Collection Evaluation—
Theory and the Search for Structure

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DAVID H. STAM, BORROWING from René Dubos, urges us to think global-ly and act locally in developing collections, observing, "all libraries are linked in a great chain of access."[1] Philosophically, a good case can be made for this point of view, while considerable empirical evidence could be gathered to support it. Just how libraries and collections are linked, however, is an open question, particularly important for its implications about how they are accessed and used. The number of ways they could be linked is very large. We could use our imaginations and create all sorts of fanciful images—chain-linked fences, sociological organisms, ecological spaces, food webs, or even galaxies and clusters of galaxies. But library theory is in sad shape when it can only be described by image or metaphor—that a library is like something instead of being something. What a library really is can only be described in its own terms, its own structure. These images may have some redeeming value, though, because they hint of coherent structure. The emphasis is not so much on analogy as it is on synthesis. Atoms bind together to make a molecule, molecules a compound, compounds an organism, and so on. Everything is connected, from the minute to the massive. What binds everything together and what the whole thing looks like goes well beyond imagery. To see the whole and how the wholes are connected to make bigger wholes, and then to apply the insights discovered is the task of research, not rhetoric.

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In other words, we could gather some data, take a good look—which Stam urges us to do with comparative data from the Research Libraries Group—and see what sorts of links, if any, emerge. This approach—the empirical—has always been the best way to test our images. The analogies may be suspect, but the connections must be real. To gather and evaluate data, however, we must have some kind of framework for doing so—for containing the data and a means for evaluating it. From Stam's perspective that framework should be global and that is the perspective in this paper as well.

Thus, the purpose of this paper is twofold: first, to review the meaning and theory of collections and what is meant by structure; and second, to enumerate some of the ways that data on collections can be organized to reveal underlying global structure—the links and connections between collections, parts of collections, and the users of collections—i.e., a typology for evaluation. Evaluation consists of collecting data within some part of the typology, and then submitting the data to analytical procedures to determine the strength or weakness of the relationships.

Usually, analysis requires a prestated hypothesis about a possible relationship and a test of that hypothesis, the result of which may or may not support or explain the relationship. Ideally, hypotheses are stated in the context of some general theory. But our discipline is so devoid of theory capable of yielding viable hypotheses, that we must resort to hypothesis-generating techniques. Little more will be said in this paper about the distinction between hypothesis-testing and hypothesis-generating except to note that one is inferential and the other descriptive and exploratory, a distinction previously explored by this author.[2] Relationships lending themselves to hypothesis-testing in collection development were explored in another earlier paper.[3] The typology presented in the present paper is directed more toward structuring data for descriptive and hypothesis-generating studies.

The Meaning of the Collection

The Philosophical Image

We have a very difficult time overcoming the notion that a collection is its own reason for existence. Librarians hired to develop collections do just that—develop collections. They take their jobs very seriously and do a good job of it, whether intuitively, or logically, or systematically, or otherwise. The result is a collection which may or may not reflect the purpose of the institution, may or may not be based

on well-written policy, may or may not be comprehensive, may or may not meet minimum standards, and may or may not meet the needs of users. It is still a collection and that is what the profession of librarianship takes for granted as one of its basic and inviolate responsibilities. The official *Guidelines for Collection Development*,[4] and "Guide to Collection Evaluation Through Use and User Studies,"[5] compiled by the Resources and Technical Services Division (RTSD) of ALA, are testimony to this basic position. On the other hand, much has been said about another basic responsibility, improving service to users by analyzing circulation and other kinds of use. True, the RTSD collection development guidelines recognize the study of use—including circulation and interlibrary loan—as valid approaches to evaluation but use is seen as rationale instead of goal, evidence instead of mission. Development of "The Collection," with a capital "C," rather than service to the user, seems to be the primary mission. Without a collection a library is as nothing; it does not exist. On the other hand, some thoughtful authors believe that the emphasis has shifted to access and that, because of technological advances, good and direct service will be possible and librarians no longer will try to build and maintain large self-sufficient collections.[6] Whether a library or indeed librarianship can function without large collections, however, is not at issue here. Instead, given the basic reality of collections, how can we reconcile them with use and how can we characterize them in a way that the insights obtained would improve the availability, accessibility and, ultimately, user satisfaction?

Reflections–the World at Large
    One old metaphor says that the collection mirrors or should mirror the world at large. The metaphor implies that the world and the collection can be depicted in the same way. To "mirror" presumably means to reflect an accurate image of something. "At large" presumably refers to anything beyond the immediate or purely local community or institution. The notion is that somehow the components of the collection should correspond to the components of the environment. The RTSD *Guidelines* advise that these components should be expressed in terms of institutional mission and goals, clientele to be served, and subject boundaries.
    Rather than as reflections, perhaps we should simply think of the parts of the collection in a progressively broader, more comprehensive hierarchy beginning with the narrow restriction of the immediate or highly specialized, progressing to the global, and ending with the broadest possible universe. A basic distinction needs to be resolved,

however: whether the collection represents the world of knowledge—what is known—or the population of users or both. So the question is: To what extent does the collection represent, in terms of subjects and users, the immediate environment, the institution, the local group of institutions, the larger population, or the entire universe of knowledge? The usual way of putting this question is: Does the library have enough books and materials in each subject area to satisfy the needs of users in each of the areas or groups it serves? Again, that is not the question being asked here, though it is a perfectly valid question. Instead, we are more interested in determining how each of the components relate to each other within each level of the hierarchy and how each level of the hierarchy relates to every other.

The idea of hierarchy in librarianship is nothing novel. The quasi-military structure of the staff organization, with its professional and nonprofessional ranks (an intrinsic source of conflict, incidentally) is one type. Classification schemes like the Dewey Decimal system are others. The empirical components of the latter type, objects or ideas arranged in graded series, can be very difficult to identify and enumerate. In taxonomy, for example, to describe a new species of insect is one thing; to place it in the right genus and family of the taxonomic hierarchy is another. And in ecology, a fascinating and difficult problem is to identify the many unrelated species in different phyla of an ecological food chain—frogs, birds, insects, etc.—and how they relate or depend on each other.

