Sublanguage Terms:
Dictionaries, Usage, and Automatic Classification

Robert M. Losee and Stephanie W. Haas∗
School of Information and Library Science
University of North Carolina
Chapel Hill, NC 27599-3360 U.S.A.

Fax: 919-962-8071
losee@ils.unc.edu
stephani@ils.unc.edu

February 5, 2008

∗We wish to thank Nicole Magas for her assistance with the data collection described here.
Abstract

The use of terms from natural and social scientific titles and abstracts is studied from the perspective of sublanguages and their specialized dictionaries. Different notions of sublanguage distinctiveness are explored. Objective methods for separating hard and soft sciences are suggested based on measures of sublanguage use, dictionary characteristics, and sublanguage distinctiveness. Abstracts were automatically classified with a high degree of accuracy by using a formula that considers the degree of uniqueness of terms in each sublanguage. This may prove useful for text filtering or information retrieval systems.

1 Introduction

A sublanguage (SL) is the written or spoken language that is used in a particular field or discipline by people working in the field, especially to communicate with their colleagues (1). An SL differs from the general language used by people under ordinary circumstances in both its structure and its vocabulary. For example, it may include syntactic constructions that would be considered ungrammatical in general language, such as omitting verbs (2). It may include words or phrases that are not used in general language, and may also use familiar words in unfamiliar ways. It differs from jargon, although jargon may be part of an SL, in that jargon refers exclusively to the vocabulary used in the discourse.

When specialists in a particular field or discipline communicate informally, the discipline’s SL facilitates their communication by allowing them to be precise in their terminology, and frequently, to be more concise in their expression. When specialists communicate in more formal settings (e.g., a journal article), their language acquires some of the characteristics of general language. The grammar of their language will be that of general language and will conform to the norms of standard language. Their language will still, however, contain the vocabulary of the SL. These specialized terms may be the best (or only) way to describe their topic. The language in this formal setting will thus be a blend of general language and SL characteristics.

One place that this type of language, with mostly standard structure, but a highly specialized vocabulary, appears is in journal titles, abstracts, and articles. Here, it provides a challenge for a variety of language analysis, filtering, and retrieval systems. A highly specialized vocabulary contains terms that are not in standard dictionaries, resulting in coverage gaps for systems that depend on a dictionary for syntactic and/or semantic information. Haas (3) found that 20% of the word tokens in a set of computer science abstracts were not found in a standard college dictionary. Sixty-two percent of the SL word tokens (technical terms) identified by an expert were not found in the dictionary. The lack of coverage of the SL terms is not surprising, given the wealth of terms used in various disciplines, the speed with which new terminology is adopted, and the propensity of authors to coin new terms. SL words that do appear in the standard dictionary are frequently marked as belonging to that domain, for instance, with the name of the domain appearing in italics after the headword.
Specialized dictionaries may be sought to expand the coverage of the standard dictionary. A dictionary written to describe words and concepts in a particular discipline may be expected to contain more of the SL terms, and more of the SL senses or meanings of terms, than a general dictionary. Specialized dictionaries also indicate what the important terms and concepts in their disciplines are. The coverage of these specialized dictionaries, however, may vary widely. Haas (?) studied the coverage provided by a set of computer science dictionaries of vocabulary in a set of abstracts, and found that coverage of SL word tokens ranged from 20% to 78%.

2 Goals of Research

The overall goal of this research is to examine language usage in titles and abstracts drawn from an array of disciplines to determine interesting usage differences between them. We looked at usage from several perspectives. First, we looked at word frequencies, and especially at the frequencies of SL terms. Next, we looked at the coverage of the SL terms in the titles and abstracts by special dictionaries for each of the domains, and by a general dictionary. Finally, we examined the use of vocabulary as a means for identifying the domain of an abstract.

It has been shown that abstracts from different disciplines are distinguishable by topic and structure (?). The focus of this research is on the usage of SL vocabulary in abstracts from scholarly work in a variety of fields. Differences in usage may reflect differences in topic and structure, as well as other as yet unidentified factors.

Word frequencies, the overlap of usage between related and unrelated domains, inclusion of SL terms in general and specialized dictionaries, and similar data are informative about the nature of the language used in different disciplines and the differences between the disciplines (?). In particular, there are interesting differences between the usage patterns in scientific disciplines, such as Mathematics and Physics, and humanities and social science fields such as History and Sociology. These differences may include the way in which exposition is structured, the kind of information that is considered necessary in reporting on research (?), sentence structure (?), or the amount of synonymy (?).

Usage refers to both the words that are used and the word senses that are used. The list of SL terms used in a discipline may include words that are not used (or are used very infrequently) in general language, such as the Physics term “dipole”. SL terms may also include words that are familiar in general language, but are used in a special, very specific sense in the language of the domain. An example of this is the Biology term “linear”, which refers either to a long, narrow leaf, or a row of pollen grains. Word and word sense usage in a particular discipline may also be “borrowed” from related domains. In this case, it can be difficult to say that a term is or is not in the SL of the discipline. The most common example of borrowing seen in this research is the use of mathematical terms in Physics, Electrical Engineering, and Biology abstracts. This kind of borrowing is to be expected, since Mathematic is an important tool in these
fields. Whether borrowed terms should be considered part of the SL may be a matter of definition.

