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PROCEEDINGS OF THE 6th ASIS SIG/CR CLASSIFICATION RESEARCH WORKSHOP

Mapping Sentences and Classification Schedules As Methods of Displaying Facets

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Two separate streams of facet research emerged during the 1930s and 1940s. In India, S.R. Ranganathan developed facet theory in the context of his work on bibliographic classification systems, and in Israel L. Guttman developed facet theory in the context of the behavioural sciences. Ranganathan and Guttman used the term "facet" and its associated terms (e.g., "facet analysis") with identical meanings and each researcher developed analytico-synthetic methods appropriate for his own field. The paper describes the method each field developed for displaying facet structures, and the two methods are compared. The paper suggests that facet analysis in general and mapping sentences in particular have properties that can be usefully exploited in the development of all types of classification systems, including but not limited to, bibliographic classification systems.

I. Background and Introduction

Two separate streams of facet research emerged during the 1930s and 1940s, each of which evolved into a highly influential and widely discussed research area. The first stream arose from the work of S.R. Ranganathan in bibliographic classification theory, where the facet concept guided the development of new bibliographic classification systems (e.g., Ranganathan, 1933; *Bliss Bibliographic Classification*, 2nd ed., 1984- (BBC2)) and thesauri, beginning with thesaurofacets (e.g., Aitchison, 1969). The second stream arose from the work of Louis Guttman in the social sciences, where the same idea of a "facet" guided research in sociology, psychology and education, among others. Despite world-wide dissemination of the facet idea, these two general areas of research did not overlap or influence each other, nor were correspondences between them identified for about fifty years (Beghtol, 1995).

S.R. Ranganathan was born in India in 1895 and became a Professor of Mathematics at the University of Madras. In 1925, after his appointment as Chief Librarian at the University, he went to study at the School of Librarianship, University of London. He returned to India dissatisfied with then-current classification systems, and began on the trip back to develop his faceted *Colon Classification* (CC). The first edition was published in 1933 (Ranganathan, 1933), and Ranganathan continued to work on the facet idea for the rest of his life. Thus, Ranganathan, who first used the term "facet" in a technical sense in 1944 (Ranganathan, 1944), developed facet theory in the context of his work on bibliographic classification systems.

Louis Guttman was born in Brooklyn, N.Y. in 1916, and received his Ph.D. in sociology from the University of Minnesota. After working as Expert Consultant to the Secretary of War, Research Branch of the Information and Education Division of the U.S. Army and in post-doctoral research positions at the University of Chicago and Cornell University, he moved to Jerusalem. There, he founded the Israel Institute of Applied Social Research and became its Scientific Director. Later he became Professor of Social and

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Psychological Assessment at Hebrew University. Guttman developed facet theory as a result of his dissatisfaction with then-available statistical procedures he used in his work in the behavioural sciences (e.g., 1959), but he did not use the term "facet" technically until 1953 (Guttman, 1953). Like Ranganathan, Guttman developed the analytico-synthetic methods of facet analysis in the context of his own field of interest, and this stream of facet research continues to generate much interest. For example, a special issue of *Applied Psychology: An International Review* was devoted to social science facet theory (1990).

The purpose of this paper is to describe one way in which the function of facet analysis in each field determined the direction facet research took in that field. Each area developed its own appropriate method of displaying facet structures and these methods are sufficiently different to be interesting. In bibliographic classification systems, facet structure is displayed in the "schedules" of the system, and in the behavioural sciences facet structure is displayed in a "mapping sentence." In each case, the research context in which facets were used led to the creation of a unique and appropriate form of display.

II. The Concept of a "Facet" and Its Purpose in Each Field

In both fields, a facet corresponds to a set that is a component of a Cartesian product. A simple illustration is: "A facet...is any set of mutually exclusive categories. For instance, all furniture may be described in terms of the room in which it might be used; its price, style, etc. 'Rooms,' 'prices,' and 'styles' are all facets" (Canter, 1985: vi). Each facet may be conisdered alone or in combination (i.e., on an analytico-synthetic basis).

In each stream of facet research, the facet idea is usually expressed in ways that mirror the characteristic concerns of the field. For example, bibliographic classification systems are concerned with subdividing the world of knowledge on the basis of the "subjects" that are contained in documents in order to allow documents to be classified in the system. Consequently, a "facet" is defined appropriately, i.e., "...every subject has one or more aspects which correspond to the characteristics used as a basis for division. The sum total of the divisions of each aspect we shall call a facet" (Palmer and Wells, 1951: 31). In this case, subdivision of the world of knowledge into facets occurs on the basis of one characteristic of division at a time, and the purpose of this subdivision is to create facets that can be combined to express the subject of any document. In bibliographic classificaton, the individual components of each facet are called "foci" or "subfacets."

