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RELEVANCE OF SCIENCE INFORMATION: ORIGINS AND DIMENSIONS OF RELEVANCE AND THEIR IMPLICATIONS TO INFORMATION RETRIEVAL

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Abstract—Relevance is the key abstract concept in information retrieval. For effective information retrieval the system needs to retrieve documents based on the user's notion of relevance. To find dimensions and characteristics of relevance, 24 graduate students' relevance judgments were observed. The findings are (1) that relevance is multidimensional; (2) that there are two types of relevance dimension, primary and secondary; (3) that relevance dimensions show three orientations, problem, use, and value; and (4) that the problem orientation is primary to the other orientations. The implications of these findings are (1) that four characteristics of important relevance dimensions were found; (2) that the important dimensions need to be applied to the system's measurement of relevance; (3) that relationships between thesaurus terms need to be set following the important dimensions; (4) that the important dimensions are useful for the effective evaluation of information retrieval; and (5) that these and the orientations of relevance are useful to observe users' relevance judgments for the study of variables affecting relevance judgments. © 1997 Elsevier Science Ltd

1. INTRODUCTION

In information retrieval there are three kinds of relevance judgments, as shown in Fig. 1. The first one (RJ1) is the user's relevance judgment on a collection of actual documents. The second one (RJ2) is the system's relevance judgment with document representations. The last one (RJ3) is the user's relevance judgment with representations of documents which are judged relevant by the system.

Considering effectiveness of information retrieval in terms of relevance judgment, the effectiveness is the extent to which the system judges the documents relevant which are judged relevant by the user. So the effectiveness depends on the similarity between RJ1 and RJ2. It is
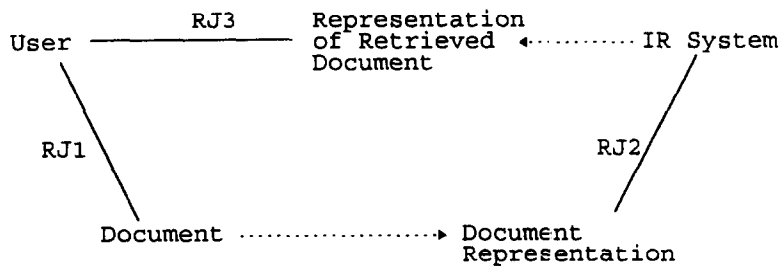
RJ: Relevance Judgment

Fig. 1. Relevance judgments in information retrieval.

because the role of an information retrieval system is to make preliminary relevance judgments for the user. Also the effectiveness depends on the similarity between RJ1 and RJ3. User's relevance judgments with document representations need to be the same with the ones with actual documents.

For effective information retrieval, three things need to be effective: document representation, problem representation, and the notion of relevance. Documents need to be represented for the system to make correct relevance judgments (for $RJ1 \cong RJ2$) and for the user to make correct relevance judgments (for $RJ1 \cong RJ3$). The user's problem needs to be represented for the system to make correct relevance judgments (for $RJ1 \cong RJ2$). Lastly, the system needs to use the user's notion of relevance for the measurement of relevance. If the user and the system use different notions for relevance judgments, RJ1 and RJ2 will not be similar and the effectiveness will be low. All of these should effectively work together for effective information retrieval. This study focuses on the notion of relevance.

Relevance is the key concept for information retrieval. A notion of relevance works in the process of information retrieval. Certain algorithms to measure the relevance of a document are implemented in information retrieval systems. A problem representation can be modified through relevance feedback, as shown in Fig. 2. The relationship between the two problem representations is RELEVANCE1. Also a search can be expanded based on the representation of a relevant document. The relationship between the two document representations is RELEVANCE2. The relationship between the initial problem representation and the representation of the relevant document retrieved through the modification or expansion is RELEVANCE3 which is the combination of RELEVANCE1 and RELEVANCE2. As well as these, there are several others which are the applications of the notion of relevance. All of these need to be based on the user's notion of relevance for effective information retrieval.

In spite of this critical importance of relevance, information retrieval systems have been built without intensive observations of relevance. The actual study of relevance itself is rare, whereas there have been many studies of variables affecting relevance judgments. Relevance has been studied in a speculative way. The speculative notions of relevance are theories or hypotheses to be tested, not true definitions or frameworks applicable to information retrieval.

The purpose of this study is to reveal dimensions and characteristics of relevance through qualitatively observing and analyzing descriptions of relevance. There are several areas to which the user's notion of relevance needs to be applied. The results of this study have important implications to these areas because these results come from actual users' relevance judgments.
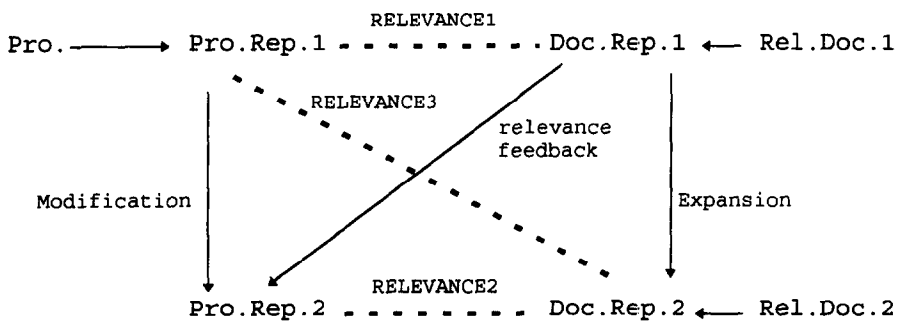
Pro.Rep.1: Problem representation before a modification
Pro.Rep.2: Problem representation after a modification
Doc.Rep.1: Representation of a relevant document retrieved before an expansion
Doc.Rep.2: Representation of a relevant document retrieved after an expansion
————→ : Process
- - - - - · : Relevance

Fig. 2. Relevance in information retrieval.