A chain in which the larger species feeds upon the smaller is unidimensional—the birds eat the snakes, the snakes eat the frogs, the frogs eat the insects, and so on. But a chain in which they all feed upon each other is a web—the wasp eats the spider, or the spider eats the wasp, and the bird eats either—and is multidimensional.[7]

We might ask, What ecological chains and webs exist in our collections or networks? What independent and interdependent groups of individuals are there? Are there groups of individuals who use each other's materials to the exclusion of others? What clusters of subjects are used by what clusters of others? Are there clusters of library collections used exclusively for interlibrary loan by individual members of the clusters? Are there certain forms of materials that are used exclusively by certain groups of users? Are there certain forms associated exclusively with certain subjects? And what forms have characteristics in common? Can these clusters and groups be placed in a library ecosystem? If so, what is their importance? Are they unidimensional? Multidimensional? How can we describe this great biblioecosystem?

Perhaps the most important question of all is, What good are these potential insights? We have several good schemes for classifying our collections and we can easily count the number of users and the number of books. There are many studies which have done just that. What else do we need to know? Obviously we do not know what it is we do not know, but we do know that despite our best efforts, we do many things incorrectly or poorly. Why, for example, are less than half of the materials in so many libraries never used? Why are government documents underused? Why despite multimillion dollar book budgets are so many users frustrated in finding materials? Why do so many faculty never borrow a book or journal? And why do engineering students boast of never having set foot in the library? And should we worry about that? Why, in other words, do so many of our precious collections sit on the shelves gathering dust, while so many users cannot find the materials they want? Critics claim that one method is no better than another, but whatever helps to answer questions of this sort should also help to improve both collections and satisfaction.

The Context of Collections

Parts and People
In the early history of libraries, the advantages of bringing large numbers of books to a central location was obvious. The scholar no longer needed to build a larger personal collection. Even so, good libraries were scarce and, of necessity, restricted access to membership, or to their immediate constituency such as students and faculty of a college or members of a local geographic community. Although networking, computers and telecommunications make exhaustive collections no longer necessary, the basic reasons for maintaining libraries have not changed. The advantages are still obvious, but the components of the collection and the constituency—the parts and people—have become much more complex.

There is no need here to enumerate those components. Suggestions for doing so are included in the RTSD *Guidelines* and other methodological documents. For evaluation and for the typology to be outlined, however, it is necessary to know at least the broad classes. Those classes include the following:

1. *The users and user groups.* For evaluation, data would be gathered on individual users (anonymously and confidentially, of course) or

       individual groups. In a university, an individual might be a physi-
       cist, say, while a group might be the department of physics.
2. *The subjects.* Using any classification scheme, data would be
       gathered on any group of subjects, subtopics, or larger aggregates of
       topics within any particular level of a hierarchical scheme.
3. *The forms.* Since forms may be user-dependent or subject-dependent
       (e.g., certain groups may tend to use certain forms or subjects more
       than others) it would be necessary to enumerate the various forms—
       books, journals, maps, films, etc.
4. *The aggregates.* Users, subjects and forms may be aggregated in any
       meaningful way—for example, book > topic > subject > collection
       > network or scientist > discipline > department > college > univer-
       sity > network.

    These broad classes are familiar enough and ordinary; enumera-
tion alone offers no particular insight. But with powerful descriptive
techniques developed in recent years it is possible to discover (some
analysts say "recover") some extraordinary insights from ordinary
material.

The Paradigms
    Standard textbooks on collection development include discussion
of various approaches to collection evaluation. These discussions are
satisfactory insofar as they attempt to describe or simply list existing
practice—the paradigms. All of them are short on theory—necessarily
so, since collection development itself is short on theory. A paradigm, as
defined by Thomas Kuhn, is the extent to which the practitioners of a
discipline agree on its laws, theory and method.[8] Some fields, like
physics are high-paradigm fields. Others, like librarianship are low- or
preparadigm fields. We have few laws, precious little theory (but lots of
philosophy), limited methodology, and therefore little agreement. The
diversity of papers in this issue of *Library Trends* and the oft-made
comment "that there are no sure methods" are good examples. If there is
any agreement in library studies, it is on the methodology: anyone can
readily produce a checklist of methods, although we falter on how to
apply them, and descriptive methods are often confused with inferen-
tial. More importantly, when methods are discussed, we have no clear
idea of the theory in which the method resides, nor any clear idea of how
the components to be evaluated relate to one another. Good research and
good evaluation always set out to define and test the relationships
between one thing and another. Citation to authority, list-checking,
classification counts and reference to standards rarely do that. They are

qualitative methods, where personal judgment always seems to be the deciding factor.

Minimums and Ho-Hums

Of traditional methods, perhaps authoritative checklists have the most validity. They at least have been compiled by scholars familiar with a field. Minimum standards, however, have little credibility. There is no empirical evidence whatsoever that some magic minimum number of volumes will automatically bestow quality on a collection. It is ludicrous to maintain, for example, that two academic libraries, both with the same number of faculty and students, should necessarily have equal collection sizes. If one is in a humanities college and the other is in engineering, it is obvious that one requires more volumes than the other. Out of context, one minimum is "as good as another." No institution, to the author's knowledge, has ever been disaccredited for want of a good collection. Accrediting agencies are quite happy if the collection shows growth.

Theory and the Eleven Concerns of Science

Without scientific method, theory will not develop, and without theory, librarianship will not progress. No one pretends any more that librarianship is really a science, but there is no reason why librarianship should not be concerned with the concerns of science. Those concerns, as listed by Scriven, are observation, description, definition, classification, measurement, experimentation, generalization, explanation, prediction, evaluation, and control of the world (environment).[9] Good science addresses all of these concerns, not in isolation, but as a process, each in the context of all the others. The eleventh concern, control of the environment is, by itself, not so much science but engineering and technology; and it is with this concern that librarianship has been most preoccupied. In the last decade, we have seen major technological applications to traditional library processes, but with little change in old concepts. Bibliographic control and physical description, despite all the argument, is a success, while subject classification and access is a near failure. In the eighties, the microcomputer is all the rage, but theory in librarianship is not a hot topic. Theory has neither relevance, nor importance, neither meaning nor interest to the vast majority of librarians trained to do reference, cataloging, acquisitions, online retrieval, circulation, bibliography, or interlibrary loan—the staples of librarianship. They know what they have to do and can do it without

worrying about theory—like the young mechanic who can tear down and rebuild an automobile without reference to a manual and without understanding principle.

