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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

THE ROLE OF GRAPHIC DISPLAY OF CONCEPT RELATIONSHIPS IN INDEXING AND RETRIEVAL VOCABULARIES including a THESAURUS OF DOCUMENTATION TERMS

by

L. ROLLING

1965

Directorate "Dissemination of Information"
Center for Information and Documentation - CID

Paper presented at the FID/CR International Study Conference
on Classification Research
Elsinore, Denmark - September 14-18, 1964

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C O N T E N T S

1. INFORMATION FLOW AND GRAPHIC ARTS

A certain type of information flow occurs in almost every field of every human activity. The best known examples are the flow of knowledge between teacher and student and the conveying of information by way of published documents from authors and editors to the general public or to specialized audiences.

Almost every kind of administrative work consists in making available, recording, processing, or disseminating some kind of information. Even in the most routine types of manual work, some instructions have to be conveyed to the worker. Publicity involves passing on ideas to potential customers. Artists and composers have a message to transmit to those who look and listen.

Let us now consider the various media by which information is transmitted. Speech is one such method of communication, written or printed text is another. Although they are both certainly the most widely used methods, they are not necessarily the most efficient.

The importance of the graphic arts as a way of communicating knowledge is continuously increasing, a trend which is being underestimated by many, and particularly by the documentation world.

Of course, nobody will ignore the tremendous development of the television and motion picture industries, based on the techniques of photography; in fact, knowledge is conveyed quickly and without effort to the spectator; but the photographic arts have their shortcomings and limitations, and other types of graphic representation are required to illustrate a great number of subjects; especially theoretical questions, and problems involving some type of generalization can be profitably represented by maps and charts, drawings and flow-sheets, plots and curves, graphs and diagrams.

2. USE OF GRAPHIC METHODS IN DOCUMENTATION

The problem raised by modern documentation techniques, and especially those related to classification research, are of this type relying on generalization that should take advantage from graphic methods. It is true that, in recent years, linguists, working f.ex. in the field of automatic translation, have extensively used graphic methods in an attempt to make the logical structure of sentences accessible to machine processing.

But the main and most essential problem in documentation is the compatibility between

a) the author's concepts

b) the free-language words used by the author to represent these concepts, and

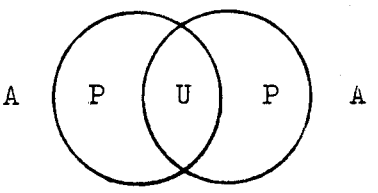
c) the standardized form of representation adopted by the documentalist for the storage and retrieval of the information,

and the convertibility from one to the other.

It is surprising to note that no attempt was made to call upon the various methods of graphic representation to get closer to this problem. Yet the Euler diagram, well known to the supporters of classification and indexing by concept coordination, showed that it is possible to represent the subject coverage of a keyword or classification code by a two-dimensional area.

It is obvious that a comprehensive representation of a semantic field would require much more than two dimensions; materialistic considerations , however, imposed severe limitations.

I have thus tried to represent a complete subject field and its terminology in a two-dimensional continuum, with every concept, word, or keyword represented by a limited area within the subject field.



A = Alien
P = Penumbral
U = Umbral

Fig. 1: Euler Diagram

The circles represent the subject coverage of two keywords used for document retrieval by concept coordination. Relevant documents are found only in the area (U) covered by both keywords, whereas the crescents (P) represent partially pertinent documents.

As the experts assembled in Elsinore have a great variety of backgrounds, the subject field of documentation was chosen for this experiment, in order to hold the discussion open for everybody. This appeared to be a perilous enterprise, because of the fluctuating terminology of the subject field. By all means, it must be clearly stated that it was not intended to clarify definitively the terminology of documentation. However, it should be interesting to show how, even in the absence of a generally accepted standardized vocabulary, graphic representation overcomes most of the difficulties inherent in a fluctuating terminology.

3. CONSTRUCTION OF TERMINOLOGY CHARTS

A compilation was made of various term lists and glossaries in the field of documentation (11 to 21), and a total of 648 terms were selected as falling within the limits of the subject field. These terms were divided into six groups of equal importance, corresponding to the following topics :

Do1	: Publications	(124)
Do2	: Terminology	(85)
Do3	: Classification	(99)
Do4	: Indexing	(96)
Do5	: Information Storage	(120)
Do6	: Information Retrieval	(124)

In the second step the terms of the six groups were entered on separate charts, and every term was assigned a position in accordance with its relationships with the neighboring terms. Relations of hierarchy, synonymy, and association (co-occurrence) were taken into consideration.

Fig. 2 is the chart representing group Do2 (Terminology).

A number of terms have gathered to form clumps of related terms, and others form clusters around one term particularly representative of the concept involved.

In a third step, an attempt was made to define the subject area covered by each of the terms, using curves similar to the circles of the Euler diagram*). Fig. 3 shows the chart corresponding to the Do2 (Terminology) group. Obviously there is a great deal of overlapping between the subject areas covered by the various terms. This corresponds to the natural redundancy of free language, but is also due to a lack of consistency in the definitions existing for a number of terms.

Fig. 3 includes some examples of synonyms (SPELLING/ORTHOGRAPHY, MEANING/SIGNIFICATION), near-synonyms and related terms (KNOWLEDGE/INFORMATION, GLOSSARIES/DICTIONARIES), and terms having a hierarchic relationship (WORDS/KEYWORDS).

