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Progress Report on a New Scheme for the Classification of Knowledge

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Outline of the theory of a proposed new scheme of classification of knowledge, specifying its basic assumptions and its points of departure from existing schemes, describing possible mathematical models for the scheme, and indicating the mnemonic notation and coding proposed. Progress is reported on the development of applications of the scheme to general and special library classifications and to the document collections of small organisations, groups and individuals. Possibilities for future research are outlined and further potential applications are listed.
(Author)

1. Introduction

For several years, there have been widespread criticisms of the UDC and other existing systems for the classification of knowledge, and their users have become increasingly aware of their inadequacies and limits. Partly because of this situation and partly because I faced severe classification and information retrieval problems in my own scientific work, I began, in 1967, to formulate a possible alternative approach to the classification of knowledge which, I hoped, would help to fill this gap and usefully complement the existing general classifications. I outlined some of its principles and possible applications in my first paper [1], and proposed a mathematical structure and introduced some possible notations in my second paper [2]. The present article summarises the theoretical approach, reports on current progress in several application areas, gives some illustrative examples, and indicates possible future developments.

2. Theoretical Approach

The basis of the proposed new scheme is the subdivision of *knowledge*, defined here as the universe of discourse, of everything that has been written about, described or discussed, into *subjects*, i. e. specific subdivisions of knowledge. In this respect, it is complementary to the approach used by the Classification Research Group (CRG), which concentrates on synthesising subjects from individual terms, namely entities, abstract concepts, processes, and activities.

Shera [3] listed eight requirements for a traditional scheme of classification:

1. Linearity of subject arrangement;
2. Inclusiveness (coverage of all knowledge);
3. Meaningfulness of all terms;
4. Meaningful differences between all terms;
5. Significant arrangements of terms;
6. Unique arrangement of terms;
7. Infinite hospitality to new terms;
8. A uniquely definable notation for each term.

Problems arise because, if *all* these requirements are met, it is very difficult and often impossible to meet at least some of the following desirable criteria:

9. Helpful collocation, whereby related subjects are arranged 'close together';
10. Adaptability to a wide variety of library and user needs and to the rapid advances of knowledge;
11. Logical structure of arrangement of related subjects;
12. Ease of use by classifiers, indexers, librarians, information officers, readers, and other users.

On examining this situation, I concluded that the root of the difficulties was the use of an exclusively hierarchical system, which failed to take account of the facts that the structure of knowledge is like a network, and that meaningful units of subject matter often overlap. Because of this, I proposed abandoning three of the traditional criteria, namely linearity, unique arrangement, and standard notation.

In the scheme, knowledge is to be subdivided into subjects of different degrees of specificness, including:
fields, roughly equivalent to traditional basic disciplines, such as Philosophy, Mathematics, Physics, Economics;
subfields, corresponding to major divisions of fields, e. g. Optics is a subfield of physics;
topics, corresponding to subdivisions of a subfield, e. g. Optical System is a topic in Optics;
groupings, which are convenient sets of fields, such as Mathematical Sciences which consists of Logic, Mathematics, Mathematical Statistics, Numerical Analysis, Mathematical Modelling, General Systems Theory.

Note that the distinctions between these categories are not very precise, and that a subject may advance from one category to another more general category, in course of time; for example, Quantum Optics has developed from a topic in Optics to a subfield of Physics, and Numerical Analysis and Mathematical Statistics have developed from branches of Mathematics to fields in their own right. More occasionally, a field becomes obsolescent and must be relegated to a more specific category, e. g. Divinity, Alchemy, which were very prominent in the Middle Ages but constitute a much smaller proportion of the universe of discourse today. The more general a category, the greater the tendency of its members to overlap; thus most of the groupings are interlocking, several emerging new fields overlap with their neighbours, e. g. Biochemistry overlaps with Chemistry and Biology, subfields occasionally overlap, but topics are usually mutually distinct, except in cases where they are deliberately formed as compounds.

The first objective of the proposed scheme is to form a *map of knowledge*, that is, to determine the identity of

all significant subjects of discourse that are in use or have been in use, and to chart the relationships between them. This map, being a network, can be represented by a mathematical structure and also by a system of coding. Thus there is a collection of subjects, each represented by a suitable object in the mathematical structure and by a set of codes in the notation of the scheme; note that a subject does not usually have a unique code, because several alternative schemes of notation are allowed.