There is another class of terms used in the discourse of a discipline that is harder to classify as SL or not SL. These are terms that are crucial to the discussion of the important topics in the discipline, but are not specific to that discipline. For example, many different disciplines use the term “model” to describe a set of concepts and the relationships between them. It would be difficult to discuss research without using this term. We cannot say that this is an SL term in Physics or in Sociology or some other discipline because its usage is the same in all the disciplines. On the other hand, in studying the language that experts in the field use to discuss their work, this is clearly an integral term. Bonzi (1984) chose not to include such terms in her study.

Usage in a specific discipline can also be studied by looking at special dictionaries for the discipline. Although editorial policy differs from dictionary to dictionary, the terms chosen for inclusion in a dictionary are generally those used often enough that a reader of literature in the field may be expected to encounter them, and which are central to the field, so that it is important that a reader knows what they mean. Terms may be identified for inclusion by a variety of means, including looking at textbooks, journals and other standard works in the field. The dictionary can be viewed as an authority on SL usage in the discipline. It is important to point out, however, that the words included in such a dictionary will be only a portion of the words in the discipline’s SL. One problem is that of new terms; a dictionary, especially in print format, will always be a few years behind current usage. Nor can a dictionary include words that are coined by a single researcher, but not picked up by researchers in the field as a whole. The reader must expect that such terms are defined in the particular paper in which they are used. Finally, no dictionary is complete: the restrictions of space and time will always lead to the omission from the dictionary of terms that another person might consider important.

A specialized dictionary may also include some of the terms described in the preceding section that are crucial to the discourse of the domain, but not specific to just that SL. One way these can be identified is by examining specialized dictionaries from several disciplines. Not only will these terms appear in more than one dictionary, they will also be defined in approximately the same way.

General, or standard, college or unabridged dictionaries contain SL terms from many disciplines. Frequently the words or word senses are explicitly marked with the name of the field in which they are used. Definitions given in a general dictionary may not be as detailed or complete as those in a specialized dictionary. For example, the term “linear” referred to earlier had two senses given in the Biology dictionary. The standard dictionary, however, lists only the first one as a Biology SL sense. The other sense is not listed at all. Damerau (?) discusses some additional problems with using standard dictionaries as an aid in identifying SL terms.

In summary, which terms are considered to be part of the SL may vary according to several factors. Dictionaries will necessarily be incomplete, and will also include words that may be borrowed from another SL, or that are common to several disciplines’ SLs.
Domain experts will similarly have some disagreement on whether such terms are part of the SL. To define an SL as consisting of only those core terms that are unique to it, and agreed upon by all sources ignores the realities of scholarly discourse. Yet it is clear that there are boundaries between SLs, however fuzzy they may be. By examining terms in light of both dictionary and text based standards, we hope to discover some ways in which SLs can be differentiated.

3 Materials

Abstracts representing work in eight different disciplines were collected by querying CD-ROM databases for each discipline. Five queries were constructed for each discipline to obtain five sets of abstracts, containing between 22 and 50 abstracts each. (Fifty was arbitrarily chosen as the upper limit. For queries that returned more than 50 abstracts, only the first 50 were used.) Queries were designed to describe an entire topic, rather than pinpoint a specific aspect of a topic. It was thought that in this way, a broader sample of the SL could be obtained. Queries were developed using a variety of basic reference and textbook materials from the disciplines. Strategies included extracting phrases from back of the book indexes, and using topics from review questions or exercises in textbooks. The queries consisted of one to three keywords. As examples, a Physics query was “planetary atmospheres”, and a sociology query was “prison and violence”. Table 1 shows the average and total number of abstracts and word tokens for each discipline and for the entire collection. No limitations on date were placed on the abstracts other than those of retrieval order for those queries that returned more than 50 abstracts, and those inherent in the topic. For example, a query on “planetary atmospheres” would be influenced by when data was received via space probes, whereas one on “Archimedes” would not have such strong temporal influences.

Specialized dictionaries for each domain were chosen from the UNC-CH library. In cases where more than one dictionary was available, recent (within the last decade) dictionaries were chosen over older dictionaries, and those claiming a larger number of entries over those with a smaller number. The recency of a dictionary may have some effect on its coverage of SL terms. Given the time lag inherent in publishing a printed dictionary, a dictionary published in 1990, for example, may not include important terms from abstracts published in the same year. This disparity will be greater in disciplines where the vocabulary changes rapidly, such as Computer Science, and less noticeable in disciplines whose vocabularies evolve less rapidly. Since no date restrictions were explicitly placed on the abstracts, we do not expect this to be a problem for this research. Rather, this will reflect the realities of using specialized dictionaries as a knowledge source. The rate of change of SL vocabulary, and its effect on the use of dictionaries in various information tasks, deserves further investigation, particularly with the advent of online dictionaries. Appendix A contains a complete list of the general and specialized dictionaries.