In this study relevance is considered as the relationship between the document and the user, which is mentioned by the user for the evaluation of a document.

2. LITERATURE REVIEW

There have been many studies of relevance and relevance judgments, and several information retrieval models in which a notion of relevance is implemented. The notions of relevance in them are critically analyzed here.

2.1. Theoretical studies of relevance

Wilson's (1973) situational relevance focuses on practicality. Relevant information is the information which can meet the actual information needs of a user. The author defined relevance in terms of practicality, which is not easier to define than relevance, as criticized by Saracevic (1975).

Cooper's (1971) logical relevance was, as the author said, the one limited to a data retrieval and a question answering system, not for a bibliographic information retrieval system.

Schamber et al. (1990) listed three traits of relevance: (1) multidimensional, (2) dynamic, and (3) complex but systematic and measurable (p. 774). If these traits are true, dimensions of relevance and their interactions with variables need to be studied.

Saracevic (1975) identified several views of relevance from the relationship between components in science communication. The components were the user, system, subject literature, subject knowledge, knowledge of the judge, question, and others. These views showed that relevance is important in the entire process of information service.

There are several other theoretical studies of the nature and definition of relevance. However, it is questionable that these have been, or will be, useful for the development of a system. These need to be verified through observing actual users' relevance judgments for practical implications.

2.2. Qualitative studies of relevance judgment

In recent years, there have been a few qualitative studies of relevance judgment. Barry's (1994) study was "to describe the criteria mentioned by users evaluating the information within documents as it related to the users' information need situation" (p. 149). The author found 7 groups of criterion: (1) the information content of documents; (2) user's previous experience and background; (3) user's belief and preferences; (4) other information and sources within the information environment; (5) sources of document; (6) document as a physical entity; and (7) the user's situation.

Park (1993) also found several criteria. These were (1) interpretation of citation including title, author name, journal name, etc.; (2) internal (experience) context including user's previous experience and perceptions, and user's level of expertise in the problem area; (3) external (search) context including perceptions of the search quality, purpose of search, perception about the availability of information, etc.; and (4) problem (content) context including same (similar) problem for definition, different problem—not of interest, new information in the problem context, etc.

In their studies of document selection behavior, Wang and Soergel (1993) found several criteria: novelty, topicality, orientation, subject area, quality, availability, recency, etc. They also identified several document information elements: title, abstract, descriptors, author/editor, publisher, journal, etc. They built a document selection model from the relationships between the criteria and the document information elements.

Schamber (1992) studied the criteria used for the evaluation of information, whereas the three studies above were done in the academic environment. The criteria the author found were:

accuracy, currency, specificity, geographical proximity, accessibility, clarity, presentation quality, etc.

These studies had a commonality. They were studies of the factors affecting the relevance of a document. This fact can be seen through the criteria they found. Most of these are not relevance dimensions, which are the relationships between the document and the user. These are the criteria used for the relevance judgment which work as the factors affecting the relevance of a document.

2.3. Relevance implemented in information retrieval models

As Saracevic (1975) said, "underlying all information systems is some interpretation of the notion of relevance" (p. 321). The notions of relevance implied in them need to be critically analyzed.

2.3.1. Relevance as the similarity of term selection. In manual indexing and some information retrieval models, such as Boolean and the vector space model, the notion of relevance is implied as the similarity of term selection between the user and the system, including the indexer. It is assumed that users and systems will select the same terms for the same document. The reviews by Markey (1984) and Leonard (1975) showed that this assumption may be invalid. The consistency in index term selection ranged 4–82% and 10–80%. These showed that indexers select terms inconsistently to a certain extent and imply that users may also select different terms for the same document. The consistency between the user and the indexer would be lower because of different view points on a document. Relevance is neither guaranteed by, nor inherent in, the similarity of term selection.

2.3.2. Relevance as the similarity of syntactic structures. One of the purposes of natural language processing is to show the syntactic structure of phrases or sentences to represent the document and the problem. Gay and Croft (1990) attempted to distinguish the meanings of nominal compounds of the same terms through assigning roles and types to the terms. Metzler *et al.* (1990) developed the "constituent object parser" which is capable of producing a binary tree to show the hierarchical syntactic structure of a sentence. These attempts were based on the assumption that the meaning is inherent in the syntactic structure and that the similarity of the syntactic structure is relevance. Salton *et al.* (1990) pointed out that to analyze the meaning of text with the computer, the computer must have a knowledge base in which semantic and pragmatic knowledge works to supplement the syntactic analysis. They also said that it was impossible to put semantic and pragmatic knowledge in the computer. If this is true, the meaning analyzed by the computer has a limitation and the similarity of the syntactic structure would not guarantee the relevance. Considering inconsistency in term selection, the validity of this notion of relevance will be lower.

2.3.3. Relevance as term frequency in the text. Term frequency and term discrimination value have been used for automatic indexing and classification (Salton, 1989). A certain relationship between term frequency and relevance was assumed. To increase the effectiveness of a word frequency model, Liddy (1990) made an algorithm to resolve an anaphora which refers to an entity. The resolution was expected to increase the effectiveness if the assumption was right. The accuracy of the resolution ranged from 83% to 99%, but the effect of the resolution was not evident. Clear relationships between word frequency and relevance need to be verified.