In [2], the mathematical structure chosen for the scheme was a *directed graph*, i. e. a network of points connected by directed lines, each point corresponding to a subject, and the direction of a line between the points representing two subjects is from the more inclusive subject to the more specific subject; if the subjects are non-comparable, there is no line between the points representing them.

The following relations were used:

Equivalence (=) S = T means that subjects S and T are identical:
Non-equivalence (≠) S ≠ T means that subjects S and T are not identical;
Less than (<) S < T means that S is part of T;
More than (>) S > T means that S includes T; i. e. T is part of S;
Noncomparability (%) S % T means that none of the relations S = T, S < T, S > T holds between S and T.

For completeness, include a *universal subject*, U, corresponding to the whole of knowledge, such that U > S for all subjects S, and a *null subject*, N, with no knowledge content, such that N < S for all subjects S.

It is evident that this structure is not hierarchical, because it is possible to find combinations of subjects S, X, Y, such that X > S, Y > S, but X % Y, whereas, in a hierarchy, the relations X > S, Y > S would imply that one of the relations X = Y, X > Y, X < Y holds. However, sets of subjects can be extracted, all members of which from a hierarchy in relation to each other.

The formulation given in [2] is only provisional and needs revision and further development, in the light of comments and criticisms already made on it. For example, investigation is needed of the possibility of using a *lattice* as the appropriate mathematical structure. In a more accurate formulation, account must be taken of overlaps between subjects and the difficulties of precise definition for many subjects. This suggests that, at the next stage, a mathematical model should be used in which subjects are represented by sets of points, consisting of the most specific topics into which they can be divided. For this sort of model, the relations = ≠ < > would still apply, but there would be two forms of noncomparability;
Overlap (o) S o T means that S and T overlap and S % T;
Non-overlap (∅) S ∅ T means that S and T do not overlap, i. e. there is no subject X such that X < S and X < T, except for the null subject N.

Subject codes can be compounded by the use of *connectors*; this is a convenient way of representing subsidiary subjects which are either aspects of a single subject or show several subjects in relationship to each other.

In [2], the following set of connectors was used:

S.A.	means *subdivision* A of subject S
S.A.B.	means subdivision B of subdivision A of S, and so on
SnA	means subdivision A according to *facet n* in a faceted classification of S
S, X	means specific example X in subject S
S:T	means subject S applied to subject T
S:	means 'applied S'
S;	means 'principles of S', 'pure S'
S+T	means the *combined subject* consisting of knowledge belonging to S and/or T
S&T	means the *overlap* of S and T, consisting of knowledge belonging to both S and T
S–T	means the *subtractions* of T from S, consisting of knowledge belonging to S but not to T
S–	means *various*, not explicitly specified, aspects of S
S/	means *miscellaneous* aspects of S, usually parts of S awaiting further classification
S?	means a body of knowledge, believed to be S, but where there is some uncertainty about the correctness of this assignment

It is arguable that an insufficient number of relations and connectors have been chosen for the scheme, but I have, at the present stage, deliberately kept the number fairly small, for simplicity; this seems to be fairly adequate for the present applications of the scheme, where very detailed subdivisions of knowledge are not usually envisaged. More elaborate sets of relations have been proposed, such as those developed by Farradane [4], but, whereas they can be applied to very fine and exact specifications of topic, they are correspondingly harder to use without special training.

A mnemonic notation has been proposed [2], available in several variants, to cater for different library and user needs. For a given noncompounded subject, each variant uses a combination of capital letters, related to the full name of the subject. The first two, but not the third, variant uses connector symbols for the codes of compound subjects. The first variant uses single letters for a few very broad groupings (this is optional), two-letter codes for groupings and (optionally) for other main classes (i. e. those that are fields), three-letter codes for fields, four-letter codes for subfields. The second variant uses four-letter codes for groupings and fields as well as subfields. The third variant uses more mnemonic codes (usually not more than ten capital letters) for subjects of all categories. Two-letter codes are available for major types of library contents; for details, see [2]. The codes are intended for public use, but a user can define his own piece of code by replacing the first letter of a piece of code in any variant by *. Provision is also available for those who wish to incorporate sections of coding from standard classification schemes. Two alternative symbol sets have been suggested [2], one of which can be used on typewriters and the other of which can be used on standard computer input/output equipment, including remote terminals.