In the behavioural sciences, facets are used to design research projects and to formulate laws of social research, and the definition of "facet" reflects this orientation. One characterization is "...[one] way of describing the universe [of interest] is to say it consists of all the attributes of interest to the investigation which have a common content, so that they are classified under a single heading which indicates that content. ...The investigator indicates the content of interest by the title he chooses for the universe, and all attributes with that content belong in the universe" (Guttman, 1944: 141). Thus, a social researcher may define a universe of investigation by choosing, naming, and studying facets. In this field, the components of each facet are called "elements."

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III. Displaying Facets

It is generally assumed that methods of displaying information influence how and how well the information is understood. For example, the centrality of graphics to the comprehension of quantitative data was demonstrated by Wainer (1992), who presented three examples of displays that made scientific discoveries possible. One of the reasons for the various display changes in the *Thesaurus of Psychological Index Terms* was to improve the clarity of the thesaurus for users (Walker and Mulholland, 1992). Coll and Coll found that in their field the literature on display was "in disarray" (1993:745) and so they created a framework for research to determine the quality of table and graph presentations in information systems. Their framework contained sixteen variables divided into 5 sections (i.e., User Variables; Task Variables; Presentation Medium Variables; Data Variables; and Work Group Variables, 1993: 746, Table 1)).

No research appears to have been done, however, on how displays of qualitative concepts are constrained by the requirements of different research fields. The present paper undertakes a preliminary comparison of two methods of facet structure display on the basis of the function for which facets are used in bibliographic classification systems and in research design in the social sciences. Both fields valued the analytico-synthetic qualities of facet analysis, but each created a preferred method of facet expression.

A. Classification Schedules

In bibliographic classification, faceted systems are designed so that foci from various facets can be combined into a statement of a document subject. Notation is generally based on principles that are considered basic to a "good" notaton, e.g., expressiveness, mnemonic quality, stable citation order, unique facet indicators. In Ranganathan's CC, for example, citation order for each Basic Class followed a variation of his five postulated fundamental categories in the general facet formula: Personality, Matter, Energy, Space and Time (PMEST). Each facet was preceded by a punctuation mark to indicate that a different facet was going to appear (e.g., Matter is preceded by a semi-colon). Figure 1 shows the partial Library Science schedules for libraries from CC, 6th ed. (Ranganathan, 1964). Here, for example, all "Trans-local" foci start with 1, all "Local" foci start with 2, and all "Business" and "Other [business libraries]" foci start with 4. These notations would be preceded by a facet indicator to show which facet was being notated.

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Figure 1: Facet Display, *Colon Classification*, 6th ed.
(Ranganathan, 1964:2·30)

Partial Library Science schedules

	2 [P];[M]:[E] [2P]	[Facet formula for the class]
1	**Trans-local**	
11	World	
13	Nation...	
2	**Local**	
21	District	
22	City...	
4	**Business**	
42	Industry	
44	Newspaper office...	
	Others by **(SD)**	[Subject Device]
	(Illustrative)	
4(Q)	Religious	
4(X81)	Insurance	

Figure 2: Facet Display, *Bliss Bibliographic Classification*, 2nd ed
(Mills and Broughton, 1987: 100)

Partial Schedules, Class T, Economics

ECONOMIC SYSTEMS BY HISTORICAL FACTORS
[Economics T]
[(Economics of specific industries & services) TPU]...
(Economic history & conditions)
.(Periods)
.. * Add to - 2 letter B/V from Schedule 4A
.(Places)
.. * Add to - 3 letters A/BX following TBC...
(Social aspects)
. * Add to - 4 numbers & letters 4/9, A/S, U/Z from the main classification, except for classes
. otherwise provided for;
. - e.g. political parties & the industry concerned - 4RL...
(Management)
. * Add to - 7 letters Q/Y following T in TQ/TY
(Individual firms)
.(Favoured firm(s))...
.. * Add to - 85
.(Other firms)
.. * Add to - 8 letters C/Z from Schedule 2, followed by an alphabetising mark for firms name.
* Examples: supposing UOM is classmark for motor-car industry:
Export subsidies in the industry TPU OM7 O;
Industrial relations and Citroen TPU OM8 F(CIT) 6C.