2.3.4. Relevance as the probability of relevance judgment. In the probabilistic model, the notion of relevance is the probability of the user's judgment of relevance (e.g. Maron & Kuhns, 1960). This notion of relevance denotes that the more a document was judged relevant by past users of a term, the more likely the document is judged relevant by a current user of the term. This notion assumes that the characteristics of current users are similar to those of past users, and that current users would make relevance judgments similar to the ones made by the past users. If this assumption is wrong and current users make relevance judgments different from the ones made by past users, the validity of this model will be low. The validity of probabilistic relevance also depends on the distribution of relevance judgments. If the distribution is wide, information retrieval will be ineffective. The studies of variables affecting relevance judgments

(e.g. Cuadra & Katter, 1967), reviews of consistency in index term selection by Leonard (1975) and Markey (1984), and the three traits of relevance listed by Schamber *et al.* (1990) imply that a wide distribution is highly possible. In addition to these, this notion focuses only on the quantity of relevance. Differences between relevance dimensions were assumed to be meaningless for the effectiveness of information retrieval. For example, the relevance of similarity between the document and the problem was treated the same as the relevance of relatedness of the document to the problem. Only the quantity of relevance matters in this model.

2.4. Relevance in the study of variables affecting relevance judgments

For the study of variables affecting relevance judgments, the degree of the overall relevance of a document and its variations were widely used (e.g. Cuadra & Katter, 1967). Relevance was thought to be unidimensional and incapable of being broken into its dimensions. The degree of the overall relevance simplifies the meaning of relevance. If relevance is multidimensional, as Schamber *et al.* (1990) said, dimensions of relevance need to be found. Through these, user's relevance judgments and effects of independent variables can be seen more clearly.

2.5. Relevance in citation

A cited document had a certain relevance to the citing document. The relationship between them is the relevance shown in the product of problem solving. In information retrieval, the relevance of a document is judged during problem solving. These types of relevance are closely related to each other because the process is for the product.

In Table 1 relationships between the cited and the citing document are listed. The quantitative relationship pertains to how much a cited document is relevant to the citing document. The qualitative relationship pertains to the relevance dimension. Some qualitative relationships are similar to the relevance of similarity between the document and the problem, which is widely used in existing information retrieval systems, e.g. one or more authors in common, same text, and similar research. There are also various relevance dimensions which existing systems cannot afford effectively. It would be difficult to say that the systems depending on the similarity, term frequency, or the probability can effectively retrieve applied, improved, modified, contradictory, evolutionary, or negational documents. In addition to these, documents of various relevance dimensions would be needed during the problem solving process. These relevance dimensions need to be implemented in the system to retrieve documents of these relevance dimensions. Through analyzing user's descriptions of relevance (equivalent to the text in the citing

Table 1. Relationships between the citing and the cited documents

Quantitative relationship	Noted only (Lipetz, 1965), distinguished (Lipetz, 1965), sibling (Hodges, 1978), organic or perfunctory (Moravcsik & Murugesan, 1975), essential (Chubin & Moitra, 1975), supplementary (Chubin & Moitra, 1975), basic (Chubin & Moitra, 1975), subsidiary (Chubin & Moitra, 1975), partial (Chubin & Moitra, 1975), totals (Chubin & Moitra, 1975), additional (Chubin & Moitra, 1975), perfunctory (Chubin & Moitra, 1975), not specifically mentioned in the text (Bonzi, 1982), barely mentioned in the text (Bonzi, 1982), one quotation or discussion of one point in the text (Bonzi, 1982), two or more quotations or points discussed in the text (Bonzi, 1982).
Qualitative relationship	One or more authors in common (Lipetz, 1965), same text (Lipetz, 1965), abstract or condensation (Lipetz, 1965), continuation (Lipetz, 1965), precursor (Lipetz, 1965), inclusion (Lipetz, 1965), applied (Lipetz, 1965), improved or modified (Lipetz, 1965), changed the precision (Lipetz, 1965), changed the scope of applicability (Lipetz, 1965), similar research (Duncan *et al.*, 1981), same paper (Duncan *et al.*, 1981), contradictory research (Duncan *et al.*, 1981), further detail (Duncan *et al.*, 1981), oppositional (Hodges, 1978), corroborative (Hodges, 1978), evolutionary or juxtapositional (Moravcsik & Murugesan, 1975), confirmative or negational (Moravcsik & Murugesan, 1975), affirmative (Chubin & Moitra, 1975), confirmation (Finney, 1979), negational (Chubin & Moitra, 1975; Finney, 1979) newness and originality (Spigel-Rosing, 1977), importance of object of investigation (Spigel-Rosing, 1977).

document), relevance dimensions (equivalent to relationships between the cited and the citing document) need to be found.

2.6. Schutz's study of relevance in philosophy

Schutz (1970) explained the knowledge construction process in terms of three types of relevance: topical relevance, interpretational relevance, and motivational relevance, which are three relationships between a stimulus and a person. Topical relevance is the relationship of difference or unfamiliarity which is used when selecting a topic as a problem. Interpretive relevance is the relationship of closeness or similarity which is used when interpreting the problem which is unfamiliar to a person. Motivational relevance is the relationship of importance. Considering relevance as the relationship between a document and a user, there would be various types of relevance during a problem solving process.