A systematic sample of 500 terms was taken from each database. A list of all terms
Table 1: Average (over 5 queries) and total numbers of documents and words in the titles and abstracts for each discipline.

| Domain                | Documents |       | Words       |       |
|-----------------------|-----------|-------|-------------|-------|
|                       | Total     | Average | Total      | Average |
| Biology               | 185       | 37.0  | 7257       | 1451.4 |
| Economics             | 203       | 40.6  | 6550       | 1310.0 |
| Electrical Engineering| 226       | 45.2  | 6777       | 1355.4 |
| History               | 221       | 44.2  | 5689       | 1137.8 |
| Math                  | 235       | 47.0  | 8912       | 1782.4 |
| Physics               | 234       | 46.8  | 6662       | 1332.4 |
| Psychology            | 250       | 50.0  | 7715       | 1543.0 |
| Sociology             | 240       | 48.0  | 9148       | 1829.6 |
| Combined              | 1794      | 224.25| 58710      | 7338.75|

in a given database was sorted by frequency of occurrence and then a systematic sample (every \( n \)th term so that the sample size was 500) taken from that database. Each author then separately identified those words from the sample that could possibly be a SL terms, omitting stop words (function words) and other obviously general words such as “present”. Those words that were considered to be possible SL terms by either author were looked up in the appropriate specialized dictionary. Words were coded according to the following four categories:

0 – No entry in the specialized dictionary.

1 – Headword of entry exactly matches the target word.

2 – Headword is phrase that starts with the target word.

3 – Headword of entry is inflectional variant of the target word (e.g., a different verb form, or a singular/plural variant).

Those few terms that might be “true” SL terms that were not included in the dictionary were considered not to be SL terms for the purposes of the data analysis described below.

4 Term Frequencies in Sublanguages

Table 2 shows the percent of occurrences for the terms found or not found in the sub-language dictionaries. The largest percent of terms found in the dictionary in one form or another was a tie between Electrical Engineering and Physics, each of which had 66 percent of their terms found in the specialized dictionary. The smallest percent of terms found in a sublanguage dictionary was 17 percent for Sociology.
Table 2: Percent of occurrences for terms in dictionaries. Numbers are rounded to the nearest whole percent so the sum of the numbers in a row may not add to 100%.

| Database   | Not in Dict. | Exact Match | Start of Phrase | Term Variant |
|------------|--------------|-------------|-----------------|--------------|
| Biology    | 73           | 7           | 12              | 9            |
| Economics  | 63           | 5           | 14              | 18           |
| Elec. Eng. | 44           | 16          | 18              | 23           |
| History    | 82           | 5           | 6               | 7            |
| Math       | 65           | 17          | 2               | 10           |
| Physics    | 44           | 16          | 18              | 23           |
| Psychology | 63           | 9           | 18              | 10           |
| Sociology  | 83           | 3           | 4               | 10           |

In most cases, more terms occurred at the start of a phrase in the dictionary than as an exact match for the single term in the dictionary. If one combines the number of terms that are exact matches with the exact matches at the start of a phrase, the percent of terms varies from 7 and 11 percent (Sociology and History) to 34 percent (Electrical Engineering and Physics).

The last two categories offer the possibility of “false positives”, where the term in the dictionary is not the same as that used in the abstracts. Many words in the “start of phrase” category occurred at the beginning of more than one entry. In Physics, for example, the word “atomic” was the initial word of six entries. One or more of these entry phrases may have been used in the text, or the word may have been used in a different phrase. In general, however, entries starting with the same word are somewhat related. It should also be noted that merely finding a word in the dictionary does not mean that it was used in its SL sense in the abstracts.

In the case of the “term variant” category, a false positive would mean that an inflectional variant of a term had a different meaning from the term itself, for example, that a past tense meant something different from the infinitive. While this is theoretically possible, it was not noticed in this data.

Table 3 shows that the average term frequencies for those terms that are exact matches or occur at the start of the phrase are much higher than for terms not in the dictionary or are term variants of terms that occur in the dictionary. For all domains except for Economics, the average term frequency for exact matches is higher than the average term frequency for terms not in the dictionary. For all domains except for Mathematics, the average term frequency for terms occurring at the start of a phrase was higher than for terms not in the dictionary.

It is interesting to note that Mathematics had the highest average term frequency for the exact match category. This indicates that the vocabulary used in the Mathematics abstracts matches that listed in the dictionary better than that of the other disciplines. It is possible that this reflects a slower rate of change in the Mathematics domain, i.e.,
Table 3: Average term frequency based on dictionary status for different sublanguages.

| Database       | Not in Dict. | Exact Match | Start of Phrase | Term Variant |
|----------------|--------------|-------------|-----------------|--------------|
| Biology        | 5.26         | 7.24        | 6.03            | 3.40         |
| Economics      | 3.93         | 3.75        | 8.56            | 3.84         |
| Elec. Eng.     | 3.50         | 7.29        | 7.13            | 3.76         |
| History        | 2.65         | 5.52        | 5.40            | 3.94         |
| Math           | 5.40         | 11.34       | 3.70            | 4.71         |
| Physics        | 3.46         | 8.47        | 6.96            | 7.74         |
| Psychology     | 4.43         | 5.62        | 4.63            | 2.51         |
| Sociology      | 4.23         | 8.43        | 18.15           | 4.02         |
| Averages:      | 4.11         | 7.21        | 7.57            | 4.24         |
| % change from  |              |             |                 |              |
| Not in Dict.   | 0%           | +75%        | +84%            | +3%          |

in the adoption of new terms, thus allowing the dictionary to remain current for a longer period of time. This possibility requires more investigation.

These term frequencies may be useful in separating terms likely to occur in a specialized dictionary from terms not likely to occur in a specialized dictionary, that is, the separation of SL terms from general terms. While the averages suggest that we may be able to discriminate based on term frequencies, preliminary investigations into the correlations between term discrimination measures and term sublanguage status showed that little useful discrimination is actually obtained. This suggests that term frequencies alone are inadequate for accurate automatic identification of specialized terminology. We did not pursue this line of investigation.