The charts thus developed define with a maximum of accuracy the subject coverage of the terms represented, but they are far too intricate to be used themselves for indexing and retrieval. They constitute a sort of graphic demonstration of the impossibility of using natural language for documentation purposes. The solution adopted by the documentalists for this problem is to compile a standardized vocabulary by cutting out or prohibiting the use of synonyms and redundant terms, which are connected to the standard terms by several types of cross-references such as the SPECIFIC TO, GENERIC TO, ALSO SEE of the Defense Documentation Center (formerly ASTIA) Thesaurus (12) and the BROADER TERM, NARROWER TERM, RELATED TERM of the Engineers Joint Council Thesaurus (13). An average of 8 cross-references per term confers a cumbersome bulkiness to these thesauri.

A graphic representation of this solution can be achieved by introducing into the initial chart (Fig. 2) a number of arbitrary boundaries separating the essential concepts, but not the clumps and clusters of related terms. The whole subject field is thus divided into a number of non-overlapping polygonal domains, each of which contains a set of terms linked by hierarchic or synonymy relations. Each can be represented by one single term or keyword, which is shown underlined in Fig. 4. This procedure greatly facilitates the choice of the term to be used as keyword. The signification of the standardized keyword is defined graphically by the area of the polygonal domain, which is limited by the existence of the neighboring domains.

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*) In the original Euler diagram, the circles representing keywords are used to delimit areas in a continuum representing the documents; the present curves are used to delimit the meaning of words in a continuum representing the concepts.

The advantage of this disposition is that every concept corresponding to one well-defined spot in the two-dimensional plane will be represented by one single term and not by a number of synonyms or related terms. For the documentalists, the difficulties lie in the somewhat arbitrarily modified definitions of the terms when they are taken from the natural language into the standardized vocabulary. In the graphic display the definition and especially the limits of application of a keyword can be taken in at a glance.

As presented in Fig. 4, the charts are perfectly usable for indexing and retrieval purposes, without the aid of any alphabetical list or such complicated and cumbersome tools as scope notes and cross-references. Especially helpful is the fact that a single glance at the chart shows the conceptual coverage of a keyword and indicates which keyword is to be used instead of a given non-keyword term.

Many documentalists, however, accustomed to the strict order of classification, will be disappointed by the absence of obviously displayed hierarchic connections. Others will be bothered by the presence of so many redundant terms, the use of which is prohibited. A variant of the terminology chart was therefore constructed: it is the arrowgraph, presented in Fig. 5 and in Fig. 6 (Euratom Thesaurus).

After deleting non-keyword terms from the chart, the domain boundaries are replaced by perpendicular arrows; if the chart is well constructed, the arrows are found to represent relations between keywords; in the case of a hierarchic relationship the direction of the arrow is from the generic to the specific term; terms on the same hierarchic level and terms otherwise related are connected by double arrows.

This sort of graphic display is simpler, easy to take in at a glance, and notably more appealing to people with a sense of hierarchy. The documentalist can enter the graph at the first keyword that comes to his mind, and follow the arrows up to the most pertinent keyword available in the graph; some arrows may even lead to related terms in other graphs of the system. The arrowgraph type of representation was therefore used for the preparation of the Euratom-Thesaurus, which is in use at the CID, Euratom's Information and Documentation Center (1,2,3,4) (Fig. 6).

While the arrowgraphs take care of the cumbersome cross-referencing between keywords, they do not do away with the obligation to compile a glossary of non-keyword terms with references to the keywords that should be used instead.

The annexed "Thesaurus of Documentation Terms" consists of six terminology charts prepared for the above-mentioned six keyword groups, and of an alphabetical list of the keywords resulting from this compilation. The structure of the Thesaurus thus obtained is slightly different from that of the Euratom-Thesaurus (1), which comprises arrowgraphs representing 43 keyword groups.

4. APPLICATIONS OF TERMINOLOGY CHARTS

The Thesaurus of Documentation Terms has been used for keyword assignment to several hundred documents. The average indexing depth was 6.7 keywords.

Consistency of indexing was acceptable, though much lower than the consistency attained with the Euratom-Thesaurus after 3 years of indexing activity by expert documentalists using a fixed terminology.

Experience with keyword graphs was gained mainly from extensive use of the Euratom-Thesaurus, which serves for indexing and retrieval in the field of nuclear science and technology. Indexing at the CID started in 1961; today ten university-trained documentalists at the CID and a number of contract-holders in scientific institutes are active assigning keywords to abstracts of documents of nuclear interest. More than 250,000 documents have already been analysed, and 60,000 will be added every year. As the indexing depth varies between 10 and 15 keywords per item, almost 3 million keywords are available for retrieval at the present time. This huge effort in money and manpower was, of course, closely supervised and its efficiency was regularly evaluated and compared with the standards established in other documentation centers. On the other hand, retrieval operations are in the pilot stage, and only a limited number of search requests have been processed to date. Nevertheless, the efficiency of the graphic display schemes was clearly established for the three areas in which use is made of them : thesaurus updating, indexing, and retrieval.

4.1 Thesaurus Updating

A retrieval system based on concept coordination is operated with a maximum of efficiency if the frequency of assignment of all the keywords is of the same order of magnitude. Heavily posted keywords present low selectivity, whereas seldom used terms encumber the system. One method of improving a thesaurus is therefore to determine periodically the frequency of assignment of its keywords; low-frequency keywords are eliminated and their postings transferred to terms of higher generic level; the posting to high frequency keywords can be divided between a number of newly introduced terms representing more specific concepts.