The number of good references to theory in the library literature are few, and those addressing collection development and evaluation might fill half a page. Buckland addresses theory of library services in many contexts, one of which is collection development and retrieval—about which he concludes pessimistically "that a combination of inability to predict the future, lack of management information, and present technology conspire to make collection development an imprecise art."[10] He adopts a standard definition of theory from Webster's *Third New International Dictionary of the English Language Unabridged*, "3.a.(1) The body of generalizations and principles developed in association with practice in a field of activity (as medicine, music) and forming its content as an intellectual discipline,"[11] giving several examples appearing to fit this definition. One example, "Structure as Theory," is also consistent with one of the two main objectives of this paper: a typology for discovering structure in collections. According to Buckland:

> In an important philosophical sense, the description of structure *is* [Buckland's italics] theory, in that structure is, by definition, the relationship between things....Material on structural relationships in library service constitutes an important part of "the body of generalizations and principles developed in association with practice."[12]

Hannaford discusses a basic requirement of good theory—i.e., the ability to explain—but concludes only that collection development can be scientific.[13] Hernon writes on the need for theory in the development of government documents collections, particularly by studies involving the development and testing of models and descriptive research.[14]

In a lucid essay on bibliometric theory, O'Connor and Voos expose the inability of inherently univariate and unidimensional methods such as Bradford's Law to contribute to theory of library use:[15]

> If bibliometric distributions have identifiable causes, then multidimensional analyses may provide more fruitful avenues of research than plotting new hyperbolic distributions. This multidimensional issue has serious implications for the sustained relevance of bibliometric distributions as aids to library decision-making.[16]

In this paper, the multidimensional approach is crucial in the search for structure.

Theoretical Models

Characteristic of too many theoretical models is their lack of testability. Atkinson presents a model of the contexts in which an individual document is selected: (a) knowledge of the document, (b) fixing its relationship to other documents, and (c) knowledge of the collection, its clientele and what is being published.[17] He concludes that, despite "mechanical" guidelines, selection can never be impartial or objective. Hazen advocates a structured subject approach to collection development in a complex, all-inclusive model containing all possible interlocking quantitative and qualitative variables, while criticizing studies limited to a small number of testable variables.[18] He concedes that his model is "not now qualifiable."

Empirical Studies

Baughman writes that "effective collection building is assumed to rest on identifying a structure" consisting of the overlapping relationships between demand, the knowledge of disciplines and literature patterns.[19] He provides empirical examples of literature patterns, overlapping subject areas and Bradford's Law distributions found in the social sciences.

Two of the most theoretically and empirically important effort recently to describe library use are those by Paul Metz[20] and Stephen Bulick.[21] Bulick has generated elaborate tables of subject areas used by students and faculty in different disciplines at Virginia Polytechnic Institute and State University. His data are invaluable for answering the basic question of who uses what and for looking at interdisciplinary relationships. His finding of a high degree of cross-disciplinary circulation (i.e., reading in a subject field by readers outside that field) agrees with this author's findings, though they differ in degree;[22] and such findings make "it all the more important that library collections serve the needs of 'outside' readers."[23] Metz also explores the relationships between cross-disciplinary circulation and the configuration of branch and department libraries on university campuses.[24] Without question, Metz's study and his thoughtful discussion of the implications is a major contribution to the methodology of collection evaluation and use. Global analysis of the kind of data he has collected should contribute significantly to the theory and structure of collections.

Like Metz, Bulick is concerned with who uses what. Both describe use of subject by disciplines, but they differ in orientation. Whereas Metz is more concerned with specifics and practicalities, Bulick is more concerned with general understanding and theory. He places the use of

libraries and hence the development of collections directly in the sociology of knowledge, citing Kuhn's concept of paradigm development and the concepts of ethnocentricity and supportiveness explored by this author.[25] It is important, Bulick notes, for librarians to understand subject relationships among disciplines. His Chapter VI, in particular, "Subject Use Among Disciplines," explores two questions: (a) which disciplines are net users of subject material from the others, and (b) whether evidence points to the existence of subject boundaries.[26] His data, from the University of Pittsburgh, are arrayed in matrices which readily facilitate investigation of his concerns—basically, crosstabulation of circulation by aggregated LC classes and members of social science disciplines. Though he stops short of multidimensional analysis, his data clearly support the possibility of "a larger dimension to what happens in the library."[27] He concludes that "the social sciences have much in common," and that "it is probably a bad idea to separate collections by social science discipline."[28]

Any structure discovered from Metz's data or from that using the typology to be suggested here or from any other must, of course, be theoretical, as Buckland says. But it would be structure discovered through observation and therefore empirical and thus capable of yielding testable hypotheses.

The Methodology of Structure

"Looking for patterns" is a phrase often used to describe virtually any research objective in librarianship. If holdings are ranked by LC class, the resulting table is described as a "pattern." If a relationship is found between two variables, it is described as a "pattern." In a stricter sense, a pattern should be something one can follow—like a path—or trace—like a template. Pattern should also imply something we can visualize or at least diagram, but nothing in the word implies much more than a linear or one-dimensional perspective, though surely multidimensional relationships exist in library practice.

"Structure" may be a better word for multidimensional perspective. If we were to visualize a structure in the familiar sense of the term, we would perhaps see a block, a cube, a house, or even a library—i.e., a three-dimensional edifice with length, width or height. And that is precisely what a structure is—an edifice, except that the dimensions need not be three. They can be one, two, three, or more. The vast majority of empirical studies in librarianship, and in collection development and evaluation in particular, have been one-dimensional or, if more than one, not recognized as such.