While I believe that a mnemonic notation is desirable for the proposed classification scheme, I wish to point out

that it could be used with various other forms of notation, perhaps with minor alterations to the notation used for some of the connectors.

3. The Development of a Preliminary Map of Knowledge

Note on Notation. Each grouping, mentioned in this section, has, enclosed between brackets after its full name, its proposed one-, two- or (occasionally) three-letter code in Variant 1 and its proposed four-letter code in Variant 2.

The *totality of knowledge* (U) can be broadly subdivided into Science/Technology (S, ST, SCTE) and The Humanities (HU, HUMN), though these two groups overlap, especially in the grouping Psychological Sciences and Technologies (PS, PSST) and Social Sciences, Technologies and Studies (SO, SOST). Largely overlapping S but, for some purposes, useful to consider separately, are the Integrative Disciplines (I, ID, INTD), which are essentially unifying or common principles, theories and techniques, which can be applied to practically the whole range of subjects. At the frontiers of the contemporary scientific conceptual framework and beyond is a region of more or less unknown phenomena (X, PT, PATR), which in turn subdivides into Parascience (PA, PASC), i. e. the 'border areas' of science, and The Transcendental (TR, TRSC), which is more or less 'out of reach of' contemporary science.

Knowledge can also be subdivided approximately into discipline-oriented (D, DI, DIOR); event-oriented (E, EV, EVOR); problem-oriented (P, PR, PROR); and value-oriented (V, VA, VAOR) subjects. Another subdivision is into empirical (EM, EMPI), methodological (ME, METH), and theoretical (TH, THEO) subjects.

S subdivides further into Mathematical Sciences (MA, MASC); Science (in the narrower sense) (SC, SCIE); Technology (TE, TECH); Parascience (PA, PASC); Methodologies (ME, METH); parts of the last three of these groupings lie beyond the borders of science. SC splits further into Natural Sciences (NA, NASC) and Human Sciences (HS, HUSC), the latter consisting mainly of parts of PS and SO. NA consists of Physical Sciences (FS, PHSC) and Biological Sciences (BI, BISC). TE subdivides approximately into Engineering (EN, ENGN); Food, Agriculture, Farming, Fishery, Forestry (FA, FAGF); Medicine/Healing/Health (MD, MEDH); Useful Arts/Crafts (UA, USAR), consisting of most parts of TE that are not science-based. ST can also be subdivided into Physical Sciences and Technologies/Engineering (PH, PHST); Biological Sciences and Technologies (BI, BIST); Social Sciences, Technologies and Studies (SO, SOST).

I subdivides into Philosophy (FI, PHI, PHIL); Universal Studies (UN, UNST), i. e. studies of the universe as a whole; Methodologies (ME, METH); Mathematical Sciences (MA, MATH); Information, Communication, Control, Computing (IC, ICCC); Systems Sciences, Technologies and Studies (SY, SYST). These groupings overlap considerably with each other, and PHI also partly overlaps with H and V, outside I.

H subdivides into Psychological Sciences, Technologies and Studies (PS, PSST); Education (ED, EDUC); most of X; Religion (RE); most of V; most of P; most of E; Social Sciences, Technologies and Studies (SO, SOST); Languages (LA, LANG). V subdivides further into Ethics, Morality, Philosophy of Life (ET, ETHM) and Arts (AR, ARTS), including Fine Arts, Music, and Performing Arts, as well as overlapping with SO. E can be divided approximately, according to the time of its subject-matter, into History (HI, HIS, HIST); Current Affairs (CA, CAF, CAFF); Futures (FU, FUT, FUTR); these refer, respectively, to actual past events, actual recent and contemporary events, and predicted or postulated or possible future events. P overlaps extensively with TE, PS, SO and V; two of its additional groupings that are especially important are Practical Living (PL, PRLI), a rather wide-ranging set of subjects which covers a variety of aspects of H, and The Environment (in the widest sense) (EN, ENVM). Major subdivisions of SO include Economics/Finance (EC, ECFI) and Organisation/Policies/Administration/Management (OR, ORPM).