5 Usage

Usage was examined from several perspectives, including term frequency and specialized and standard dictionary definitions of terms, to identify differences between disciplines and families of disciplines.

5.1 Frequencies

Terms were ranked for each database by their Poisson percentile. This percentile provides a measure of the degree to which a term has a higher than expected frequency of occurrence in the database in question. The average frequency of term occurrence is computed by dividing the total number of occurrences of the term in question from across all the different databases by the number of databases. This average is then compared statistically with the number of term occurrences in the database in question.
The number of times a term occurs in a body of text, either an individual title, abstract, full text, or a database, may be described probabilistically using the Poisson distribution (\(?\), \(\lambda\), \(\lambda_1\), \(\lambda_2\), \(\lambda_3\)). This describes a body of text as being “about” a topic to a certain degree. Current researchers often assume that the Poisson distribution is close to the actual empirical distribution describing a given set of term frequencies and, despite the fact that term frequency data is not exactly Poisson distributed, the Poisson distribution of term frequencies is a useful approximation. The research described below explicitly assumes the Two Poisson Effectiveness Hypothesis (\(\lambda\)), which states, in part, that “even though terms are not Poisson distributed and independent, the term frequencies are distributed in a manner close enough to the Poisson distribution that the [performance] degradation due to the failure of the distribution assumption to be met is compensated for by the increase in information provided by non-binary term frequencies.” We do not attempt here to determine whether the terms are in fact distributed in a Poisson manner; for research on the degree to which terms are Poisson distributed, the reader is referred to (\(\lambda\), \(\lambda_1\), \(\lambda_2\), \(\lambda_3\)). Instead, we assume that terms are close to being Poisson distributed and that making this assumption may increase classification performance enough through the incorporation of term frequencies, that this will counteract the obvious decrease in performance that occurs due to the failure of the Poisson term distribution assumption to be met.

The two-Poisson model (\(\lambda\), \(\lambda_1\), \(\lambda_2\)) assumes that there are two bodies of text; one about a topic and the other not about the topic, and that term frequencies are Poisson distributed in each body of text. More recently, the three-Poisson model (\(\lambda\), \(\lambda_1\), \(\lambda_2\)) has been developed to model three bodies of text that vary in their degrees of being “about” the term. The two-Poisson model can be shown to be a special case of the three-Poisson model and a model assuming that terms in all bodies of text are described by the Poisson distribution, a one-Poisson model, can be shown to be a special case of the two-Poisson model. We treat “discipline” as topicality here and use the one-Poisson model as a model of term distributions in disciplines.

Assuming that terms in a body of text are generated by a Poisson process allows one to measure the probability that one will have \(x\) occurrences of a term given an average frequency of \(\lambda\) as,

\[ P_{x,\lambda} = \Pr(x|\lambda) = \frac{e^{-\lambda} \lambda^x}{x!}. \]

This distribution assumes that \(x\) is an integer and that the production process is memoryless, that is, the presence of a term in one location in a text doesn’t affect its presence either way in later produced sections of the text. While this may be a weak assumption to make when working with single documents, where stylistic considerations have a great impact on the choice of terms used by an author, the Poisson distribution assumption is reasonable in a database consisting of hundreds of different titles and abstracts written independently by different authors.

The Poisson percentile for a term occurring \(t\) times in a database, where the average frequency of occurrence across all databases is \(\lambda\), may be measured as \(\sum_{i=0}^{t} P_{i,\lambda}\). This
Table 4: The 5 top ranked and the 5 bottom ranked terms from each database. Top ranked terms have very similar or identical Poisson percentile values between .99999 and 1 and the bottom ranked terms all have different values in the range of 0 to .01.

Percentage will approach 1 when a term occurs in a database with a frequency that is much higher in this database than is usually found in the databases as a whole. Similarly, a low positive value would be found with a term that is commonly found in the databases but is rare in this particular database: such terms are seldom found.

While the technique described here assumes that terms are distributed in a manner roughly similar to the Poisson distribution, other distributions may prove useful in other circumstances. For example, using the normal distribution instead of the Poisson distribution may be desirable in cases where the average frequency of occurrence approaches the hundreds or higher and minimizing computation speed is important for the application.

Table 4 lists the 5 top and bottom terms for each database after the terms were ranked by their Poisson percentile. Note that these are extracted from the list of all ranked terms and not just from those identified as SL terms. Those at the top can in some way be considered especially characteristic of the SL used in that database, not because they were used frequently, but because they were used more frequently than expected, given their frequency in the rest of the collection. These words are clearly associated with central topics in their disciplines. The bottom ranked terms are somewhat harder to characterize – they are more of a mixed bag. Some of them
are general language words, such as “during” and “their”. Some are general ‘research description’ terms, such as “discussed” and “method”.

It is interesting to note that although there is no overlap between disciplines in the top ranked terms, there is some in the bottom ranked terms. This is due in part to the ranking procedure, which gives a high rank to terms that are relatively rare (whether as SL terms or not), while those terms at the bottom of the lists are those terms likely to occur more evenly throughout the databases. These latter terms, while being specialized vocabulary for some domains, do occur in other domains and therefore receive a low position using this ranking method.