An interlibrary loan study, for example, which concludes that Little Library A borrows from Bigger Library B which borrows from Still Bigger Library C which, in turn borrows from Biggest Library D, like our biological niche space above, would be unidimensional, as in figure 1a. But if the study shows that all borrow from each other, then the structure would be at least two-dimensional: A borrows from C which borrows from B which borrows from A and so on, as in figure 1b.

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A---->B---->C---->D
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figure 1a.

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     B-------D
    / \     /
   /   \   /
  /     \ /
 A-------C
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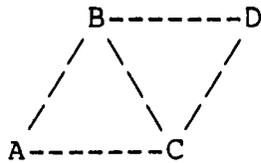figure 1b.

Likewise, our principal classification systems, Dewey Decimal (DDC) and Library of Congress (LC), are unidimensional when used as location codes, since they do not permit a book to reside in more than one location. Books shelved together may also have similarities to books shelved elsewhere in another part of the library, but our unidimensional practice cannot handle this multidimensional reality. To take a familiar example, some books on statistics are classified in sociology, even though they have an obvious relationship to other statistics books classified in mathematics. Though we may not be able to shelve these books together, we should and can find some other way to recognize their multidimensional similarity.

Simple shelflist counts are another example of one-dimensional practice that tells us little about the collection. The list in table 1 shows that Class D has twice as many books as Class A, that E has more than B, and so on, and from it could be computed a total, an average and

perhaps a standard deviation, but little else of help in evaluating the collection would be derived.

TABLE 1
SIMPLE SHELFLIST COUNT

LC class	Shelf Count
A	1,500
B	2,000
C	1,800
D	3,000
E	2,300
F	2,100

From this count alone, it cannot be determined, for example, what books in D and E, or D and F, have in common. Were this information included, classification, retrieval and evaluation could be improved. Users are familiar with the major limitations of library catalogs: lack of detail in subject headings and the inability to identify alternative access points. Solutions to these problems may lie in systems that supply more detail on co-occurring information in books, subjects and even whole collections. Examples are the number of subject headings held in common by pairs of books in a subject area, the number of copies or titles by the same author held in common by a pair of subjects, or the number of books held in common by a pair of libraries in a network. There may be many other points of similarity not discernible using conventional evaluation methods. "Something in common" is another way of saying "connected," and if something is connected it must have structure.

In short, a "structure" is something we can see. No matter how skillful a writer may be in verbally describing a new automobile, a sculpture, or movie, readers or listeners still want to know "what it looks like"—i.e., to "see it." No matter how well librarians describe their collections, the description would be more meaningful and accessible if it let readers "see" its structure. Traditional research may succeed in finding significant relationships between variables which describe parts of collections or the use of collections, and librarians may make evaluative judgments accordingly, but it is very difficult to see the collection as a whole.

Three methods for discovering structure are multidimensional scaling (MDS), cluster analysis, and tree fitting—familiar techniques in

psychology, marketing, communication, sociology, anthropology, and other social science fields. They are not yet familiar in librarianship, though MDS has been extensively used to describe relationships between scientists and between disciplines using cocitation data.[29] Classic MDS was developed by Torgerson.[30] An excellent and readable treatment of MDS appears in a little book by Kruskal and Wish.[31] Basically, MDS plots the similarity (or association) between two things (like cities) in a set of things as distances on a map. The map can be drawn in one, two, three, or more dimensions—like the straight-line distance between several cities in a row, or a conventional two-dimensional map, or in three dimensions, in which the third dimension would be altitude. Four or more dimensions are not easily plotted, except in two-dimensional combinations. Whenever something in common can be counted (or measured) between all pairs of things in a group of things or all pairs of persons, say, in a group of persons—e.g., the number of times two authors are cited together, or the number of book titles two persons in a group both own—then a multidimensional map can be drawn. The result is a multidimensional picture—a structure—of the entire group.

Cluster analysis, often done with MDS, determines which objects in the group being studied (e.g., scientists, subject areas, journals, animals, books, collections) are most similar to each other and then plots them into homogeneous, or mutually exclusive groups. A good treatment of cluster analysis appears in Anderberg.[32] If done in the context of MDS, and if clusters are truly present, they will show up on the multidimensional map. It is possible that the objects are all equally similar or dissimilar, and thus no clusters will appear. In any case, the clusters, as part of the entire group of objects, can readily be visualized. An interesting application of cluster analysis is the study of subject coverage of online databases by Yerkey.[33] Yerkey's clusters are interpreted in terms of tree fitting.

Tree fitting arranges pairs of objects in an increasingly detailed hierarchical diagram like the branches of a tree. The diagram is sometimes called a dendrogram, and though it is not dimensional, it is readily visualized and easily grasped as in figure 2.

An example of collection-use analysis using MDS with cluster analysis and a tree diagram is given in McGrath.[34] Shepard gives an excellent comparison of results using MDS, cluster analysis and tree fitting.[35] How data are organized as input for these techniques is outlined in the next section.
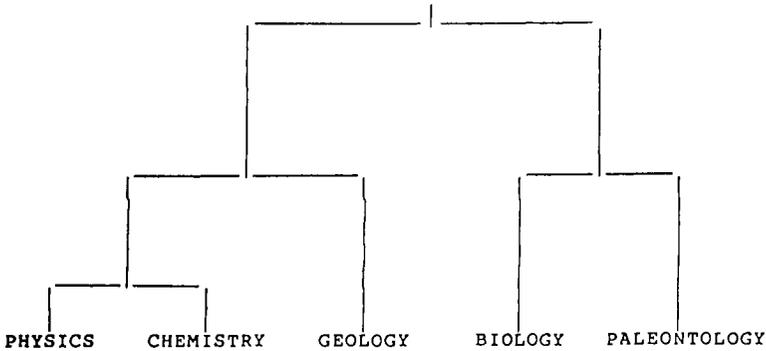
PHYSICS   CHEMISTRY   GEOLOGY   BIOLOGY   PALEONTOLOGY

figure 2. Tree Diagram

A General Typology for Discovering Pattern and Structure in Collections

This section contains a typology of models which have the capability of discovering visible structure in whole collections. The terminology follows that of Shepard[36] and Young and Lewyckyj.[37] For the most part these models depart from classic, inferential, hypothesis-testing practice, in that they are initially descriptive and hypothesis-generating. Once the data are collected and processed, then never-before-seen "hidden structure" is presumably discovered. Hypotheses may then be generated to explain that structure, though it is not within the scope of this paper to discuss them. Several explanatory, or inferential and hypothesis-testing methods (e.g., t-test, analysis of variance, chi-square, correlation, and multiple regression) have been used in library research for a number of years, and at least one of them (chi-square) is now commonplace.