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Figure 3: Facet Display, *Bliss Bibliographic Classification*, 2nd ed
(Mills and Broughton, 1984: 77)

Partial Schedules, Class K, Society

```
[SOCIAL STRUCTURE]
    [(Types of groups)]
        [KINSHIP]
            [Family & marriage (general)]
                [FAMILY]
                    [(Structure)]
                        [(Properties of family)]...
            (Types of families)
            . (By demographic factors)
    R       . . Statistical families...
    S       . . Standard families...
            . (By cohesiveness)
    U       . . Atomistic families
    V       . . Domestic families...
KCK         . (By group characteristics)
KCK B       . . Large families
    C       . . Small families
    E       . . Young families
```

Figure 2 shows a more recent facet display from BBC2, Class T, "Economics." Here, the basic notation for "Economics of specific industries and services" is TPU, and various notations are added to TPU, sometimes from Class T (e.g., "Management"), and sometimes from the whole classification (e.g., "Social aspects"). Figure 3, from BBC2, Class K "Society", shows how the hierarchy of the system is displayed at the top of a page. The hierarchy moves from [SOCIAL STRUCTURE] down through six hierarchical levels to [(Properties of family)] before the section of the schedules for (Types of families) begins. Here, KCK is the notation for the characteristic of division (By group characteristics), and a further space and letter is added for various foci within the (By group characteristics) facet. Throughout BBC2, citation order is mechanized by the use of retroactive notation, which is combined in the reverse order of the schedules and thus obviates the need for facet indicators.

B. Mapping Sentences

In social research, facet structure is shown by a "mapping sentence." Figure 4 shows a mapping sentence that may be used to illustrate the concept. This mapping sentence contains a universe of interest that has been divided into four "domain facets" (i.e., Facet A: Base of Comparison; Facet B: Entity; Facet C: Educational Goals; Facet D: Data Type) and one "range facet" (i.e., "high[ly] positive" to "high[ly] negative" opinion). The mapping

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Figure 4: Mapping Sentence, Educational Goals
(based on Lewy and Shye, 1978: 215-216)

	Facet A: Base of Comparison		*Facet B: Entity*	
The *worth* relative to	a_1 absolute standards a_2 alternative entity a_3 cost	of	b_1 personnel b_2 procedures b_3 processes b_4 programs	
	Facet C: Educational Goal			
for attaining	c_1 knowledge c_2 comprehension c_3 attitude c_4 affect c_5 values c_6 interest			as determined by the evaluator through
Facet D: Data Type				
d_1 performance scores d_2 questionnaire items d_3 direct observation		-------> [ranges from a]	high[ly] positive . . high[ly] negative	

[opinion of the] worth of the entity for the specified goal

sentence sets out all possible content of research into the worth of items for achieving certain educational goals. For example, using this mapping sentence, one might conduct research showing that "The *worth* relative to the (a_3 cost) of (b_2 personnel) for attaining (c_5 values) as determined by the evaluator through (d_1 direct observation) ranges from (a highly positive to a highly negative) opinion of the worth of the entity (i.e., personnel) for the specified goal, (i.e., attaining values)". All possible combinations of elements from each facet may be ascertained from the mapping sentence, and it would be possible to conduct a research project using each combination. If this were done, the entire universe of interest would have been exhausted. Each such combination of facet elements using one element from each facet is called a "structuple", i.e., $a_3b_2c_5d_1$ is the structuple for the above example. The simple notation for each element is based on the letter for each facet.

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Figure 5: Mapping Sentence for Fractions
(after Doron, 1987: 144)

An examinee (x) is asked to test item in (*A*: a_1 verbal; a_2 numerical; a_3 verbal and numerical) language, involving a task which requires

(*B*: b_1 knowing properties; b_2 recognizing mathematical concepts; b_3 knowing techniques of computation; b_4 computing; b_5 comprehending principles; b_6 solving practical problems) in the domain of (*C*: n_1 addition; n_2 subtraction; n_3 multiplication; n_4 division; n_5 finding the whole amount; n_6 combination of n_1 - n_6)

where the first number is a (*O*: o_1 natural number; o_2 fraction; o_3 improper fraction), the second a (*P*: o_1 natural number; o_2 fraction; o_3 improper fraction)

and the third is (*Q*: q_1 non-existent; q_2 a natural number; q_3 a fraction; q_4 an improper fraction) and

(*J*: j_1 the denominators are equal; j_2 the denominators are relatively prime; j_3 the denominators have a common factor; j_4 one denominator is a multiple of another; j_5 a combination of j_1 to j_4 holds) ----------> (*R*: correctly; incorrectly)

Figure 5 shows a mapping sentence constructed to check the content and construct validity of item banks for test items on simple fractions. In this case, the mapping sentence created a definitional system for making up test questions by combining the elements of each facet into all possible structuples. Statistical operations may be carried out on the basis of the mapping sentence to test the content and construct validity of the items generated on the basis of the mapping sentence (Doron, 1987). The analytico-synthetic principle is clearly visible. In addition, we may note that facet O is repeated in P and repeated with the addition of "q_1 non-existent" in facet Q. Repetition is necessary because only one element from each facet can be chosen, but problems testing knowledge of fractions would need at least two numbers. Further, facet Q needs element "q_1 non-existent" in case the problem does not have three numbers.