5.2 Comparison with Specialized Dictionary Definitions

Merely finding a word from a particular set of abstracts in the specialized dictionary for that discipline does not guarantee that the word is being used in the abstracts in its SL sense, as defined in the dictionary. Many words that have a very specific meaning in a particular domain are also used with a different, more general meaning, in general language. The usage of words classified as 1’s, that is, with exact matches in the dictionaries, were of greatest interest to us. We wished to determine what portion of these words were being used in their SL sense and what portion in a general sense. We were specifically interested in two types of comparisons. First, we wondered if SL words with the highest Poisson rankings were used differently from those with the lowest rankings within any discipline. Second, we wondered if there were any differences in usage between disciplines, or between classes of disciplines.

The top 10 and bottom 10 ranked terms classified as 1’s from each discipline were selected for examination. Each instance of their usage in the discipline’s abstracts was categorized into one of the following groups.

- **SSL - Same sense, SL.** The word token in the abstract used the same SL word sense as that defined in the special dictionary. For example, in the Electrical Engineering dictionary, the word “array” is defined as “1) photovoltaic converter - a combination of panels coordinated in structure and function. 2) solar cell - a combination of solar cell panels or paddles coordinated in structure and function.” The majority (96%) of its occurrences in the Electrical Engineering abstracts were used in one of these two senses.

- **SG - Same sense, general.** The word token in the abstract used the same sense as that defined in the special dictionary, which was a general definition. That is, the special dictionary defined the word to mean the same as its meaning in general language. For example, the economics dictionary defined the word “merger” as “An amalgamation of two or more firms into a new firm.” In general language, it is used in the same way.

- **DSL - Different sense, SL.** The word token in the abstract is used in a different sense from that defined in the special dictionary, but it is still used as an SL term.
Table 5: Usage of top and bottom 10 sublanguage words.

For example, the Biology dictionary defined the word “linear” as “1) a leaf having parallel sides, and at least 4 to 5 times as long as broad. 2) a tetrad of pollen grains in a single row.” In the Biology abstracts, it was generally used to refer to a mathematical array.

**DG - Different sense, general.** The word token in the abstract is used in a different sense from that defined in the special dictionary, and its usage was in a general language sense. For example, the Physics dictionary defined the word “period” as “the time occupied in one complete movement of a vibration or oscillation”. In the Physics abstracts, it was used in the general sense of “a span of time.”

Table 5 shows the average percentage and variance of occurrences of the top 10 and bottom 10 1’s. The disciplines are divided into two groups, one group contains what may be considered the “scientific” or “hard science” disciplines, and the other group contains the humanities and social science disciplines. This division minimized the variances. (We will use the term “scientific” for the first group merely for the sake of exposition; we do not intend to comment on the nature of the work done by any discipline.)

There are some very interesting differences in the distribution of the terms. In the scientific disciplines, a total of 73.8% of the occurrences were SL usages (SSL + DSL), while in the humanities and social science disciplines only 9.9% were. In the humanities and social sciences, the majority of the usages were classified as SG. Not only were terms mostly used in a general sense, it is these general senses that were defined in
the specialized dictionaries. For example, the History dictionary contained an entry for “France”, which was defined as a country in Western Europe, etc. Obviously, the word “France” has the same meaning in general discourse.

The picture changes somewhat in looking at the bottom 10 1’s. In the scientific disciplines, 60.9% of the term occurrences were used in a general sense. Interestingly, 70.8% of the humanities and social science term occurrences were used in a general sense, a smaller proportion than the top-ranked terms. However, about half of these were used in a general sense different from that defined in the special dictionary. Note that none of the terms in the humanities and social sciences were used in an SL sense different from that defined in the special dictionary.

In summary, most of the occurrences of the top-ranked words used the same sense as that defined in the discipline’s special dictionary, whether that was an SL or a general sense. Most of the occurrences of the bottom-ranked words in the scientific disciplines were used in a different sense from that given in the dictionary. Only one third of the humanities and social science terms’ occurrences were used in a different sense. This finding indicates some interesting characteristics about the vocabulary used in scholarly abstracts, and how the disciplines differ in this regard. In scientific disciplines such as Mathematics or Physics, the words that occur more frequently than expected (the top-ranked terms) are generally used in a specific, SL sense. The infrequent words that could also be used in an SL sense are not used that way. There is a shift in usage between the top ranked words and the bottom ranked words. This particular shift does not occur in the other disciplines. In these disciplines, the vocabulary is less distinct from that of general language, as seen by the number of occurrences classified as SG. The shift in usage between the top and bottom ranked words seen here is that the top ranked words are primarily used in the same general sense as that defined in the specialized dictionary, while the bottom ranked words are used almost as frequently in a different general sense. In addition, there are more SSL occurrences. This shift, however, is not as marked as that seen in the scientific disciplines.

5.3 Measures of Sublanguage Characteristics

Given the usage patterns found in the scientific and humanities and social science disciplines, the next question is whether these patterns can be used to measure the characteristics of a particular SL. We propose a usage based measure,

\[ M_u = \frac{SSL + DSL}{SSL + SG + DSL + DG} \]  

(1)

that may be interpreted as the percent of term uses (for terms in the dictionary) that are used in the text in a sublanguage sense, or the probability that a term is used in a sublanguage sense given that the term is “present” in the dictionary. \( M_u \) values may be indicative of the degree to which terms in the sublanguage are differentiated from those in general language. A small \( M_u \) indicates that “technical” terms, (those in the SL), are frequently used in non-technical senses, while an \( M_u \) of 1 represents these terms being
used only in a technical sense. Values for the measure for the top ten type 1 terms and
the bottom ten type 1 terms for each database are given in Table 6.