Two-Way Input from One-Way Practice

All of the models require input from two-way matrices with many rows and columns of data. Technically, a matrix can be a single row or column, but the power of multivariate methods stem from their ability to handle large matrices—up to one hundred or more rows and columns.

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A matrix may have objects in both rows and columns, or objects in the columns and attributes in the rows. Both the rows and columns are submitted to analysis and thus are "two-way." In conventional data analysis, the data are usually one-way where the rows are the unit of analysis and only the columns (variables) are submitted to analysis. (An exception is two-way analysis of variance.) Procedures for submitting these models to analysis can be found in Young and Lewyckyj.[38] There is no limit to the number of objects or attributes possible in any given matrix, though more than about one hundred would strain current computer programs and make interpretation overly difficult. On the other hand, fewer than ten would probably discover little if any structure.

Critical to interpretation of the matrices and their analysis is the definition of the input data. Four data types are listed by Shepard in his taxonomy.[39] These are:

1. *Proximity data.* Some measure of similarity, substitutability, affinity, confusion, association, correlation, interaction, dissimilarity, distance, closeness, or co-occurrence. Proximity data can also be derived from dominance or profile data. Data can be either in a square matrix in which rows and columns correspond to the same objects or in a symmetric martix in which rows and columns correspond to different objects.

2. *Dominance data.* A measure of the extent to which the row object is preferred to, is chosen over, defeats, or otherwise dominates the column object. Data are arranged in square matrices and rows and columns correspond to the same objects.

3. *Profile data.* The data format is rectangular. Rows correspond to objects and columns correspond to variables (or vice versa). Each entry gives the measured value of one object with respect to one of the variables. The row (or column) of m measured values for any object is considered to be a profile characterizing that object. Proximity and dominance data can also be treated as profile data.

4. *Conjoint measurement data.* Rectangular matrix, rows correspond to n levels of one variable and columns correspond to m levels of another variable. (This type of data is not considered further in this paper and no examples are given. The reader may wish to explore it independently.)

Examples and considerable elaboration of these four data types are given by Shepard.[40]

Two-Way Input for Multidimensional Output; Eight Models for Data Collection

Each of the following descriptive models are defined in terms of the first three of Shepard's four data types.

1. Subject Structure Model

General Model. This model seeks to determine how subject areas are related to each other. Objects are individual subject areas, which may be defined as subject headings, disciplines, individual classification numbers, or groups of classification numbers. There are no attributes in this model.

Matrix. Square, symmetric or asymmetric. Rows and columns represent the same objects—i.e., subject/subject. (For examples see the appendix under the definitions for symmetric and asymmetric.)

Data. Proximity data. Examples: the number of times something co-occurs between any pair of subjects; the number of subject headings shared by two disciplines, or the number of books which could be classified in any pair of disciplines—e.g., biological statistics, or the history of medicine.

Method. Classic Euclidean MDS and cluster analysis.

Output. Multidimensional maps showing spatial distances between every pair of subjects. Subject clusters may also show on the map; or a tree diagram showing most similar pairs and clusters. The model and the data are defined by Torgerson.[41]

2. User Structure Model

General model. This model seeks to determine the relationships between individual users or groups of users, in terms of their common interests. Objects may be occupations, academic departments, majors, or disciplines. There are no attributes in this model.

Matrix. Square, symmetric or asymmetric. Rows and columns represent the same objects (see table 2 for example).

Data. Proximity data. Example: the number of books with common classification numbers charged out or otherwise used by any pair of user groups. In the example, biologists charged out 39 books having the same class numbers as books charged out by chemists.

Method. Classic Euclidean MDS and cluster analysis.

Output. Maps showing spatial distance between every pair of user groups, clusters of user groups, or a tree diagram. Output may be interpreted as subject use of the collection and evaluated accordingly. *Reference.* The model and the data are defined by Torgerson.[42]

TABLE 2
SHARED USE BY USER GROUPS OR USER "OVERLAP"

	Biologists	Chemists	Geologists	Physicists
Biologists	--			
Chemists	39	--		
Geologists	13	27	--	
Physicists	9	59	31	--

3. Subject/user model

General model. This model seeks to determine the relationship between subject areas and the users. Individual users or user groups are the objects, and subject areas are the attributes—or vice versa, depending on one's perspective or research objective. Technically, called "multidimensional unfolding."

Matrix. Nonsymmetric; rectangular, can be square, a special case. Rows and columns represent different things (see table 3 for example).

TABLE 3
USE OF SUBJECT AREAS BY USER GROUPS

	Biologists	Chemists	Geologists	Physicists
Biology	113	35	8	15
Chemistry	47	153	26	36
Geology	9	13	109	12
Physics	8	14	19	123

Data. Proximity data. Example: number of books, articles, or other materials charged out or otherwise used on a subject by practitioners of the subject. Typical of data in this model is the larger diagonal; users tend to use more of the materials in their own discipline.

Method. Finding structure in rectangular matrices, with multidimensional unfolding, is uncertain. Better results are achieved by rendering the matrix symmetric or, if square, treating it as asymmetric, and then using classic MDS as in 1 and 2 above. Symmetrization methods cannot be discussed here, except to say that correlation of rows or columns works well if data are not sparse.

