]. These calculations are highly aggregatable since they are applied to a single book, a collection of books by a single author or time period, or an entire collection of books. We can also study the relations between these measures as is possible in a data cube.

Stylometric analysis not only considers the words in use but also accounts for other statistical elements of style such as word length, sentence length, use of punctuation and many other features. Analysis of this type tends to be used in assisting with author attribution as well as studying the development of an author over time [CP04].

Even analogies, and thus semantics, can be studied using a WoW data cube. Analogies of the form *A is to B as C is to D* [TL03] can be characterized by cooccurrences: two words connected by a *joining word* such as *has*, *on*, and *with* (64 joining words were initially proposed [TL03]). Pairs of words related by similar joining terms are analogous.

Other applications we foresee include user-driven mining for specific frequent phrases, computer-assisted topos searches, providing rich Information Retrieval feedback, and even user-driven exploration in order to improve computational linguistics algorithms.

3 WoW Creation

The development of our application begins with the creation of the WoW. This involves the three stages of ETL mentioned previously. The extraction in our case will involve the plain text and XML documents of Project Gutenberg [Pro05], a large corpus of literary works that is not in a suitable form for immediate analysis (other book collections might be added later). Project Gutenberg's documents contain irrelevant data such as the disclaimer and information on when the document was created. Also included in each preface are details about the author, date of publication, and other facts which must be extracted for indexing or statistical purposes. The transformation phase will involve the calculation of all data that will be stored in the WoW such as word frequency, punctuation frequency, and sentence lengths. The loading phase will involve the actual creation and storage of the data cubes containing the calculated items.

Our WoW is forced to deal with the same issues as any other data warehouse. At times data, such as the author's nationality, is missing and must be handled. Also, new books are added to corpora daily, and a means for loading these new books into the WoW must be created.

4 WoW Schema

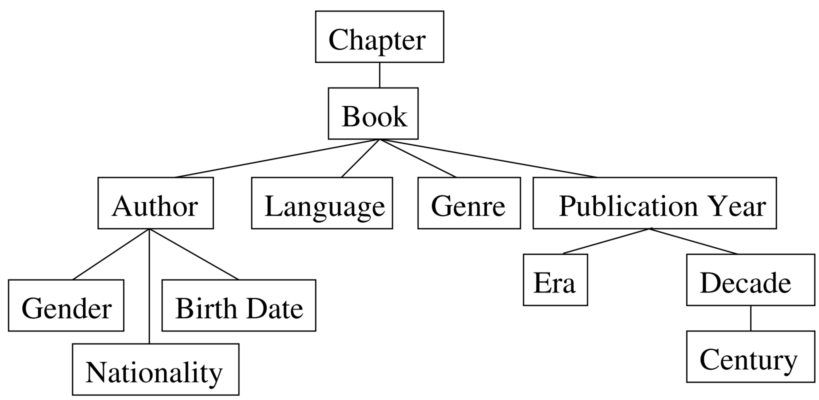
The main strength of an OLAP application is its efficient evaluation of aggregate queries across several dimensions and at different level of granularity. These queries generally take advantage of the hierarchical nature of cube dimensions and the hierarchy is not always obvious. The schema of the WoW requires that the hierarchies for both books and words be considered.

4.1 Dimension Hierarchies

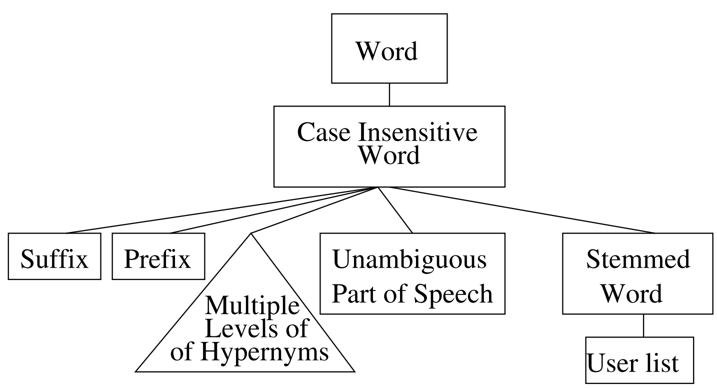
The "book" hierarchy maintains its finest detail at the level of chapters and is shown in Figure 3(a).

The year of publication may be generalized to a literary era (eg Victorian); alternatively, the year may be generalized to decade and then to century. Note that eras may not fit nicely into decades or centuries.

Several natural generalizations may help word studies. Refer to Figure 3(b), where stemming groups together the forms sharing a stem. Alternatively, words



(a) Book hierarchy.



(b) Word hierarchy.

Figure 3: Some WoW dimensions.

can be grouped according to their final suffix. Some words (eg *skit*) can be unambiguously classified by part of speech, whereas classifying other polysemous words may be impossible for our system (even if we try to employ NLP parsers, which is not planned). Thus "unknown" may be a common generalization in the WoW.

Hypernyms, for instance as provided by WordNet or by the classification in Roget's Thesaurus, provide another way to group words. This poses several difficulties involving polysemy whose resolution is ongoing.

Finally, tools such as Signature allow user-specified word lists. Given a set of "interesting" word stems, a stemmed word can be classified as belonging to [one of] the user's lists or belonging to no list[1].