The ratio of the usage measure $M_u$ for the top terms to that for the bottom terms
provides a measure of the difference between these two areas:

$$M_\Delta = \ln\left(\frac{M_u^{Top}}{M_u^{Bottom}}\right),$$

where $M_u^{Top}$ represents the $M_u$ value for the top ten terms, with similar notation used
for the bottom ten terms. Table 6 shows the $M_\Delta$ values for each database. It may be
the case that $M_\Delta$ is a measure of the discipline “hardness” or degree of precision of the
SL for an academic field. Scientific disciplines may exhibit a greater degree of variation
between the rate of terms most likely to be used in an SL sense for those terms that are
expected to be most characteristic of the SL vs. for those terms that are least expected
to characterize the SL. This is an area that merits further investigation. Questions
of interest include whether this ratio is fairly constant across an SL, and what other
features of the SL correlate with this measure.

5.4 Comparison with Standard Dictionary Definitions

A further difference in the distinctiveness of the scientific and humanities and social
science vocabularies can be seen by examining entries in the standard college dictionary.
The terms classified as 1’s from each discipline were looked up in the dictionary, first to
see whether there was an entry for the word, and next to see if one or more of the word
senses was marked as being a term from that discipline. There was little difference in
the number of terms with entries. 78.7% of the scientific disciplines’ terms had entries,
ranging from 94% (Biology) to 40.4% (Physics). In the humanities and social sciences,
81.2% of the terms had entries, ranging from 100% of the Sociology terms to 52% of
the History terms. It is interesting to note that many of the History terms were proper
nouns (e.g., names of countries or people), which are not listed in the main entries of most standard dictionaries. The History dictionary, on the other hand, contained a large number of proper noun entries. An average of 12.7% of the technical entries were marked with the specific discipline name. None of the Sociology and History terms were marked, and 4.2% of the economics terms were marked, yielding an average number of marked terms for the humanities and social sciences of 1.4%. Few of the humanities and social science terms have meanings which are distinct from those of general usage. When one considers the topics covered by these disciplines, this finding makes sense. They study objects and concepts that make up ordinary life, which are also the topics of general conversation and writing. In contrast, the highly scientific disciplines such as Physics or Mathematics are concerned with more esoteric concepts that are not the subject of general discourse.

Different fields have SLs that may be understood to be distinctive in several different senses. For example, a particular SL may be seen as distinct from another SL when the two SLs use different terminology. The term “muon” occurring in the Physics SL would not be expected to occur in a Psychology SL. This form of distinctiveness is probably the easiest form to measure with automated techniques capable of looking for string occurrences in either or both SLs. A different form of distinction occurs when an SL uses a term in a different sense than in another SL. For example, the term “affect” occurs in both the psychological and physics literature, but has a specialized meaning for psychologists in addition to the meaning common to both of the SLs. An extreme example of the use of different senses for different SLs would be the case where two SLs have exactly the same vocabulary but different senses in every case. If philosophers who suggest that we each have our own meaning for terms are correct, the SL that each of us uses (idiolect) is distinctive in this “sense” sense.

We may measure the general distinctiveness of an SL by noting the overlap between terms defined in an SL dictionary with those terms defined in a general dictionary. It may be computed as

$$D_{SL,G} = 1 - \frac{|SL \cap G|}{|SL|},$$  \hspace{1cm} (3)

where $SL$ is the set of terms in the sublanguage dictionary, $G$ the set of terms in the general dictionary, and where $|x|$ is the number of items in set $x$. The distinctiveness measure $D_{SL,G}$ will have a value of 1 when there is no overlap, that is, the sublanguage is completely separated from the general language, while $D_{SL,G} = 0$ when the two sets of terms are identical. The percentages of entries of technical terms in the general dictionary may be converted to this $D_{SL,G}$ value by subtracting them from 100 and then dividing the result by 100. For example, the fact that 40.4% of the physics terminology was included in the general dictionary results in $D_{Physics,G} = .596$, while $D_{Sociology,G} = 0$, suggesting that the SL for Physics is more distinctive than that for Sociology, which is at the minimum value.

These distinctiveness results may be interpreted in two ways, depending on the assumptions one makes concerning the inherent technicality of SLs. If we believe that SLs
are unequal in terms of their technicality, that is, some languages are inherently more specialized than others, the $D_{SG}$ may measure the degree to which more specialized terminology is used in the more technical languages.

If, on the other hand, all SLs are assumed to be specialized to the same degree, the differing $D_{SG}$ values may be understood as the degree to which the differences between the SL and the general language moves from being that of a terminological difference to being a difference in sense or meaning. Physics might be interpreted as having a greater degree of terminological distinctiveness than Sociology; the latter more frequently uses the same terminology as the general language but must use the terms in different senses if the SLs are to be equally specialized.

The definitions in general dictionaries for terms in the humanities and social sciences were suggested above to seldom have different senses in the SL and the general language. If we accept these dictionary definitions as capturing the true meanings of the terms, then disciplines such as Physics do have more distinctive SLs than do disciplines such as Sociology and the hypothesis that SLs have the same degree of specialization is wrong. If, on the other hand, we assume that the Sociological definition of “crowd” is the same as the general definition of “crowd” but that, for a sociologist, the term brings to mind a specialized constellation of images, then we might wish to claim that the senses of the general and SL terms are in fact different, despite the similarity of the definitions, and we do not have empirical support for the claim that sublanguages have different degrees of distinctiveness.