Output. Four types of maps can be generated with this input model, depending on how the matrix is symmetrized: maps showing distances between (1) user-groups in subject space, (2) between subjects in user-groups space, or (3) a user/subject map, in which the discipline of the user and the subject are treated as the same object, or (4) between subject areas and user-groups, in which case, the input matrix must be doubled by having both rows and columns consist of both user-groups and subject areas.

References. the data are defined by Coombs[43] and an example of output is given by McGrath.[44]

4. User/formats model

General model. This model seeks to determine the relationship between users and specific formats of library materials. Intent is to depict the collection in terms of use by format—i.e., how users are grouped or concentrated in terms of the type of materials they use. Individual user groups are the objects and the formats of materials are the attributes. Multidimensional unfolding model.

Matrix. One or the other of the objects (the user groups) or the attributes (the formats—e.g., books, journals, maps, fiche, film, newspapers, manuscripts, slides) are likely to be more numerous, so that the matrix would be rectangular and nonsymmetric.

Data. Profile data. Example: the number of units of a particular format used by a particular user group.

Method. If classic MDS is used, the matrix must be symmetrized. This model may prove to be awkward to interpret, however. If the number of objects or attributes are not large, more traditional hypothesis-testing methods, such as analysis of variance and discriminant analysis may be more appropriate. These methods would determine whether one format was used more than another, and which formats more appropriately belong to one user group or another. However, if the number of objects or attributes are large, MDS and cluster analysis are better.

Output. Maps showing distances between users in format space.

Reference. The matrix and data are defined by Shepard.[45]

5. Subject/format model

General model. This model seeks to determine the relationship between subject areas and specific format of materials. Intent is to depict the collection in terms of subjects by format—i.e., how subjects are grouped or in terms of the type of materials. Individual subjects are the objects and the formats of materials are the attributes. Multidimensional unfolding.

Matrix. Like the user/formats model, and for the same reason, this matrix would be rectangular and nonsymmetic.

Data. Profile data. Example: the number of units of a subject in each format.

Method. As in model 4 above.

Output. Maps showing distances between subjects in format space.

Reference. The matrix and data are defined by Shepard.[46]

The following models seek structure in networks, comparing entire collections to each other for the purpose of cooperative collection use and development, shared cataloging and interlibrary loan. Users at the network level would be the libraries themselves.

6. Network Model I: Shared Titles

General model. This model addresses what is traditionally called "title overlap." It seeks to determine the relationship between individual libraries in terms of their shared holdings without regard to what those holdings are. Individual libraries—i.e., their collections—are the objects.

Matrix. Square, symmetric. Rows and columns represent the same individual library collections (see table 4 for example).

TABLE 4
SHARED HOLDINGS OR "TITLE OVERLAP"

		Library			
		A	B	C	D
	A	--			
Library:	B	68	--		
	C	89	79	--	
	D	92	85	98	--

Data. Proximity data. Example: number of titles held in common by each pair of libraries.

Method. Classic MDS and cluster analysis.

Output. A map in two or more dimensions showing the distances between library collections. Tree diagram showing hierarchical clusters of libraries.

References. Examples of output for this model are given by McGrath.[47] The literature of overlap has been reviewed by Potter.[48] The matrix and data are defined by Shepard.[49]

7. Network Model II: Shared Subjects or Subject Overlap

General model. This model seeks to determine the relationship between libraries in terms of their shared subject areas, but without regard to whether they share individual titles. The libraries are the objects, and individual subjects or LC or Dewey classes are the attributes.

Matrix. Rectangular, asymmetric. Rows and columns are different (see for example table 5).

TABLE 5

HOLDINGS BY LIBRARIES AND LC SUBCLASSES OR "SUBJECT OVERLAP"

			Libraries		
Classes	A	B	C	D	E
AC	9	5	9	3	4
AE	4	3	7	8	9
AG	2	3	2	6	8
BF	3	7	8	1	1
BJ	9	7	6	4	2
...	.....				

Data. Profile data. Example: Number of volumes held by each library in each class of the LC or Dewey schedules.

Method. Matrix must be symmetrized on the columns—i.e., the libraries. Then classic MDS can be used.

Output. Multidimensional maps of distances between libraries in subject space.

References. The matrix and data are defined by Young and Lewyckyj[50] and Shepard.[51]

8. Network Model III: Cooperative Use of Collections

General model. This model evaluates the extent to which libraries in a network use each other's holdings. A library is both object and attribute—more specifically, user and usee.

Matrix. Square, asymmetric, unfolding. Rows and columns are the same, but data are transitive, or directional. The columns represent

those libraries using each of the other libraries. Each row represents a library that is used by all other libraries (see table 6 for example).

TABLE 6

INTERLIBRARY LOANS: AMOUNTS BORROWED AND LENT
BY LIBRARIES

		Borrowing Libraries			
		A	B	C	D
	A	623	0	4	0
Lending	B	11	911	13	4
Libraries:	C	2	5	1218	3
	D	30	19	12	801

Data. Profile data. Examples: each cell of the matrix represents the number of (1) items borrowed from one library by another or, (2) catalog records used by another. In the example above, Library D borrowed 0, 4, 3, items respectively, from A, B and C, but loaned 30, 19, 12 to A, B and C. The numbers in the diagonal would be very large, representing a library's own use of itself.

Method. Multidimensional unfolding. Results more interpretable if the matrix is symmetrized so that classic MDS may be used.

Output. For the unfolding model, probably a one-dimensional map— i.e., on a line, with the libraries arranged with high users on one end and low users on the other. For classic MDS, at least a two-dimensional map, showing clusters if any.

Reference. The matrix and data are defined by Shepard.[52]

The above typology is neither formal nor complete. Many other models, objects, attributes, and data sources are possible. The basic intent has been to illustrate the principle of organizing data in rows and columns in such a way that their respective objects or attributes would have meaningful relationships to each other—particularly when the number of rows and columns is large, as it is likely to be in evaluation of the collections. The power of traditional hypothesis-testing models is limited to a relatively small number of variables, whereas the methods discussed in the typology—MDS and cluster analysis—can reduce large matrices to something we can more readily comprehend and visualize.