The terminology charts (Fig. 4) are valuable tools for this operation. Eliminating a term from the Thesaurus amounts to deleting the line under it and the domain boundary that separates it from the keyword which is going to absorb it and collect its postings.

Example : Multilingual Dictionaries, initially selected as a keyword, is absorbed by Dictionaries, and the term is placed into the same domain.

Splitting of highly posted keywords amounts to introducing new boundaries. The chart shows clearly which new references are to be introduced.

Example : If Semantics is used too often, Roots and Etymology could be made separate keywords of lower posting in addition to Semantics. The reference "Cognates use Roots"

A newly introduced concept easily finds its optimal position in the chart.

Examples : Ruly English finds its place between Language Analysis and Artificial Languages. Amalgamates is placed near Polyterms.

In practice, all recent modifications can be accounted for by writing them in color until they are officialized by the next thesaurus revision. It has also proved useful to introduce frequency data into the arrowgraphs in order to take in at a glance the relative importance of neighboring or related keywords.

4.2 Indexing

Indexing can be based on the terminology charts (Fig. 4) alone. The documentalist will mentally draw a line circumscribing the conceptual area covered on the chart by the document to be analyzed. Fig. 4 shows such a dotted line, delimiting the contents of a paper analyzing the problem of synonymy in keyword thesauri.

Our limited experience with the Thesaurus of Documentation Terms shows that a marked gain in time and an increase in indexing consistency can be achieved.

These conclusions apply well to a relatively small collection indexed by untrained documentalists, and should not be generalized. Indexing work to Euratom's large collection of documents requires highly trained expert documentalists who have the terminology of their special subject field in mind, and who need only an occasional glance at the glossary and the keyword graphs corresponding to other subject fields. But if the time gain due to the graphs is not important, the consistency and completeness of indexing are very remarkable.

In a recent experiment, three documents were analysed by ten documentalists specialized in different fields and with different degrees of training. Whereas the "ideal" analysis (established after extensive discussion of the results) included an average of 11 keywords, the documentalists had assigned an average of 14 keywords, 8 of which were identical with 8 of the "ideal" analysis. The indexing consistency was thus established to be 8/11 or 73 percent. Completeness rated even higher, since the missing 3 among the "ideal" keywords were partly covered by related terms among the 6 additional keywords assigned.

These results compare very favorably with those of a comparable consistency test using an excellent alphanumerical classification of the field of nuclear technology. In this test, ten documents were coded by six documentalists having great experience but different backgrounds. The consistency rated as low as 23 percent.

Tests are presently being carried out on a larger scale in order to obtain more significative results.

4.3 Retrieval

While it is important for good indexing to find the most specific keyword applying to a concept expressed in a document, it is absolutely

essential for good retrieval to find all the terms on which relevant documents could have been posted in the indexing phase. Similarly, the introduction to the Engineers Joint Council Thesaurus of Engineering Terms (13) emphasizes that

> "It is good practice not to depend upon redundancy of indexing and to phrase comprehensive inquiries into several alternative forms irrespective of the indexing rules"

Whereas an alphabetical thesaurus requires a lot of page-turning to follow the cross-references up to a few pertinent terms, the use of arrowgraphs makes it practically impossible to overlook one pertinent keyword. Starting from one pertinent term, the documentalist simply follows the arrows leading to other keywords and takes note of all the words encountered which are pertinent, i.e. which could have been assigned to relevant documents.

The importance of this procedure will appear from the following example, which corresponds to an actual search received by Euratom's documentation department.

The question was : select all documents relating to the production of cobalt isotopes.

As both terms are Thesaurus keywords, a document describing the same topic could have been exhaustively indexed by

1. COBALT ISOTOPES
2. PRODUCTION

But the user of an information service wants to receive all pertinent documents, including those with the titles

"Preparation of radiocobalt"

"Separation of cobalt-60 from fission products"

and "Manufacture of gamma sources for industrial radiography"

which were obviously indexed with different sets of keywords. In practice, the arrowgraphs will lead from PRODUCTION to PREPARATION, RECOVERY, ENRICHMENT and further to SEPARATION PROCESSES and ISOTOPE SEPARATION, and show the way from COBALT ISOTOPES to RADIOISOTOPES, RADIATION SOURCES, and GAMMA SOURCES.

5. FURTHER DEVELOPMENTS

5.1 Other thesauri using display schemes

Taking the Euratom-Thesaurus as an example, a number of other institutions have started developing terminology charts for their documentation services.

One system now in operation is that of the Technical Documentation Center of the Dutch Army (TDCK) (5,11).

It involves more than 10,000 keywords and makes use of an improved peek-a-boo equipment. In the graphic display schemes, the keywords are arranged on concentric circles representing the different hierarchic levels, with the group head terms placed at the center of the graphs (Fig. 7). This example shows that the graphic display method adapts itselfs to vocabularies of great specificity, and that it is possible to introduce hierarchy to a greater extent, if required.