3. RESEARCH QUESTIONS

Relevance is an important concept in information retrieval. A notion of relevance works in the process of information retrieval. For effective information retrieval, relevance dimensions used by the user for the evaluation of documents need to be used in the process. A system has an algorithm to measure the relevance of a document. If the system employs a relevance dimension which is different from the one used by the user, the system and the user will make different relevance judgments and as a result, the effectiveness of information retrieval will be low. The relationships between the thesaurus terms need to be relevance dimensions used by the user for the evaluation of documents. It is because the modification of a problem representation and the expansion of a query are the processes to find the terms which have certain relationships with the terms in the problem representation and the query, and because these relationships are relevance dimensions, as shown in Fig. 2.

In spite of the importance of relevance dimensions, the notions of relevance were studied theoretically, the theoretical notions could not be applied for the development of an information retrieval system, the qualitative studies of relevance judgments focused mostly on the factors affecting the relevance of a document, information retrieval systems employed the notions of relevance which might be different from the ones used by the user for the evaluation of documents, and relevance was treated as a unidimensional concept. For effective information retrieval, the relevance dimensions used by actual users need to be found and applied to it. These relevance dimensions can also be applied to the evaluation of information retrieval and to the study of variables affecting relevance judgments because these can show users' relevance judgments in more detail than the simple degree of relevance. The citation studies reviewed above and the studies by Schamber et al. (1990) and by Schutz (1970) showed the high possibility of various relevance dimensions.

The first purpose of this study is to find relevance dimensions. The second purpose is to study why a document is judged relevant or irrelevant. The analysis of descriptions of why a document is relevant or irrelevant can reveal dimensions and origins of relevance. The last purpose is to study relationships among relevance dimensions. If there are multiple relevance dimensions for a document there will be certain relationships among them.Three research questions are:

• What are the dimensions of relevance?
• What are the origins of relevance?
• What are the relationships among relevance dimensions?

4. RESEARCH METHOD

The research method is explained briefly below. More detailed explanations are in Park (1995).

4.1. Subjects

Twenty-four volunteers were recruited at Rutgers: The State University of New Jersey, through a convenience and snowball sampling. They were graduate students from 14 natural and social science areas. Most of them were preparing for their Ph.D. thesis. Twelve subjects were Korean and 12 were American. They had an actual academic problem and needed an actual information search for it.

4.2. Data collection

About 100–200 citations were retrieved through DIALOG based on the subject's description of the problem. Every Nth citation was selected until the number of actual documents reached 10, with N depending on the size of a retrieved set.

Actual documents were used to collect descriptions of relevance. This was because in the pilot study there were many occasions in which the subjects could not judge the relevance because of insufficient information about the document in the citation and abstract.

The unit of relevance judgment was a portion of a document. This unit was selected because in the pilot study the subjects usually focused on a particular aspect of a document and made a relevance judgment on it, and because different parts of a document could be relevant in different ways. The subjects were asked to mark a portion of a document which was used for relevance judgment and then to describe in detail why the portion is relevant, helpful, useful, valuable, or irrelevant. The description was audiotaped and the audiotaping ranged about 7–55 min. This was transcribed into a written form and used as data.

4.3. Data analysis

The data was coded following the qualitative research method of grounded theory (Strauss, 1987; Strauss & Corbin, 1990). The coding was focused on finding the document and the other non-documentary variables, and on finding the relationships between them as relevance dimensions. The data was coded without any initial rule. The rule emerged and it was modified as the coding proceeded. When a critical change in the coding rule was needed, the data was coded again from the beginning with the modified rule. The unit of coding was a word or phrase, as shown in the examples in the following section.

After the coding, the use of each of relevance dimension was measured in three ways. First the number of document portions for which a relevance dimension was mentioned was measured as the number of uses. The second measurement consisted of the number of users who mentioned a relevance dimension. The last one was the percent use of a dimension—the percentage of the number of uses of a dimension out of the number of uses of all the relevance dimensions.

5. RESULTS

From data analysis, dimensions and characteristics of relevance were found.

5.1. Relevance dimensions

Relevance dimensions were found to be the relationship of a document variable to a problem or use variable, or to be the value of a document variable. Thirty-three relevance dimensions were found and are listed in Table 2. They are explained in Park (1995) and 12 important ones are briefly explained below. In the examples, descriptions of a document variable are underlined, descriptions of a problem or use variable are bold, and descriptions of a relevance dimension are

underlined and bold.

5.1.1. Applicable. This relevance dimension was described by "apply", "follow", "adjust", "add to", and others. An example is "...the terms **retrieval system**...can be **applied** to **MIS**...".

5.1.2. Good. This relevance dimension was described by "good", "bad", "desirable", "excellent", "nice", "best", "perfect", or "top". An example is "...it...gives me **good basis for developing another method**".

5.1.3. Helpful. This relevance dimension was described by "helpful" or "help" as in "...That is not **helpful** to **what I am proposing**...".

5.1.4. Important. This relevance dimension was described by "important" or other expressions like "key to", "matter", and "cornerstone". An example is "...this is very **important** table and told me **important** information about...".

5.1.5. Interesting. This relevance dimension was described by variations of "interest", or "concern" as in "...it is **interesting** because I may want to **substitute another metal for silver in the NbO^3**...".

5.1.6. Needed. This relevance dimension was described by "need", "want", "necessary", or "look for". An example is "...This is not what I **want**. I don't **want** this MIS model...".

5.1.7. New. This relevance dimension was described by various expressions. "Creative" and "innovative" were included because these could mean "new". An example is "...because I **have never seen** it before...".