These hierarchies allow for *rollup* queries (essentially generalizations) to be evaluated. Instead of finding the frequent words used in a chapter or book, one might be interested in the frequent words used by an author or used in a time period. The proposed WoW schema based on these hierarchies contains the following data cubes.

4.2 Cubes

To support the initial stylometric, analogy, and phrase-use queries, the WoW contains several cubes. We mention two.

1. **Sentence Style** (Book $\times$ Word $\times$ WordCount $\times$ CommaCount $\times$ ColonSemicolonCount $\times$ StopwordCount $\rightarrow$ Occurrence Count). Each "Count" is an integer, and the Word dimension represents the first word in a sentence. Many practical queries involve rollups of this cube. For instance, the average sentence length in each century can be computed from this, or we could study the use of commas by authors who write long sentences.
2. **Short Phrase** (Book$\times$Word$\times$Word$\times$Word $\times$Word $\rightarrow$ OccurrenceCount). The cube records all sequences of 4 words, and it could be used to explore common (or rare) phrases by authors or time periods.

These cubes will allow for many queries to be evaluated and would aid in all of the previously mentioned practical applications as well as a variety of other studies. We believe the development of new and more advanced queries will be stimulated by the creation of this system, since there has yet to be a literary OLAP system taking such advantage of hierarchies.

[1] "Highly masculine" words might help a feminist literary analysis.

References

[ATL] ATLAS.ti Scientific Software Development, GmbH. ATLAS.ti. http://www.atlasti.de/. last accessed June 22, 2005.

[Ber95] Michel Bernard. *À juste titre*: A lexicometric approach to the study of titles. *Literary and Linguistic Computing*, 10(2):135–141, 1995.

[BvHNT02] H. Baayen, H. van Halteren, A. Neijt, and F. Tweedi. An experiment in authorship attribution. *Journees Internationales d'Analyse Statistique des Donnees Textuelles*, 2002.

[Cod93] E.F. Codd. Providing OLAP (on-line analytical processing) to user-analysis: an IT mandate. Technical report, E.F. Codd and Associates, 1993.

[CP04] F. Can and J. Patton. Change of writing style with time. *Computers and the Humanities*, 38(1):61–82, February 2004.

[DKLP03] J. Diederich, J. Kindermann, E. Leopold, and Gerhard Paass. Authorship attribution with support vector machines. *Applied Intelligence*, 19:109–123, July 2003.

[Fos89] D. Foster. *Elegy by W.S.* Associated University Presses, Mississauga, Ontario, Canada, 1989.

[Fos00] D. Foster. *Author Unknown: on the trail of Anonymous*. Henry Holt and Company, LLC, New York, New York, USA, 2000.

[GBLP96] J. Gray, A. Bosworth, A. Layman, and H. Pirahesh. Data cube: A relational aggregation operator generalizing group-by, cross-tab, and sub-total. In *ICDE '96*, pages 152–159, 1996.

[HQ05] S. Harinath and S. R. Quinn. *Professional SQL Server Analysis Services 2005 with MDX*. Wrox, 2005.

[InT] InTEXT SYSTEMS. Intelligent Internet Tools. http://www.intext.com/. last accessed June 22, 2005.

[Lee] Leeds Electronic Text Centre. The Signature textual analysis system. http://www.etext.leeds.ac.uk/signature/. last accessed June 21, 2005.

[MCDA03] Josiane Mothe, Claude Chrisment, Bernard Dousset, and Joel Alaux. DocCube: Multi-dimensional visualization and exploration of large document sets. *Journal of the American Society for Information Science and Technology*, 54(7):650–659, 2003.

[Men87] T. Mendenhall. The characteristic curves of composition. *Science*, IX:237–249, 1887.

[MLC+00] M. C. McCabe, J. Lee, A. Chowdhury, D. Grossman, and O. Frieder. On the design and evaluation of a multi-dimensional approach to information retrieval. In *SIGIR '00*, pages 363–365, New York, NY, USA, 2000. ACM Press.

[NHJ03] Timo Niemi, Lasse Hirvonen, and Kalerva Järvelin. Multidimensional data model and query language for informetrics. *Journal of the American Society for Information Science and Technology*, 54(10):939–951, 2003.

[Pro05] Project Gutenberg Literary Archive Foundation. Project Gutenberg. http://www.gutenberg.org/, 2005.

[Sco] Michael Scott. Oxford wordsmith tools, version 4. Oxford University Press. see also http://www.lexically.net/wordsmith/, last accessed June 22, 2005.

[SFK01] E. Stamatatos, N. Fakotakis, and G. Kokkinakis. Computer-based authorship attribution without lexical measures. *Computers and the Humanities*, 35:193–214, May 2001.

[Sul01] D. Sullivan. *Document Warehousing and Text Mining: Techniques for Improving Business Operations, Marketing, and Sales*. John Wiley & Sons, 2001.

[TB98] F.J. Tweedie and R.H. Baayen. How variable may a constant be? measures of lexical richness in perspective. *Computers and the Humanities*, 32:323–352, 1998.

[TL03] P.D. Turney and M.L. Littman. Learning analogies and semantic relations. Technical report, Nantional Research Council, Institute for Information Technology, 2003.

[WPR+03] B. Wang, F. Pan, D. Ren, Y. Cui, Q. Ding, and W. Perrizo. Efficient OLAP operations for spatial data using Peano trees. In *DMKD '03*, pages 28–34, New York, NY, USA, 2003. ACM Press.