The "Circular Thesaurus" is particularly useful for chain indexing in the preparation of subject indexes of scientific journals. Starting from the center of the graph, all the keywords encountered in following the arrows down to the most pertinent keyword are linked together to form a single subject entry, which facilitates index scanning. Such chain indexing is not necessary for retrieval by concept coordination, if the equipment allows more elaborate search strategy, since the terms of the hierarchic chain can be included as alternatives in the query formulation as far as pertinent.

Another graphic display system, to be used by the Road Research Laboratories of the OCDE member countries, was recently developed by the French Road Research Laboratory, with the cooperation of the British and German Laboratories and the Bureau d'Etudes Van Dyck.

A graphical thesaurus comprising 32 keyword display schemes was developed in 3 languages; positioning of the keywords in the grid of the display is related to a four-digit identification code, which ensures compatibility with the other language versions. The system makes use of a 14,000 - position peek-a-boo equipment.

The second (revised) edition of the DDC Thesaurus (12) also includes a number of "Generic Charts" (Fig. 8), the obvious purpose of which is to assemble all keywords relating to a given subject field. It is not known, however, to what extent these charts are actually used for indexing and retrieval.

5.2 Application of Numerical Methods

In the course of the thesaurus compilation at Euratom the introduction of frequency-of-assignment data*) into the arrowgraphs made it possible to assess the relative usefulness of the keywords at a glance. This method can be applied to the terminology charts. It is theoretically possible, by moving the domain boundaries, to achieve rigorously the uniform posting which is one of the prerequisites of optimal retrieval efficiency. The domains will tend to be small in the main subject fields of interest, and become very large in the border fields, where the domains will finally be represented by keywords of a very high generic level.

Lauren Doyle (6) proposes another application of numerical methods. He proposes to determine for every couple of terms (in a document) the "association factor" which measures the frequency of co-occurrence of the terms. Word pairs having high association factors

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*) Part of these data were taken from the cumulative subject indexes of Nuclear Science Abstracts, published by the U.S.A.E.C.; the others resulted from Euratom's own indexing activity.

are connected by arrows; the resulting graph looks very similar to the Euratom arrowgraphs. One is tempted to apply the same method to pairs of keywords obtained in the indexing of a vast collection of documents, using frequency-of-occurrence data to determine the optimal position of arrows in the graphic display schemes. But the links represented in the arrowgraphs include only hierarchic and other semantic relationships and not fortuitous associations of keywords linked by concept co-ordination.

Though the conclusions of such a test will be of limited value in the compilation of a thesaurus, it is intended to determine the "association factors" for the word pairs in some of Euratom's keyword graphs.

5.3 Multilingual documentation

Translation work is seriously hampered by the fact that the corresponding words in different languages have slightly different meanings or, otherwise stated, that the areas they cover in the subject field are not congruent, but overlapping.

One could imagine developing a set of terminology charts of the same subject field, in different languages, on superimposable transparent sheets. Such a set of charts would be a valuable tool for the translator as well as for the documentalist who assigns keywords of a language differing from the language of the document.

The same principle underlies the above-mentioned multilingual display schemes of the Road Research Thesaurus : The positioning of the keywords is identical in the English, French, and German versions, thus leading to the same position code for common use by all cooperating laboratories.

5.4 Automatic Documentation

The continuity of a subject field to be treated by documentary techniques is in opposition with the discontinuity of the standardized terminology and even more with the rigor of a classification system. A documentation system will tend to be the better, the closer it adapts itself to the continuous structure of the subject field.

Classification codes as well as standardized keywords represent two modes of breaking up a subject field into discrete areas of meaning. They are essentially digital methods which can be handled by devices such as digital computers.

Analog computing, which uses continuous variables, should be more compatible with the continuous structure of subject fields. I should not be surprised, therefore, if the automatic documentation of the future made use of a combination of the high capacity of digital computers with the flexibility of analog networks.

Interesting experiments have been made in this direction by Giuliano(7), Maron and Kuhns(8), Greene(9) and Salton(10), but

both methods and equipment require an extensive program of continued development.

In the meantime we will therefore continue to use, for efficient indexing and retrieval, this familiar device that comes closest to the analog computer (and is so much cheaper) : the human mind.