Discovered Structure

Analysis of data in any of the above models could have any of the following outcomes:

1. A newly discovered structure, with a significant relationship to known functions and thus with profound contribution to new theory.
2. A newly discovered structure with no significant relationship to known functions but, because of the insights obtained, having potential contribution to theory.
3. Confirmation of known structure with a significant relationship to known functions and thus confirmation of existing theory.
4. Confirmation of known structure with no significant relationship to known functions. This is an unlikely outcome; it is difficult to imagine an existing, isolated and meaningless structure with no basis in reality.
5. No discernible structure—i.e., a purely random pattern of similarities with no significant relationship to existing function.

There is no guarantee that the search for structure would be successful, nor that it would lead to any particular discovery. Insights may still be gained, nevertheless, from evaluation of the methodology itself. Then one must determine whether the methodology is deficient, whether some other approach should be used, or whether the search for structure is a meaningful pursuit in the first place.

Evaluation and the Twelfth Concern

In Scriven's scheme, science is not complete unless all eleven concerns are addressed as a process—all the way from observation and description to experimentation, explanation, prediction, evaluation, and control. Much of library research seems contented with itself when only one of the eleven concerns is addressed. Indeed, this paper addresses but one of those concerns, description (or "morphology" as it is called in some sciences)—for that is what the reduction of large matrices sets out to accomplish, albeit in a systematic way.[53] But addressing a single concern is perfectly all right if understood in the context of all the other concerns and that it must ultimately lead to or facilitate the next stage in the process. The other papers in this issue of *Library Trends* also address but one of Scriven's concerns: evaluation. If all of these papers are taken in the larger context, they could well have substantial meaning for theory. Certainly there can be no argument that the eleventh concern,

control of collections, is the rationale for evaluation. The rationale for control, in turn, is the highest possible service to the user. For library and information science and for collection development theory that is the twelfth and ultimate concern.

Appendix

Definition of Terms
(The following terms apply to the eight models described in the text)

Asymmetric. Describes a matrix in which the rows and columns represent the same things, and the values in the upper and lower halves are two measures of the same thing, as in Table A, where both 16 and 25 measure the association between BF and HA.

TABLE A
EXAMPLE OF ASYMMETRIC MATRIX OR USE BY LC CLASSES

		LC Classes			
		BF	HA	QA	TK
	BF	--	25	13	5
LC	HA	16	--	37	8
classes:	QA	22	32	--	19
	TK	17	16	15	--

Attributes. Characteristics of the objects; analogous to variables. Usually, but not necessarily, rows represent the attributes.

Conceptual space. Space in which distances between objects are plotted. On a real map distances are plotted in geographic space. In this typology, distances are drawn in user space or subject space. Technically, space is Euclidean.

Dissimilarity. An expression of relatedness in which large numbers mean little relatedness and small numbers mean lots of relatedness—like the amount of overlap between two libraries (the number of books held in common).

Euclidean space. The straight-line distance between two points, specifically, the length of the hypotenuse in a right triangle (Pythagorean theorem).

Matrix. A set of data arranged in rows and columns. An individual cell in the matrix represents something characteristic of, or held in common between, or co-occurring between its respective row and column.

Mode. Refers to the number of sets of objects or attributes. Usually, the mode is either one or two only. Not analogous to the mode of frequency distributions.

Objects. The units being compared: e.g., persons, subject areas, disciplines, parts of the classification system, forms of materials, collections. Usually, but not necessarily, columns represent objects.

One-way data. A matrix in which only the rows or columns, not both, have identity.

Rectangular. A matrix in which the number of rows and columns are different.

Similarity. A number or value on a scale expressing relatedness between two objects, two attributes or between an attribute and an object. A large number means lots of relatedness, a small number little relatedness.

Square. A matrix in which the number of rows and columns are the same.

Symmetric. Describes a matrix in which rows and columns represent the same things, and the values in the upper half are the same as in the lower half, as in the following matrix:

TABLE B
Example of Symmetric Matrix or Use by LC Classes

		LC classes		
		BF	HA	QA	TK
	BF	--	25	13	5
LC	HA	25	--	37	8
classes:	QA	13	37	--	19
	TK	5	8	19	--

LC Classes

The upper half is usually not given, but is shown here for illustration. The diagonal is often omitted since values represent perfect correspondence of an object with itself and are therefore meaningless.

Three-way data. A set of two-way matrices.

Two-way data. A matrix in which both the rows and columns have identity.

Unfolding. Refers to a rectangular or square matrix in which the rows and columns correspond to different objects but can sometimes be treated as if they were the same objects.

References

1. Stam, David H. "Think Globally—Act Locally: Collection Development and Resource Sharing." *Collection Building* 5(Spring 1983):21.

2. McGrath, William E. "Morphology and the Structure of Libraries—A Fresh Look at Descriptive Methods for Management." *Science & Technology Libraries* 4(Spring/Summer 1984):117-32.

3. _____ . "Circulation Studies and Collection Development: Problems of Methodology, Theory and Typology for Research." In *Collection Development in Libraries: A Treatise* (Foundations in Library and Information Science: A Series of Monographs, Texts and Treatises, vol. 10, pt. B), edited by Robert D. Stueart and George B. Miller, Jr., pp. 373-403. Greenwich, Conn.: JAI Press, 1980.

4. Collection Development Committee, Resources and Technical Services Division. *Guidelines for Collection Development,* edited by David L. Perkins. Chicago: ALA, 1979.

5. Christiansen, Dorothy E., et al. "Guide to Collection Evaluation through Use and User Studies." *Library Resources & Technical Services* 27(Oct./Dec. 1983):432-40.

6. DeGennaro, Richard. "Shifting Gears: Information Technology and the Academic Library." *Library Journal* 109(15 June 1984):1204-09.

7. Worster, Donald. *Nature's Economy: The Roots of Ecology.* San Francisco, Calif.: Sierra Club Books, 1977, pp. 294-301; Pringle, Laurence. *Ecology: Science of Survival.* New York: Macmillan, 1971; and Cohen, Joel E. *Food Webs and Niche Spaces.* Princeton, N.J.: Princeton University Press, 1978.