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Figure 6: Fraction Mapping Sentence as Schedules

Items for mathematics test:

A by language of presentation
- a_1 verbal
- a_2 numerical
- a_3 verbal and numerical

B by knowledge required for task
- b_1 knowing properties
- b_2 recognizing mathematical concepts
- b_3 knowing techniques of computation
- b_4 computing
- b_5 comprehending principles
- b_6 solving practical problems

N by mathematical operation
- n_1 addition
- n_2 subtraction
- n_3 multiplication
- n_4 division
- n_5 finding the whole amount
- n_6 a combination of n_1 through n_6

O by kind of number [may be repeated as many times as needed]
- o_1 natural number
- o_2 fraction
- o_3 improper fraction

J by kind of denominator
- j_1 the denominators are equal
- j_2 the denominators are relatively prime
- j_3 the denominators have a common factor
- j_4 one denominator is a multiple of another
- j_5 a combination of j_1 to j_4 holds

IV. Brief Comparison of the Two Types of Facet Displays

The purpose of facet analysis in classification theory is to facilitate the creation of classification systems for the subjects of documents. Rather than attempting to enumerate all possible subjects, a faceted classification system allows a classifier to choose appropriate facets for expressing the document subject and to synthesize a notation to make the subject explicit. Thus, facets are required for the whole universe of the classification system, whether that be the whole world of knowledge in a general system or a smaller field in a special system. The schedules of the system attempt to set out all possible facets (with their foci) that might occur in documents. In theory, all possible combinations of foci are anticipated by careful construction of the schedules. Since any relationships among subjects may pertain in any document, exact relationships among facets are not usually established. The system generally states that certain topics exist in the document, but does not undertake to state their

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relationships. Notational issues are complex because of the large number of possible combinations that can be constructed from different facets, each of which must be unique and cited in a specified order. It is unlikely that notation from every facet will be needed for a document, but it is possible that more than one notation from a single facet may be needed to express a document subject.

In social research, the purpose of the mapping sentence is to set out appropriate facets for the universe of some kind of research problem. Usually, there are many fewer possibilities than appear in bibliographic classification systems because the entire universe of possible research problems does not have to be accommodated in each mapping sentence. Natural language can be used to establish canonical relationships among the facets. In effect, a mapping sentence is a sentence with a series of blanks that may be filled in with the elements of each facet in turn. Notation can usually be restricted to a single initial letter because the number of facets is unlikely to exceed the number of letters in the alphabet. Citation order is not a problem because the mapping sentence itself establishes an unequivocal citation order. Furthermore, an element from each facet must be used in each structuple in order to create a complete set, but more than one element from a facet is not possible in a structuple. In that case, as in Figure 5, a facet may have to be repeated.

Thus, differing purposes of analyzing a universe of concepts into facets are reflected in the way the facets may be usefully displayed. It is interesting to attempt to "translate" each kind of display into the other. Figure 6 shows the effect of displaying the domain facets from Figure 5 in the standard format of a bibliographic classifiction system. In this case, at least, a classification schedule display seems equally appropriate for the domain facets of a mapping sentence. In this translation, facet O can be repeated as many times as necessary, so that the foci do not need to include "non-existent". The opposite kind of translation does not seem equally possible, however. It seems impossible to write a mapping sentence for the faceted display in, for example, Figure 2. To attempt to do so would necessitate writing a mapping sentence that would include, for example, the capability for combining all possible periods of economic history and conditions with every other facet in the entire classification system.

V. Conclusion

This paper has described two kinds of facet display as a product of the purposes for which facet analysis was undertaken in two research areas. The intersections between the two streams of facet research warrant analysis and interpretation. One interesting consideration is that social scientists have consciously used facet principles to create classification systems. For example, a system to classify the variables involved in researching gender differences in career development has been developed through facets (Solmon, Bishop and Bresser, 1986). Wishart and Canter (1988) invented a system to classify computer software on the basis of two facets, the depth and type of user involvement, and Blum (1989) developed faceted taxonomic subclasses for the "application" class of a system for educational objectives. A particularly interesting example occurs in McGrath's (1968) discussion of the facet principle as a general method of creating classification systems. Further work on the usefulness of the social research approach to facets for classificatory purposes remains to be done.

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