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Fig. 2

REPRESENTATION OF A SUBJECT FIELD : Do 2 : TERMINOLOGY

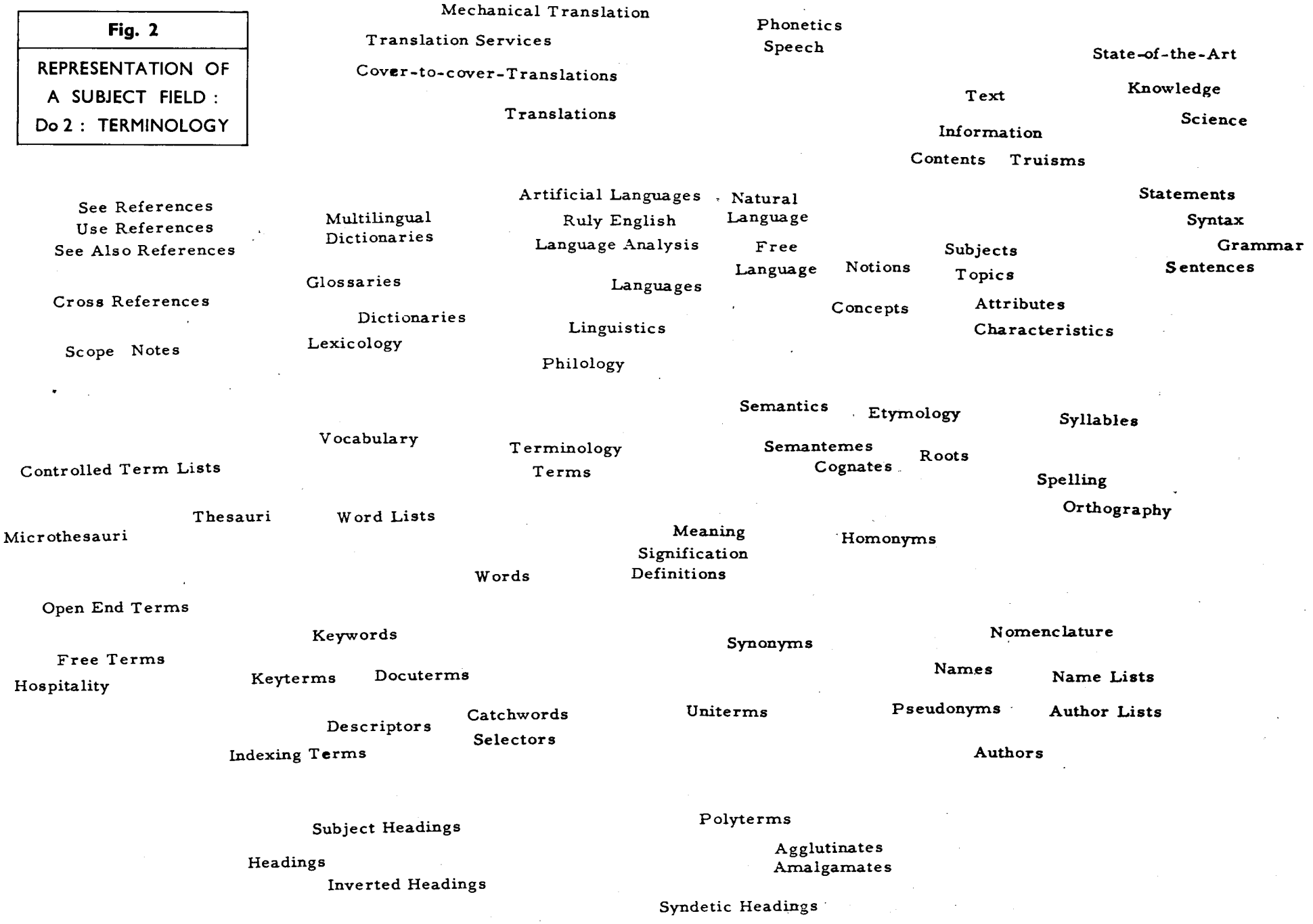
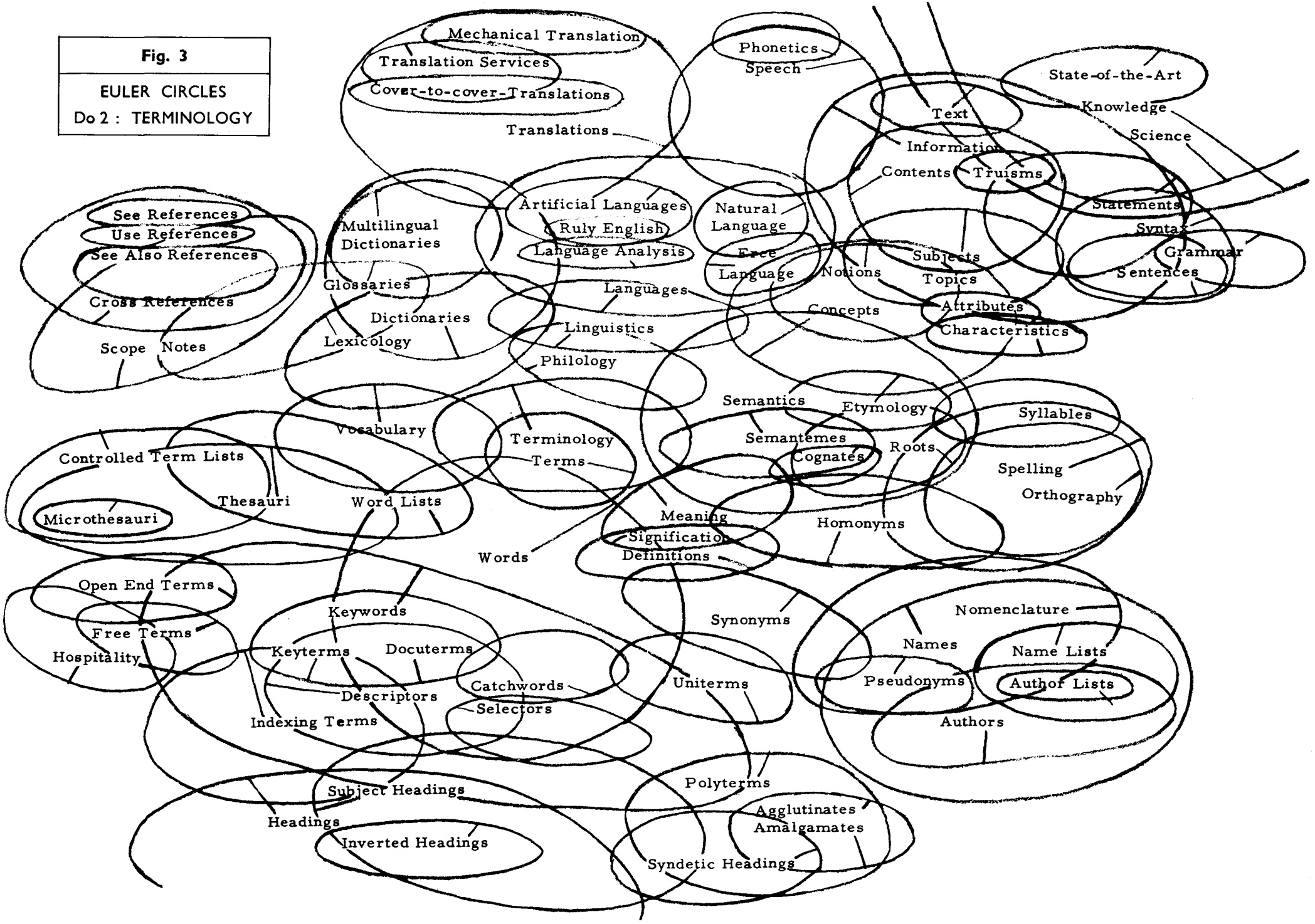