If one accepts the hypothesis that sublanguages are of equal technical specificity, it becomes necessary to address the question of the degree to which an SL can be different from a general language. Our data for Physics suggests that it has less than half of its specialized terminology occurring in the general language, while all of the specialized terminology from Sociology occurred in the general language. This may be seen as providing a possible range of values for technical terminology differences in SLs. If we accept the assumption that SLs are of equal technical specificity, there must be about this much variation in the sense differences between the SLs.

In addition to comparing SLs with the general language, two SLs may be compared with one another. More generally, the asymmetric distinctiveness of an SL $x$ from an SL $y$ may be measured as

$$D_{x,y} = 1 - \frac{|SL_x \cap SL_y|}{|SL_x|},$$  \hspace{1cm} (4)

where $SL_x$ represents the set of terms in the dictionary for sublanguage $x$.

These two distinctiveness measures may be used to examine a number of SL phenomena. As defined, they may measure the distinctiveness of those terms included in a specialized dictionary. To the extent that a sublanguage may be defined as those specialized terms occurring in a discipline specific dictionary, these dictionary based measures may be used as measures of sublanguage distinctiveness. A second approach would be to examine the definitions of terms in different SLs to study the extent to which the definitions overlap. This definition based approach is probably superior to an entry based
measure at capturing the true distinctiveness of an SL. A third possibility would be to combine dictionary definitions with meanings extracted from the context in which the terms are used in the abstracts. It would be difficult to represent these meanings in a useful way, but this approach would probably be superior to the other two. Other types of differences in meaning may similarly be used as the basis for measurement.

6 Automatic Classification into Discipline

The final question we investigated was whether term frequencies could be used to classify abstracts by discipline. Individual documents were classified or assigned to a particular database based on the Poisson percentile described above. The databases used in the analyses above and described in Table 1 were used for the classification experiments. The number of documents classified in each discipline ranged from a low of 185 for Biology to 250 for Mathematics. The results, shown in Table 7, suggest that documents may be automatically classified using this procedure with a high degree of accuracy using either the title alone or the abstract alone or when both are combined.

Experimental learning systems often gain knowledge from one set of data and then use this knowledge to process another set of data. For example, classification systems may learn from half the data and then classify the other half. They may also learn from an entire data set and then classify the set. This latter approach results in the classification system learning from an item and then using this knowledge to classify the item. A superior experimental approach to learning for classification is to learn from every item in the data set except for the item to be classified. When this is done for every item in the data set, the maximum information about database characteristics is obtained that can be obtained without tainting the learning with knowledge from the specific item to be classified. The latter experimental technique is more realistic than learning from half the data and then classifying the other half of the data. It simulates the production environment in which incoming documents are classified on the basis of all previously classified ones. The results obtained with our method of learning from

| Database  | Title | Abstract | Both |
|-----------|-------|----------|------|
| Biology   | 95.1  | 95.6     | 96.7 |
| Economics | 94.5  | 95.0     | 96.0 |
| Elec. Eng.| 97.3  | 95.5     | 96.9 |
| History   | 92.9  | 88.2     | 92.3 |
| Math      | 94.8  | 100      | 100  |
| Physics   | 96.1  | 94.0     | 94.4 |
| Psychology| 94.7  | 96.8     | 97.2 |
| Sociology | 94.9  | 100      | 100  |

Table 7: Percent of documents classified correctly into the appropriate sublanguage.
all but the document to be classified provides classification performance that is both superior to that obtained with half-and-half testing and is closer to that which would be obtained with a production classification system.

The Poisson percentile is computed somewhat differently for use in this classification procedure to provide a more conservative and realistic test of the power of this classification scheme. The term frequency for both the database in which the term occurs and for the set of databases as a whole is decreased by the term frequency for the document in question. This effectively allows for classification of a document to be based on term frequencies from all the other documents and not from the document being classified. In other words, the document being classified is not used in learning the Poisson percentile used to classify that individual document. This mimics the situation found in a document filtering system where a set of percentiles would be developed from one set of documents, already filtered, and then an arriving document would be classified based on earlier learning.

The weight for a given document was computed as the sum of the Poisson percentiles for the individual terms. Earlier tests using the product of term weights resulted in little consistent change in classification performance from that obtained using additive methods. No normalization for abstract or title size was used. Documents were classified by assigning weights (for each database) and the document being classified as a member of the database which resulted in the highest document weight for that particular document.

Terms from a list of 203 stopwords were removed from the database. For a few titles, terms occurred only in that document and, when these frequencies are subtracted from the database frequencies, the terms have a frequency of 0 with an average frequency of 0. These terms have an indeterminate and thus unusable Poisson percentile. This, combined with deletion of the stopwords, results in some titles effectively having no terms that could be used to classify the document. For our experiments these titles were randomly assigned to databases for classification purposes. The classification results reported here are thus somewhat lower than would be obtained if more ad hoc methods had been used to classify these particular titles.