5.1.8. Related. This relevance dimension was described by variations of "relate" or "something to do with", or with others like "associated", "connected", "oriented", etc. An example is "...**another species of rodent** that is sort of distantly **related to the rodent**

Table 2. Cumulative percentage and rank of use of the relevance dimensions

R^1	C^2	No. of uses	R	C	No. of users	R	C	% use	R	Average
1	15.8	Similar	1	7.7	Similar	1	16.4	Similar	1	Similar
2	28.5	Relevant	1	15.5	Related	2	27.5	Related	2	Related
3	38.1	Useful	3	21.9	Useful	3	37.4	Useful	3	Useful
4	45.8	Helpful	4	27.9	Helpful	4	45.9	Helpful	4	Helpful
5	53.3	Related	4	34.0	New	5	53.1	Relevant	5	Relevant
6	60.6	Interesting	6	39.4	Interesting	6	59.9	Interesting	6	Interesting
7	66.9	Important	7	44.4	Important	7	66.0	Good	7	New
8	72.5	New	8	48.8	Good	8	71.7	New	8	Important
9	77.0	Good	8	53.2	Studied	9	77.3	Important	9	Good
10	80.4	Studied	10	57.2	Relevant	10	81.1	Needed	10	Studied
11	82.9	Applicable	10	61.3	Needed	11	84.0	Studied	11	Needed
12	85.2	Needed	10	65.3	Applicable	12	86.0	Applicable	12	Applicable
13	87.0	Read	13	68.7	Read	13	87.6	Read	13	Read
14	88.2	Available	14	71.7	Missing	14	89.0	Specific	14	Specific
15	89.2	Appropriate	14	74.7	Focus	15	90.3	Information	15	Missing
15	90.1	Specific	16	77.4	Specific	16	↓	Missing	16	Informative
15	91.0	Supportive	17	79.8	Informative	17	↓	Rejected	17	Appropriate
18	↓	Missing	17	82.2	About	18	↓	Focus	17	Focus
18	↓	Rejected	17	84.5	Appropriate	19	↓	Available	19	Rejected
20	↓	Informative	20	86.5	Basic	19	↓	About	19	Basic
21	↓	Basic	20	88.6	Know	21	↓	Appropriate	21	About
21	↓	Focus	22	90.2	Rejected	22	↓	Basic	21	Available
21	↓	Included	22	91.9	Attractive	23	↓	Know	23	Supportive
24	↓	Attractive	24	↓	Valuable	24	↓	Attractive	24	Attractive
25	↓	Existing	25	↓	Existing	25	↓	Promising	25	Know
26	↓	Effective	25	↓	Effective	26	↓	Existing	26	Existing
26	↓	Pertinent	25	↓	Supportive	27	↓	Valuable	27	Effective
28	↓	Know	25	↓	Contributing	28	↓	Effective	28	Valuable
29	↓	About	29	↓	Promising	29	↓	Supportive	29	Included
30	↓	Valuable	20	↓	Pertinent	30	↓	Pertinent	30	Pertinent
31	↓	Promising	29	↓	Included	31	↓	Contributing	30	Promising
32	↓	Contributing	32	↓	Available	32	↓	Included	32	Contribut
33	100	Disappointing	32	100	Disappointing	33	100	Disappointing	33	Disappointing

1: Rank.
2: Cumulative percentage.

species...".

5.1.9. Relevant. The word "relevant" might not be a common word to the subjects. There might be an effect from the instruction which included the word "relevant". This relevance dimension was described with variations of "relevant". An example is "...So this particular paragraph is...**relevant to my study, in fact to future work that I intend to do**".

5.1.10. Similar. This relevance dimension was described in various ways: (1) a document description and a problem description had the same word(s); (2) a document variable and a problem variable were described as same, similar, close, or different; (3) a document variable and a problem variable had an "is" or "is not" relationship; (4) a document variable and a problem variable had a same, similar, or different aspect; (5) a document variable was a part of the topic of the problem; (6) a document variable and a problem variable were connected by an adverb, gerund, relative noun, or others which imply the similarity or difference, such as "which", "whereas", "exactly", "rather", etc.; and (7) a document variable and a problem variable had a similarity or difference in terms of geographic distance, age, chronology, etc. Examples are "...**Soil I study** and sewage are very **different** systems..." and "...strontium and udenium **which are two elements I am investigating**...".

5.1.11. Studied. This relevance dimension was described by variations of "deal with", "study ," "look", and others. An example is "...a particular concept I will need to **deal with** in my **dissertation**".

5.1.12. Useful. This relevance dimension was described by variations of "use", "try", "for", and others. An example is "...I could **use as background information.** And I can **use** this to **contrast the size of my unit cell**...".

5.2. Use of relevance dimensions

The dimensions were ranked in the order of use and average rank, the percentage of use was cumulated, and the result is shown in Table 2. The dimensions of similar, related, useful, helpful, relevant, and interesting covered about 60% of the total number of uses and the total percent use, and 37.3% of the total number of users. When the next six dimensions of new, important, good, studied, needed, and applicable were added to the top six dimensions, these accounted for more than 85% of the total number of uses and the total percent use, and more than 65% of the total number of users.