Fig. 3

EULER CIRCLES
Do 2 : TERMINOLOGY



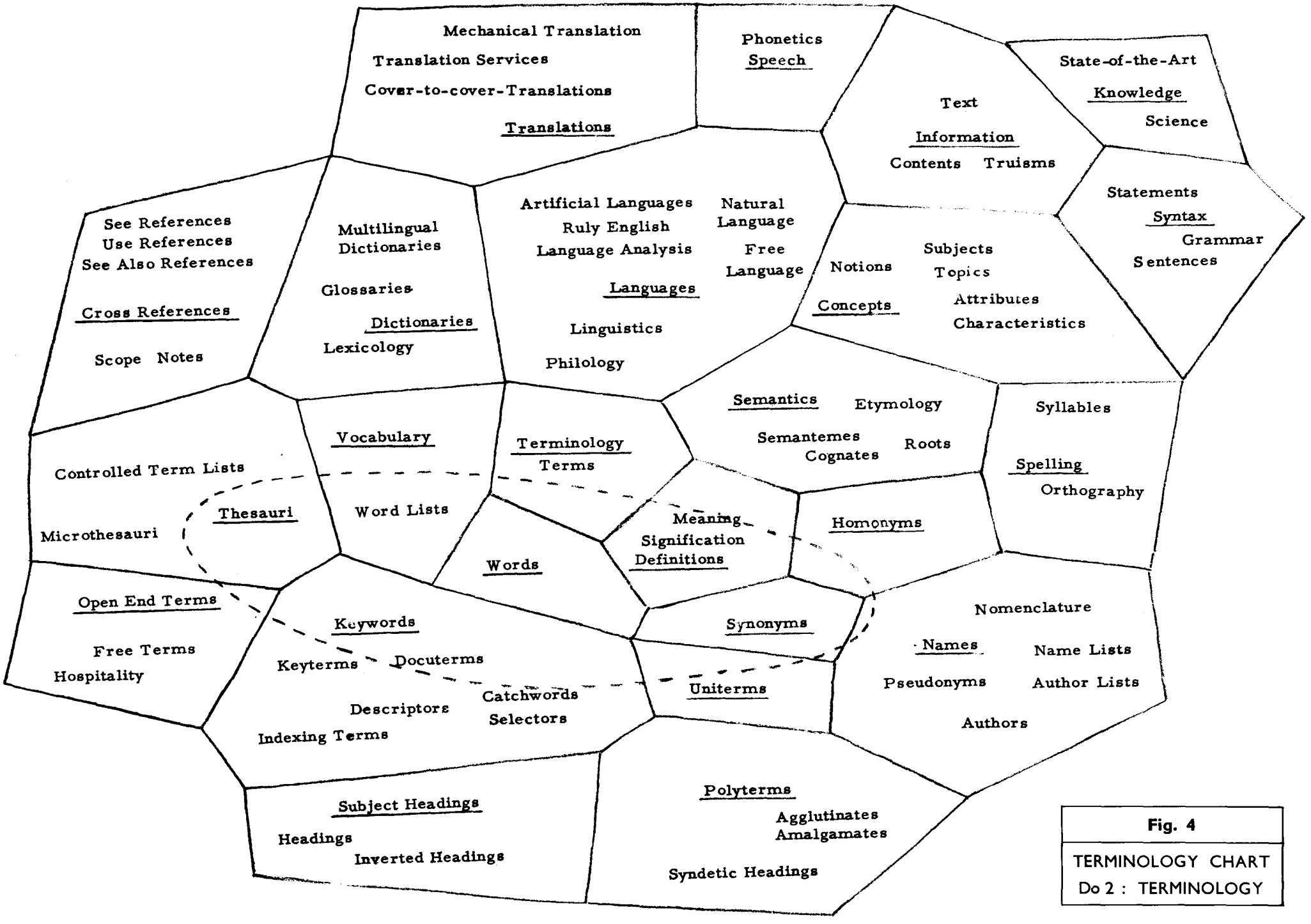


Fig. 4

TERMINOLOGY CHART