These classification results appear to be very good. Since the classification procedure “learned” from other documents than the one being classified, there must be something about the titles and abstracts that allowed them to be classified correctly at such a high rate. We believe that the high degree of accuracy obtained was due to a combination of the relatively large number of terms present in a title or an abstract and thus used in the classification procedures and the discriminating quality of the terms. While traditional information retrieval applications often discriminate based on a few keywords in the query, our abstracts and title/abstract combinations were classified based on the much larger number of terms occurring in the title, abstract, or the title and abstract combined. Classification of titles alone probably performed so well because of the high discrimination ability of terms included in the titles.
| Actual Database | Classified in:         | Bio. | Econ. | EE. | Hist. | Math. | Physics | Psych. | Soc. |
|------------------|------------------------|------|-------|-----|-------|-------|--------|--------|------|
| Biology          | 97%                    | 3    |       |     |       |       |        |        |      |
| Economics        |                        | 96   |       |     |       |       |        |        |      |
| Elec. Eng.       |                        | 97   | 1     | 1   | 1     |       |        |        |      |
| History          |                        | 1    | 92    | 2   | 4     |       |        |        |      |
| Math.            |                        |      |       |     |       | 100   |        |        |      |
| Physics          |                        | 2    | 1     | 2   | 94    | 1     |        |        |      |
| Psychology       |                        | 1    |       | 2   | 94    | 1     |        |        |      |
| Sociology        |                        |      |       |     |       |       |        |        | 100  |

Table 8: Percent classification of documents when both titles and abstracts are used for learning. Number in a column represents the percent of documents in that row that are classified as being in that column. Data is rounded to nearest whole percentage and rows may not add to 100%.

7 Qualitative Analysis of Classification Failures

The results of the classification were extremely good, as can be seen in Table 7. It is, however, informative to examine the errors in classification (Table 8). Abstracts from History and Physics seemed to be the most prone to misclassification. Given that many History articles discuss patterns of behavior that lead to specific events, the fact that 4% of the History abstracts were classified as Sociology is not surprising. This misclassification can be considered a “near miss”. In fact, Sociology “attracted” erroneous classifications from all disciplines except Biology. Those from Economics and Psychology may also be considered “near misses”, but those from the more scientific fields are more mysterious. In some cases, the topic of the abstract was the impact of a technological development on people, or the implications of a policy decision, rather than the technology itself. In other cases, the cause of the misclassification is not obvious.

The other discipline that “attracted” erroneous classifications was Mathematics. This is not surprising at all, since Mathematics is used as a language or form of expression in several fields, including Biology, Electrical Engineering, and Physics. The misclassifications of Physics abstracts as Biology, Electrical Engineering, and Mathematics can also be understood as being a result of their common mathematical language.

8 Conclusions and Discussion

Vocabulary in abstracts from different disciplines varies considerably from discipline to discipline. This is not surprising; after all, the vocabulary must represent the topics and concepts of the discipline. The more important results of our research are how these differences can be characterized and measured.
The first technique we developed is a method of measuring the technical specificity of the SL vocabulary. This measure is based on the shift of usage from SL to general meanings between the top and bottom ranked words. SLs whose vocabularies are clearly identifiable and distinct from general language will have a larger $M_u$ and a larger $M_\Delta$. SLs that are not as distinct will have smaller $M_u$ and $M_\Delta$. These SLs reflect the nature of the topics that are the target of study in their disciplines, which are concerned with issues that surround people in everyday life. The measurement of the distinctiveness of an SL will facilitate the development of a variety of language analysis and retrieval tools. For example, if one assumes that it is easier to analyze language that is similar to the more familiar general language, then it will be possible to predict the effort required to provide coverage for the language of a new discipline. Of course, the measurement is also interesting for the theoretical study of SLs, and similarities and differences between them.

The second result, related to the first, is a measure of the distinctiveness of an SL. This measure can be based on either the terms of the SL or on the terms’ definitions. The difference between these two measures may further characterize the SL. The consequences of assuming that SLs are equal in degree of technicality were examined, as well as the more traditional assumption that they differ in technicality.

The third result of this research is the development of a highly accurate method of classifying abstracts by discipline, based on word frequencies. This technique will be useful in a variety of filtering and retrieval tasks, for example, as a first task in identifying a set of abstracts that are potentially relevant to a query or information need. The misclassifications that may be characterized as “near misses” would not necessarily be irrelevant to the query, and the few remaining misclassifications could probably be easily filtered out in subsequent processing stages.
A Dictionaries used in this study

The size of each of the dictionaries below was estimated by multiplying the average number of entries on sample pages by the number of pages.

General: The American Heritage Dictionary, Second College Edition. Boston: Houghton Mifflin Company. 1985. 57,000 entries.

Biology: Chambers Biology Dictionary. Peter M. B. Walker, Ed. Cambridge: Chambers. 1989. 10,000 entries.

Economics: Dictionary of Economics. Donald Rutherford. New York: Routledge. 1992. 4,000 entries.

Electrical Engineering: IEEE Standard Dictionary of Electrical and Electronics Terms, Third Edition. Frank Jay, Ed. New York: IEEE. 1984. 22,000 entries.

History: Macmillan Concise Dictionary of World History. Bruce Wetterau, Ed. New York: Macmillan Books. 1986. 16,000 entries.

Math: Mathematics Dictionary, Fifth Edition. G. James & R. James. New York: Van Nostrand Reinhold. 1992. 2,000 entries.

Physics: Dictionary of Physics, Third Edition. H. J. Gray & Alan Isaacs, Eds. Harlow, Essex: Longman Group. 1991. 8,000 entries.

Psychology: The International Dictionary of Psychology. Stuart Sutherland. New York: Continuum. 1989. 9,000 entries.

Sociology: Sociology. David Jary & Julia Jary. New York: Harper Collins. 1991. 2,000 entries.