8. Kuhn, Thomas S. *The Structure of Scientific Revolutions,* 2d ed., enl. Chicago: University of Chicago, 1970.

9. Scriven, Michael. "The Philosophy of Science." *International Encyclopedia of the Social Sciences.* New York: Macmillan and The Free Press, 1968, vol. 14, pp. 83-92.

10. Buckland, Michael K. *Library Services in Theory and Context.* New York: Pergamon Press, 1983, p. 88.

11. Ibid., p. 35; *Webster's Third New International Dictionary of the English Language Unabridged.* Springfield, Mass.: G. & C. Merrian, 1971, *s.v.* "theory."

12. Buckland, *Library Services in Theory and Context,* p. 37.

13. Hannaford, William E. "Toward a Theory of Collection Development." In *Collection Development in Libraries,* pp. 573-83.

14. Hernon, Peter. "Documents Librarianship in the 1980s: Current Issues and Trends in Research." *Government Publications Review* 9(March/April 1982):99-120.

15. O'Connor, Daniel O., and Voos, Henry. "Empirical Laws, Theory Construction and Bibliometrics." *Library Trends* 30(Summer 1981):9-20.

16. Ibid., p. 12.

17. Atkinson, Ross. "The Citation as Intertext: Toward a Theory of the Selection Process." *Library Resources & Technical Services* 28(April/June 1984):109-19.

18. Hazen, Dan C. "Modeling Collection Development Behavior: A Preliminary Statement." *Collection Management* 4(Spring/Summer 1982):1-14.

19. Baughman, James C. "Toward a Structural Approach to Collection Development." *College & Research Libraries* 38(May 1977):242.

20. Metz, Paul. *The Landscape of Literatures: Use of Subject Collections in a University Library.* Chicago: ALA, 1983.

21. Bulick, Stephen. *Structure and Subject Interaction: Toward a Sociology of Knowledge in the Social Sciences.* New York and Basel: Marcel Dekker, 1982.

22. McGrath, William E., et al. "Ethnocentricity and Cross-Disciplinary Circulation." *College & Research Libraries* 40(Nov. 1979):511-18.

23. Metz, *Landscape of Literatures,* p. 60.

24. Ibid., pp. 95-99.

25. McGrath, "Ethnocentricity and Cross-Disciplinary Circulation."

26. Bulick, *Structure and Subject Interation,* p. 123.

27. Ibid, p. 1.

28. Ibid, p. 160.

29. Small, Henry G., and Griffith, Belver. "The Structure of Scientific Literature. I: Identifying and Graphing Specialties." *Science Studies* 4(1974):17-40.

30. Torgerson, Warren S. *Theory and Methods of Scaling.* New York: Wiley, 1958.

31. Kruskal, Joseph B., and Wish, Myron. *Multidimensional Scaling.* Beverly Hills, Calif.: Sage Publications, 1978.

32. Anderberg, Michael R. *Cluster Analysis for Applications.* New York: Academic Press, 1973.

33. Yerkey, A. Neil. "A Cluster Analysis of Retrieval Patterns Among Bibliographic Databases." *JASIS* 34(Sept. 1983):350-55.

34. McGrath, William E. "Multidimensional Mapping of Book Circulation in a University Library." *College & Research Libraries* 44(March 1983):103-15.

35. Shepard, Roger N. "Multidimensional Scaling, Tree-Fitting, and Clustering." *Science* 210(24 Oct. 1980):390-98.

36. _____ . "A Taxonomy of Some Principal Types of Data and of Multidimensional Methods for Their Analysis." In *Multidimensional Scaling; Theory and Applications in the Behavioral Sciences,* edited by Roger N. Shepard, et al., vol. 1, pp. 21-47. New York: Seminar Press, 1972.

37. Young, Forrest W., and Lewyckyj, Rostyslaw. *ALSCAL-4 User's Guide; a Guide for Users of ALSCAL-4: A Nonmetric Multidimensional Scaling and Unfolding Program with Several Individual Differences Options.* Carrboro, N.C.: Data Analysis and Theory Associates, 1979.

38. Ibid.

39. Shepard, "A Taxonomy of Some Principal Types of Data," pp. 24-29.

40. Ibid.

41. Torgerson, *Theory and Methods of Scaling.*

42. Ibid.

43. Coombs, Clyde Hamilton. *A Theory of Data.* New York: Wiley, 1964.

44. McGrath, "Multidimensional Mapping," pp. 103-15.

45. Shepard, "A Taxonomy of Some Principal Types of Data," pp. 27-28.

46. Ibid.

47. McGrath, William E. "Multidimensional Map of Library Similarities." In *Communicating Information,* (Proceedings of the 43rd Annual Meeting of the American Society for Information Science, Anaheim, Calif., 5-10 Oct. 1980), edited by Alan R. Benenfeld and Edward John Kazlauskas, vol. 17, pp. 298-300. White Plains, N.Y.: Knowledge Industry Publications, 1980; _____ . "Implications for Cooperative Collection Development in a Random Group of Academic Libraries; or, Beyond Overlap." In *Options for the Eighties* (Proceedings of the Second Conference of the Association of College and Research Libraries, Minneapolis, 1-4 October 1981), edited by Michael D. Kathman and Virgil F. Massman, Greenwich, Conn.: JAI Press, 1982; and McGrath, William E., and Hickey, Thomas B. *Research Report Prepared for OCLC on Multidimensional Mapping of Libraries Based on Shared Holdings in the OCLC Online Union Catalog.* Dublin, Ohio: OCLC Office of Research, 1983 (OCLC/OPR/RR-83/5).

48. Potter, William Gray. "Studies of Collection Overlap: A Literature Review." *Library Research* 4(Spring 1982):3-21.

49. Shepard, "A Taxonomy of Some Principal Types of Data," pp. 24-25.

50. Young, and Lewyckyj, *ALSCAL-4 User's Guide.*

51. Shepard, "A Taxonomy of Some Principal Types of Data," pp. 27-28.

52. Ibid.

53. McGrath, "Morphology and the Structure of Libraries."