Do 2 : TERMINOLOGY

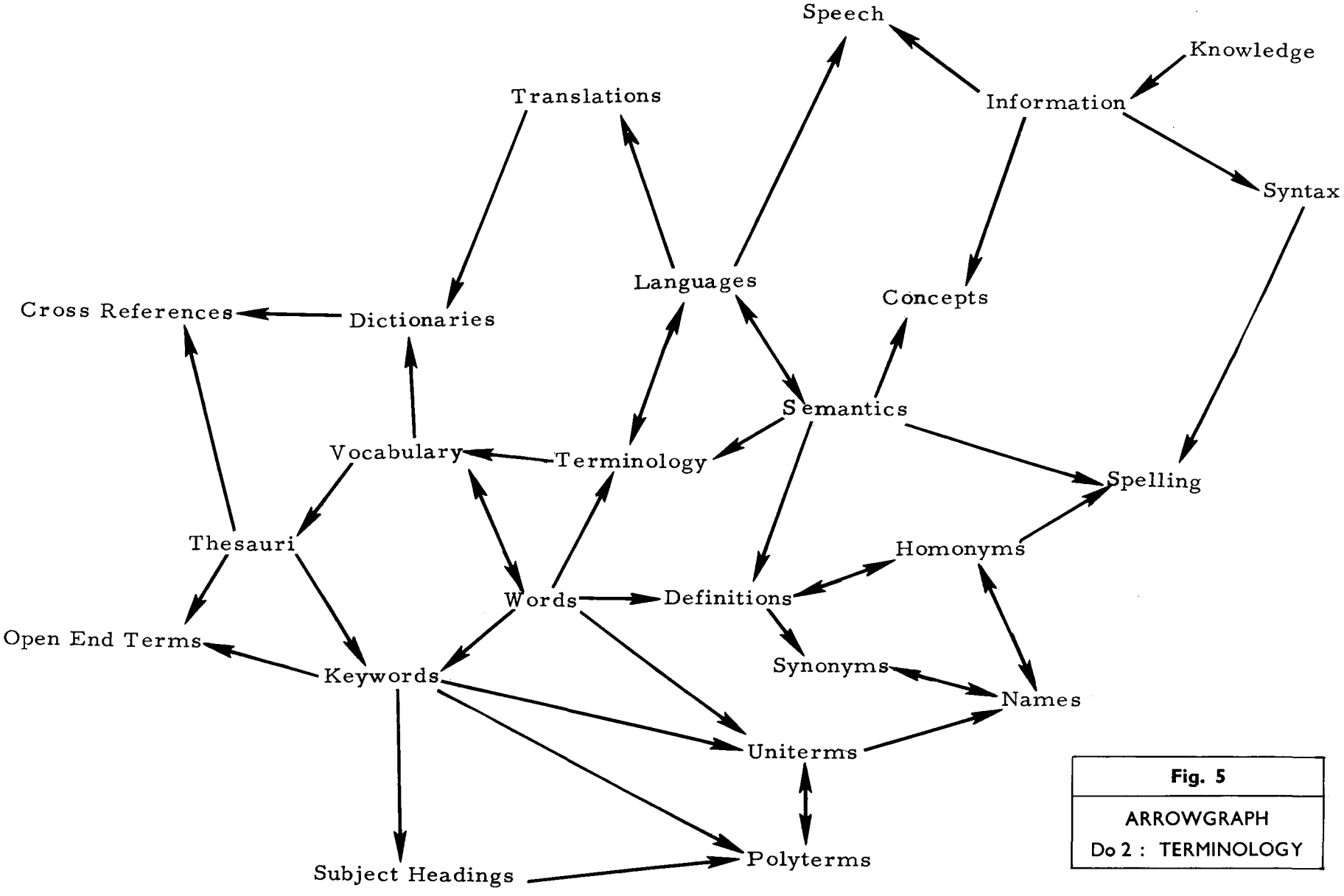
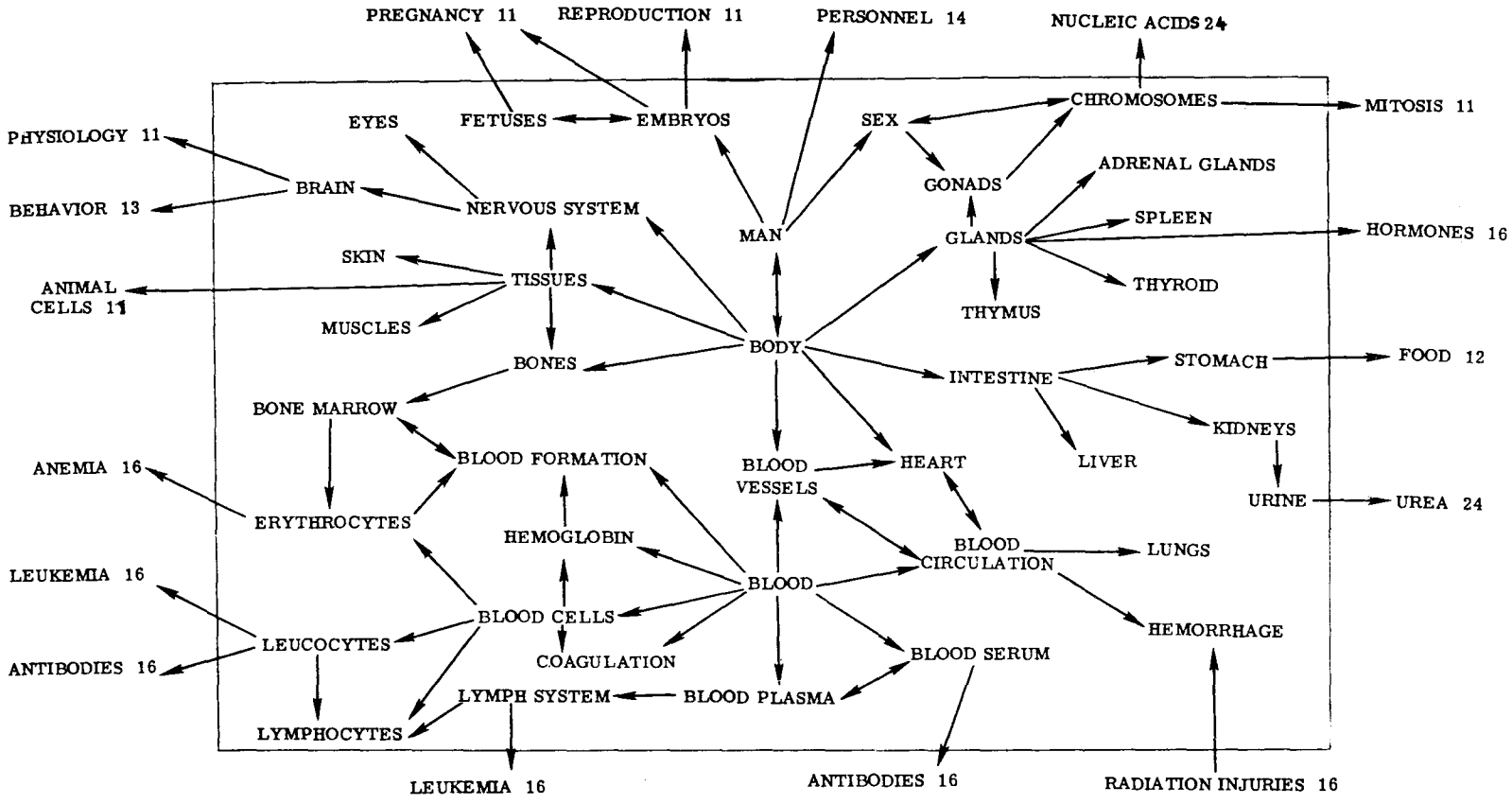