The analysis given above outlines the subdivision of contemporary knowledge into major groupings; it shows very clearly how often these groupings overlap with each other and indicates that they cannot be arranged hierarchically but only in a network of interlocking subjects.

Finally, I will report briefly on the extent to which I have developed the map of knowledge in more specific subject categories. I have already identified and coded most of the fields and many of the subfields, but I have listed topics only for a few fields and subfields. Much work still remains to be done in charting the relations between groupings, fields and subfields. I have deliberately done relatively work on topics, because the proposed new classification scheme is intended to apply mainly to the subdivision of knowledge into groupings, fields and subfields, the levels at which the deficiences of existing schemes become most obvious and severe. Subdivision of knowledge into topics is often handled well either by appropriate sections of existing general classifications or by existing classifications of specific subjects.

4. Applications to General Classifications for Libraries

One function of the map of knowledge will be to provide a comprehensive list of the subject that need to be included in a general classification. Inspection of the existing general classification schemes shows that some of the fields and subfields are either hard to place there, often having to be squeezed into very narrow sectors with the result that the notation for them is unnecessarily complicated, or sometimes that no provision is made for them at all. This is partly because of the rapid advance of knowledge, faster than the schemes are updated, and partly because the totality of subjects forms a network and cannot be forced into a single hierarchical order.

Thus it becomes increasingly difficult to assign an appropriate linear order for a classification of knowledge, yet many libraries base their arrangement on a one-dimensional shelf order. For such libraries, this means that, even if an 'ideal' scheme were available, there would be anomalies whereby some sets of closely related subjects would be placed far apart. In practice, it should be pos-

sible to overcome this dilemma partly by using library arrangements that are two-dimensional or even three-dimensional, as has been suggested previously. For example, the second dimension can be incorporated by using parallel lines of bookcases, together with other lines of bookcases perpendicular to these, and the third dimension can be introduced by assigning different subjects to shelves at different levels in the same bookcase. Using this approach, it is possible for the literature on a given subject to be located close to a larger number of the other subjects that are related to it, and thus to improve the degree of helpful collocation of the library.

Thus the most appropriate shelving arrangement may depend, not only on the user requirements and functions of a particular library but also on its physical configuration.

In practice, many libraries, especially general-purpose libraries, prefer to retain one of the general classification schemes, in spite of their defects, because conversion to a new scheme would be too costly and/or because some of the existing schemes maintain comprehensive bibliographic and cataloguing services. Even here, the map of knowledge can be applied, in order to indicate which extra subjects need to be provided for and some of the locations where they can reasonably be placed.

Although the proposed new classification scheme will have no unique shelf order, recommended for all libraries, I have given, in the Table, an illustrative example of a possible rough approximation to a shelf order for 'main classes' that might be suitable for some general libraries. Comparison with existing schemes shows that the order for this example is closest to that of the Bliss Classification. Although a beginning has already been made, further work needs to be done to draw up dictionaries, indicating the notations in existing schemes for the groupings, fields and subfields specified in the map of knowledge.

The most severe problem arising from the use of the shelf ordering given in this example occurs in connection with the arrangement of science and technology in a single order. Here, a painful choice has to be made between putting related sciences and technologies together but separating different sciences and different technologies (as in Bliss and the present example) and following a sequence of sciences by a sequence of technologies (as in DDC and UDC) thus separating closely related science-technology pairs. This difficulty can be considerably alleviated, for example, by using a pair of parallel lines of bookcases, one for the sequence of sciences, the other for the sequence of technologies.

5. Applications to Special Subject Classifications

Work is in progress on the more detailed subject analysis of the groupings I, UN, ME, MA, IC, SY, X, PA, TR,PR and of the fields Mathematics, Numerical Mathematics/ Numerical Analysis, Mathematical Statistics/Probability Theory, Computing, and Transport. I have chosen these fields because I am specially interested in them and because I have extensive experience of work in several of them. In this work, due account is being taken of existing classifications, where they are available.