5.3. Three orientations of relevance dimensions

Three patterns of relevance judgment were found. First, relevance dimensions were mentioned in connection to a specific problem variable. These relevance dimensions were oriented to the problem. For example, in Fig. 3 the relevance dimension of similar is mentioned in connection to the problem variable of the procedure the user is using.
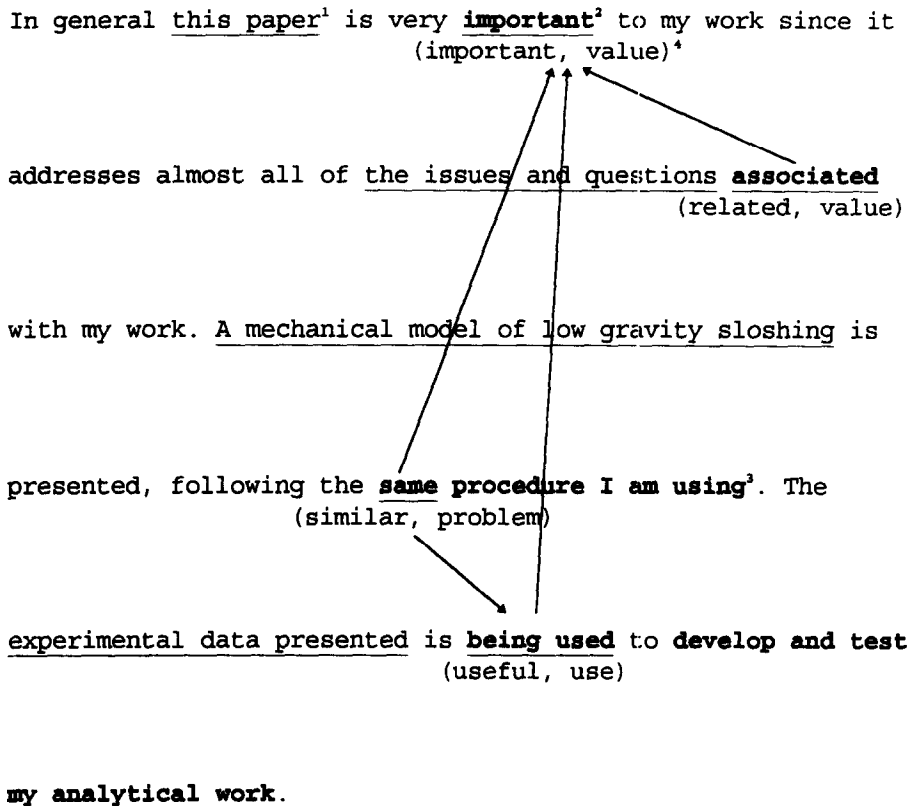
Second, relevance dimensions were mentioned in connection to a specific use variable. These relevance dimensions were oriented to the use. For example, in Fig. 3 the relevance dimension of useful is mentioned in connection to the specific use of the document variable.

Lastly, relevance dimensions were mentioned without any connection to a specific problem or use variable. These dimensions meant the overall value of a document variable and these were oriented to the value. For example, in Fig. 3 relevance dimensions of important and related are mentioned in connection to the overall problem. Incomplete relevance judgments, in which a specific problem or use variable was just not mentioned, were measured as the value orientation.

Table 3 shows the use of relevance dimensions in the three orientations. Relevance dimensions showed the value orientation most, the problem orientation next, and the use orientation. The ratio was 6.2:3.9:1 on average. Considering incomplete judgments which increase the value orientation, the actual value orientation would be lower and the other orientations would be higher. The problem orientation was higher than the use orientation.

5.4. Priority among relevance dimensions

For a document portion, multiple relevance dimensions were mentioned. A dimension had implicit or explicit relationships to other dimensions. These relationships could be found from linguistic cues such as "and", "therefore", "but", "so", "because", etc., and the logical relationship among sentences. Two types of relevance dimensions were found from the relationship: primary and secondary. A primary dimension makes the existence of secondary dimensions possible. A secondary dimension is originated from a primary one. In Fig. 3 the dimensions of related, similar, and useful are primary to the dimension of important. The

In general this paper[1] is very **important**[2] to my work since it (important, value)[4]

addresses almost all of the issues and questions **associated** (related, value)

with my work. A mechanical model of low gravity sloshing is

presented, following the **same procedure I am using**[3]. The (similar, problem)

experimental data presented is **being used** to **develop and test** (useful, use)

my analytical work.

1: Document variable
2: **Relevance dimension**
3: **problem or use variable**
4: (relevance dimension, orientation)

Fig. 3. Orientations of and relationships among relevance dimensions.

Table 3. The use of relevance dimensions in the three orientations

	Value	Problem	Use
No. of uses	57.8%	35.6%	6.6%
No. of users	52.9%	34.5%	12.5%
% use	56.5%	35.7%	7.8%
Average	55.7%	35.3%	9.0%

document is important to the user's work because the document is related to the user's work, similar to the problem variable, and useful. In addition, the dimension of useful is secondary to the dimension of similar. The document variable is useful because the document variable is similar to the problem variable. As a result, the dimensions of similar and related are primary to the other dimensions.

5.5. Priorities among the three orientations

Theoretically, the overall relationship among the three orientations can be structured, as in Fig. 4. Four cases are possible in this structure. The first one is that the relevance of a document shows only the value orientation. This means that a document variable has a value without any relevance to the problem or use. This would not be a usual case in the case of science research. A problem or use variable would not be created or changed because of a document of a high value which is not originated from any problem or use variable. A relevance dimension in the problem or use orientation is needed for a value-oriented relevance dimension. The value orientation is secondary to the other orientations.

The second case is that the relevance of a document shows only the use and the value orientation. This means that a user could identify a use of a document variable which has no relevance to any problem variable. It would be unusual for the use orientation to be primary to the problem orientation because this means an identified use of a document variable creates or changes the problem. The use orientation is secondary to the problem orientation in this case of science information service.