6. Applications to Small Document Collections

The proposed new classification scheme is especially adaptable to the collections held by small organisations and groups and individual users, where the arrangement needs to be adjusted to very special combinations of subject matter and to be made easily comprehensible and simple to apply. The public codes of the scheme may be used, but, if the user wishes, they can be supplemented by private user-assigned codes, for subjects with which the user is specially concerned, wherever this is found convenient. Again, shelf order should be adapted to specific user needs.

The new scheme can also be applied to provide a system for sorting new documents as they enter the user's library. The user starts by assigning, for example, between 6 and 24 groupings, by subject matter and/or by form of document (e. g. whether book, pamphlet, report, offprint, journal, press cutting). The user first sorts the documents into compartments corresponding to these groupings. Secondly, for each grouping, the documents in the corresponding compartment are sorted into the subclasses assigned to that grouping. If necessary, subclasses can be sorted into still finer subclasses, and so on, until all documents are in the required final categories.

The groupings chosen will often correspond to groupings or main classes or fields used in the general scheme, and the categories inside the groupings will often correspond to fields or subfields, but both groupings and subclasses within them can be user assigned wherever the user finds this convenient. It should be noted that the various stages of sorting need not all be performed with absolute accuracy, because advantage can be taken here of the network structure of knowledge, e. g. a document on Educational Psychology could reach this compartment via Education or via Psychology; as a result of this, some costs can be saved on the sorting operations.

7. Some Possibilities for Future Work

[2] lists some specific questions that need to be settled, in order to lay the foundations for further progress toward and detailed development of a practical new classification scheme.

It also suggested several projects that need to be carried out, as soon as the basic principles of the scheme have been finalised:

1. Detailed and rigorous formulation of the agreed principles;
2. Full specification of the agreed variants of notation and coding;
3. Drawing up detailed schedules for all the widely used groupings, fields, and subfields of knowledge, and for the more important topics in selected fields and subfields. This would continue preliminary work already carried out, and discussed in Sections 4 and 5 of the present article. It is *not* intended to make the schedules anything like as detailed as those of most parts of the existing general schemes.
4. Compiling dictionaries and keys between subject names (including synonyms), codes of the scheme (all chosen variants), and codes used by other standard classifications (especially DDC, UDC, Bliss). Some work on this has already been started.

Table: An Example of a Possible Main Class Order for a General Library

Name of Main Class	Coding (Variant 1)	Coding (Variant 2)	Main Classes in Bliss
Reference Works	RF	REFR	1
Generalia	U or GE	GENR	7
Integrative Disciplines	I or ID	INTD	A
Philosophy	FI or PHI	PHIL	A
Universal Studies	UN	UNST	A
Methodologies	ME	METH	A
Mathematical Sciences	MA	MATH	A
Information/Communication/Control/Computing	IC	ICCC	A?
Systems Sciences, Technologies, Studies	SY	SYST	A?
Science/Technology	S or ST	SCTE	A to H
General Science	SC	SCIE	A to G
Technology	TE	TECH	B to H, Q, U
Natural Science	NA	NASC	A to G
Physical Sciences and Technologies	PH	PHST	B to D
Physical Sciences	FS	PHSC	B to D
Engineering	EN	ENGN	B to C
Physics	FY or PHY	PHYS	B
Chemistry	CH or CHE	CHEM	C
Earth Sciences and Technologies	GE	GEST	D
Space Sciences and Technologies	AS	ASST	D
Biological Sciences and Technologies	BI	BIST	E to H
Biological Sciences	BS	BISC	E to G
Food/Agriculture/Fisheries/Forestry	FA	FAGF	F to G
Medicine/Healing/Health	MD	MEDH	H
The Humanities	H or HU	HUMN	H to Z
Human Sciences	HS	HUSC	various
Psychological Sciences, Technologies, Studies	PS	PSST	I etc.
Education	ED	EDUC	J
Subjects beyond Science	X or PT	PATR	?
Parascience	PA	PASC	?
The Transcendental	TR	TRSC	?
Religion	RE	RELG	A or K or P or Z*
Value-Oriented Subjects	V or VA	VAOR	A or K or P or Z*
Ethics/Morality/Philosophy of Life	ET	ETHM	A or K or P or Z* also Q to R
Event-Oriented Subjects	E or EV	EVOR	L to O
History	HI or HIS	HIST	L
Current Affairs	CA or CAF	CAFF	L to O
Futures	FU or FUT	FUTR	?
Problem-Oriented Subjects	P or PR	PROR	various
Practical Living	PL	PRLI	various
The Environment	NV	ENVM	?
Social Sciences, Technologies, Studies	SO	SOST	K or P, Q to T
Organisation/Policies/Management	OR	ORPM	Q to S
Management/Business	MN or MAN	MANB	Q?
Policies/Politics	PO or POL	POLI	R etc.
Law, Legal	LG or LEG	LEGL	S
Economics/Finance	EC	ECFI	T etc.
Useful Arts/Crafts	UA	USAR	U
Arts	AR	ARTS	V
Recreations	RC	RECR	V
Languages	LA	LANG	W to Y
Literature	LI	LITR	Y
Works of Fiction	FI	FICT	Y
Miscellaneous	MI	MISC	7