The third case is that the relevance of a document shows only the problem and the value orientation. This means that a user could specify a problem variable to which a document variable is relevant, but not a specific use of it. This case would be possible if the user could specify only vague and very general uses of a document variable. The last case shows a linear connection from the problem orientation, use orientation, and to the value orientation. A document variable has a relevance to a problem variable which makes a use of it possible. As a result, it has a value for the user.

The third and the last case are possible ones. In these cases the problem orientation is primary to the other orientations. Without any relevance to a problem variable, a document cannot be relevant. The value orientation is secondary to the other orientations. Without any relevance to the problem or use, a document is not valuable.
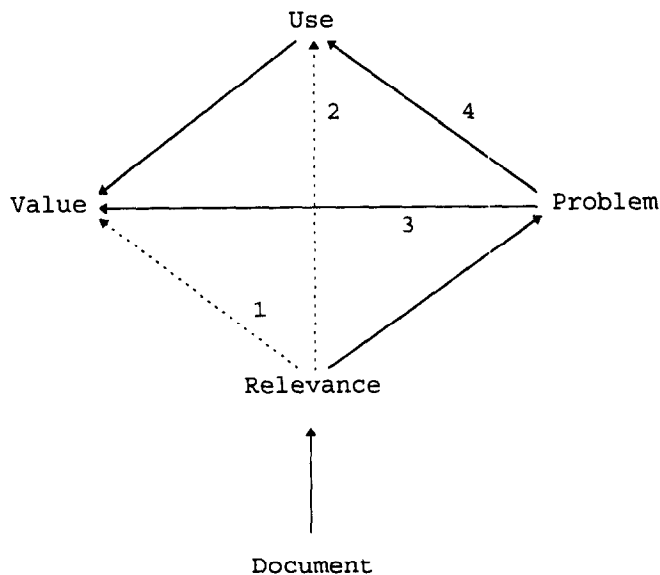

Fig. 4. Structure of three orientations.

6. ANSWERS TO THE RESEARCH QUESTIONS

The research questions are:

- What are the dimensions of relevance?
- What are the origins of relevance?
- What are the relationships among relevance dimensions?

Answering the first research question, 33 relevance dimensions were found, as shown in Table 2. The subjects used various relevance dimensions for their evaluations of retrieved documents. Answering the second research question, three orientations were found as the origins of relevance; the problem, use, and the value orientation. The relevance of a document is originated from its relationship to the problem and the use and its value to the user. Among these, the relationship to the problem is the most important (primary) one because the use of a document is possible because of it and the value of a document comes from it. Answering the third question, two types of relevance dimensions were found: primary and secondary. A primary relevance dimension makes possible the existence of a secondary dimension.

7. IMPLICATIONS

These results have implications to information retrieval and to the study of relevance judgment.

7.1. Implication to finding important relevance dimensions

This study showed four characteristics of important relevance dimensions which need be used for various purposes of the application of the notion of relevance: (1) highly used ones, (2) primary dimensions, (3) dimensions in the problem orientation, and (4) very specific and concrete dimensions hidden behind ordinary descriptions.

Twelve important relevance dimensions were found from the measurement of use. These accounted for more than 85% of the use of relevance dimensions. The subjects tended to make relevance judgments with a few important dimensions.

It was found that there are primary and secondary relevance dimensions. It was also found that there are primary and secondary orientations. The problem orientation is primary to the other orientations. As a result, primary relevance dimensions in the problem orientation are important relevance dimensions. These dimensions are the ones which make the existence of other dimensions possible.

The subjects broadly described relevance dimensions, e.g. "applied", "related", and "useful". The broad description made it difficult to find specific relevance dimensions which show concrete relationships between the document and the user. For example, the broad description of "related" did not show the specific kind of "relatedness". More specific and concrete relevance dimensions need to be found through a more intensive collection and analysis of descriptions of relevance.

7.2. Implication to measurement of relevance

The similarity between the document and the problem was widely used for the system's measurement of relevance. But it was found in this study that the use of this dimension took only about 16% of the total use. In addition to this, it was found that 30 dimensions out of 33 showed the primary orientation to a certain extent. The relevance dimension of similar is only one of the dimensions the subjects needed. These results showed the limitation of the information retrieval systems which rely only on the similarity for the measurement of relevance. These systems can

afford only a part of relevance the user needs. The implications of this study are that multiple relevance dimensions need to be used for the measurement of relevance and that the relevance dimensions which meet the four characteristics are the important ones for this purpose.

7.3. Implication to thesaurus construction

A few very broad relationships have been used in a thesaurus, such as related term, broad term, narrow term, specific term, and others (Lancaster, 1986). Two important roles of a thesaurus are to help the user represent the problem and modify the representation, and to help the system expand the search. As shown in Fig. 2, these processes need to be based on the relevance dimensions the user needs. This means that relationships between thesaurus terms need to be set following the relevance dimensions the user needs. The relevance dimensions which meet the four characteristics need to be used for thesaurus construction.

7.4. Implication to the evaluation of information retrieval

There would be three purposes of evaluation: (1) performance measure, (2) failure and success analysis, and (3) improvement. The relevance dimensions which meet the four characteristics are useful for these purposes. The relevance dimensions satisfied and unsatisfied through an information retrieval can be identified. The success and failure can be analyzed. The degree of success shows the performance. According to the success and failure analyzed, the successful input can be fortified to maximize successes and the ineffective input can be modified to minimize failures. With the cumulated success and failure analysis, the way to improve the system can be found. The three purposes of evaluation can be achieved effectively through the evaluation with important relevance dimensions.

7.5. Implication to the study of variables affecting relevance judgments

The quantitative measurement of the overall relevance of a document has been mostly used to observe users' relevance judgments for the study of variables affecting relevance judgments. The implications of these studies were limited to finding the variables and measuring the performance of the search and the system for the user group of a variable. The implication of this study is that important relevance dimensions and the three orientations are useful to observe users' relevance judgments. Relevance judgments and effects from variables will be shown in more detail and in a more meaningful way for greater implications of the study.

8. CONCLUSION

Through this study, several dimensions and other characteristics of relevance were found. Also the characteristics of important relevance dimensions were found. These results have important implications to information retrieval system design, thesaurus construction, evaluation of information retrieval, and to the study of variables affecting relevance judgments. But this study could not provide the results which are directly applicable to these because of the limitation of the data. This limitation was found as a result of the study. An important implication of this study is that it provided the direction and theoretical bases for further studies of relevance. This study was done in an academic research environment. Further studies in other environments are needed to test the applicability of the results of this study.

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REFERENCES

Barry, C. L. (1994). User-defined relevance criteria: An exploratory study. *Journal of the American Society for Information Science, 45*(3), 149–159.

Bonzi, S. (1982). Characteristics of a literature as predictors of relatedness between cited and citing works. *Journal of the American Society for Information Science, 33*(4), 208–216.

Chubin, D. E., & Moitra, S. D. (1975). Content analysis of references: Adjunct or alternative to citation counting?. *Social Studies of Sciences, 5,* 423–441.

Cooper, W. S. (1971). A definition of relevance for information retrieval. *Information Storage and Retrieval, 7,* 19–37.

Cuadra, C. A., & Katter, R. V. (1967). *Experimental studies of relevance judgment: Final report.* Santamonica, CA: System Development Corporation.

Duncan, E. B. *et al.* (1981). Qualified citation indexing: Its relevance to educational technology. In Duncan, E. B. & McAleese, R. (Eds), *Information retrieval in educational technology* (pp. 70–79). Aberdeen: University of Aberdeen Press.

Finney, B. (1979). The reference characteristics of scientific texts. Masters dissertation, Center for Information Science, City University, London.

Gay, L. S., & Croft, W. B. (1990). Interpreting nominal compounds for information retrieval. *Information Processing & Management, 26,* 21–38.

Hodges, T. (1978). Citation indexing: Its potential for bibliographic control. Ph.D. dissertation, University of California, Berkeley, CA.

Lancaster, F. W. (1986). *Vocabulary control for information retrieval.* Arlington, VA: Information Resources Press.

Leonard, L. E. (1975). Inter-indexer consistency and retrieval effectiveness: Measurement and relationship. Ph.D. thesis, University of Illinois, IL.

Liddy, E. D. (1990). Anaphora in natural language processing and information retrieval. *Information Processing & Management, 26,* 39–52.

Lipetz, B. A. (1965). Improvement of the selectivity citation indexes to science literature through the inclusion of citation relationship indicators. *American Documentation, 16*(2), 81–90.

Markey, K. (1984). Interindexer consistency tests: A literature review and report of a test of consistency in indexing visual materials. *Library and Information Science Research, 6,* 155–177.

Maron, M. E., & Kuhns, J. L. (1960). On relevance, probabilistic indexing and information retrieval. *Journal of the Association for Computing Machinery, 7*(3), 295–311.

Metzler, D. P., Hass, S. W., & Cosic, C. L. (1990). Conjunction, ellipsis, and other discontinuous constituents in the constituent object parser. *Information Processing & Management, 26,* 53–71.

Moravcsik, M. J., & Murugesan, P. (1975). Some results on the function and quality of citations. *Social Studies of Science, 5,* 86–92.

Park, H. (1995). Inferential relevance and its implications to inferential information retrieval. Ph.D. dissertation, Rutgers: The State University of New Jersey, New Brunswick, NJ.

Park, T. K. (1993). The nature of relevance in information retrieval: An empirical study. *Library Quarterly, 63*(3), 318–351.

Salton, G. (1989). *Automatic text processing.* Reading, MA: Addison-Wesley.

Salton, G., Buckley, C., & Smith, M. (1990). On the application of syntactic methodologies in automatic text analysis. *Information Processing & Management, 26,* 73–92.

Saracevic, T. (1975). Relevance: A review of and a framework for the thinking on the notion in information science. *Journal of the American Society for Information Science, 26*(6), 321–343.

Schamber, L. (1992). User's criteria for evaluation in multimedia information seeking and use situation (Ph.D. dissertation, Syracuse University, NY). *Dissertation Abstract International, 52,* 4128A

Schamber, L., Eisenberg, M. B., & Nilan, M. S. (1990). A re-examination of relevance: Toward a dynamic, situational definition. *Information Processing & Management, 26,* 755–776.

Schutz, A. (1970) *Reflection on the problem of relevance.* New Haven, NY: Yale University Press.

Spigel-Rosing, I. (1977). Science studies: Bibliometric and content analysis. *Social Studies of Science, 7,* 97–113.

Strauss, A. L. (1987). *Qualitative analysis for social scientists.* New York: Cambridge University Press.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Wang, P., & Soergel, D. (1993). Beyond topical relevance: Document selection behavior of real users of IR systems. *Proceedings of the 56th ASIS Annual Meeting, 30,* 87–92.

Wilson, P. (1973). Situational relevance. *Information Storage and Retrieval, 9,* 457–471.