Note 1 Works on Library and Information Sciences (LS, LIS or LISC) may be placed before RF or inside IC; corresponding Bliss class is 2 or J or Z.*

Note 2 For the wider groupings, the main class order shows suggested locations of works on that grouping in general, but the Bliss column shows *all* Bliss classes relevant to that grouping, against such an entry indicates the alternative class location allowed by the Bliss scheme.

5. Development of computer programs and software, to work on projects and applications related to the scheme.

Research also needs to be done on further applications of the scheme, for example:

1. Information retrieval:
   a. Search in library collections;
   b. Search in the files of 'small users';
   c. Search in data banks;
   d. Referral of enquiries to the appropriate libraries, information centres, specialist organisations, individual experts, etc.;
2. Organisation of information centres and information services, for example specifying for what subject areas they should be set up or extended;
3. Classification of projects and activities;
4. Classification of qualifications, skills, aptitudes an interests;
5. Matching of personnel to projects.

8. Conclusions

Although several features of the proposed new scheme for classifying knowledge may seem controversial, I personally believe, from my experience with it hitherto, that it will usefully complement the existing general and special classification schemes and the alternative approach being developed by the Classification Research Group. Its applications to library classification and arrangement, though useful, may be comparatively limited, but its other applications will probably be more extensive and valuable. The scheme seems to be specially well adapted to information handling with the aid of computers and to the processing of information stored in data banks.

9. Acknowledgments

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Systeme der Waren- und Aktivitätsklassifikation (Systems for the Classification of Commodities and Activities)

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To acquire a better survey of existing ordering systems for commodity classification, 3 different types of such systems are listed according to the different purposes they are intended to serve. They include supply-oriented systems (who supplies what?) for from 40,000 to 100,000 items; systems for statistical purposes (10,000 to 30,000 items) and systems for the cataloguing of commodities in companies and administrative services (up to 10,000,000 items), in the latter commodities actually on the market are included. (I. C.)

In einer Druckschrift des Netherlands Central Bureau of Statistics (CBS) (1) heißt es

"The activities in the field of commodity classifications undertaken by various international organizations have resulted in an large variety of nomenclatures between which in some cases (and with difficulty) comparisons can be made by means of cross reference keys; in other cases they are not at all possible" ... "It goes without saying that this diversity of nomenclatures does not only lead to a lack of comparability but also to an increase in cost."

Obwohl Ansätze zu verzeichnen sind, die Fülle der vorhandenen Klassifikationen zu erfassen und analysierend zu vergleichen, ist die Kenntnis der existierenden Ordnungssysteme, ihrer Beziehungen und der Tendenzen zu ihrer Harmonisierung noch unbefriedigend.

Im folgenden seien einige wenige im Felde der Ware und warenbezogener Aktivitäten bestehenden Arten von Ordnungssystemen charakterisiert:

1. Vertriebsorientierte Waren-Ordnungs- und -Informationssysteme
(für anonyme Abnehmer, 40 000 bis 10 000 Positionen)

Wo es darum geht, hunderttausende in Frage kommende