Fig. 5

ARROWGRAPH
Do 2 : TERMINOLOGY

Fig. 6



ADRENAL GLANDS
BLOOD
BLOOD CELLS
BLOOD CIRCULATION
BLOOD FORMATION
BLOOD PLASMA
BLOOD SERUM
BLOOD VESSELS
BODY
BONE MARROW
BONES
BRAIN
CHROMOSOMES
COAGULATION
EMBRYOS
ERYTHROCYTES
EYES
FETUSES
GLANDS
GONADS
HEART
HEMOGLOBIN
HEMORRHAGE
INTESTINE
KIDNEYS
LEUCOCYTES
LIVER
LUNGS
LYMPHOCYTES
LYMPH SYSTEM
MAN
MUSCLES
NERVOUS SYSTEM
SEX
SKIN
SPLEEN
STOMACH
THYMUS
THYROID
TISSUES
URINE

Fig. 7

DDC THESAURUS
GENERIC CHARTS

INFORMATION, DOCUMENTATION AND AUTOMATION

AUTOMATION

INFORMATION THEORY
- CODING

INFORMATION SYSTEMS
- INFORMATION RETRIEVAL
- MACHINE TRANSLATION
- TEACHING MACHINES

PROGRAMMING (COMPUTERS)
- PROGRAMMING LANGUAGES

MATHEMATICAL PREDICTION

COMPUTER DATA SYSTEMS
- DATA TRANSMISSION SYSTEMS

DIGITAL SYSTEMS

COMPUTERS
- ANALOG COMPUTERS
- ANALOG-DIGITAL COMPUTERS
- DIGITAL COMPUTERS
- SPECIAL-PURPOSE COMPUTERS
  - FIRE CONTROL COMPUTERS
    - BOMBING COMPUTERS
    - IMPACT COMPUTERS
    - PARALLAX COMPUTERS
    - RADAR RANGE COMPUTERS
    - TORPEDO DATA COMPUTERS
  - FLIGHT SIMULATORS
  - GUIDED MISSILE COMPUTERS
  - NAVIGATION COMPUTERS
  - DIGITAL DIFFERENTIAL ANALYZERS

ELECTRONIC ACCOUNTING MACHINES

COMPUTER SYSTEMS COMPONENTS
- COMPUTER STORAGE DEVICES
  - DELAY LINES (COMPUTER)
  - MAGNETIC CORE STORAGE
    - FERRITE CORES
  - MAGNETIC TAPE
  - PUNCHED CARDS
  - STORAGE TUBES
- INPUT-OUTPUT DEVICES
  - ANALOG-TO-DIGITAL CONVERTERS
  - CHARACTER GENERATORS
  - MAGNETIC TAPE
  - PUNCHED CARDS
  - READING MACHINES
- INTEGRATORS (COMPUTERS)

OPERATIONS RESEARCH

CYBERNETICS

SCHEDULING

COMPUTER LOGIC

MATHEMATICAL LOGIC

SEQUENCES

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PICTURES

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THESES

Fig. 8

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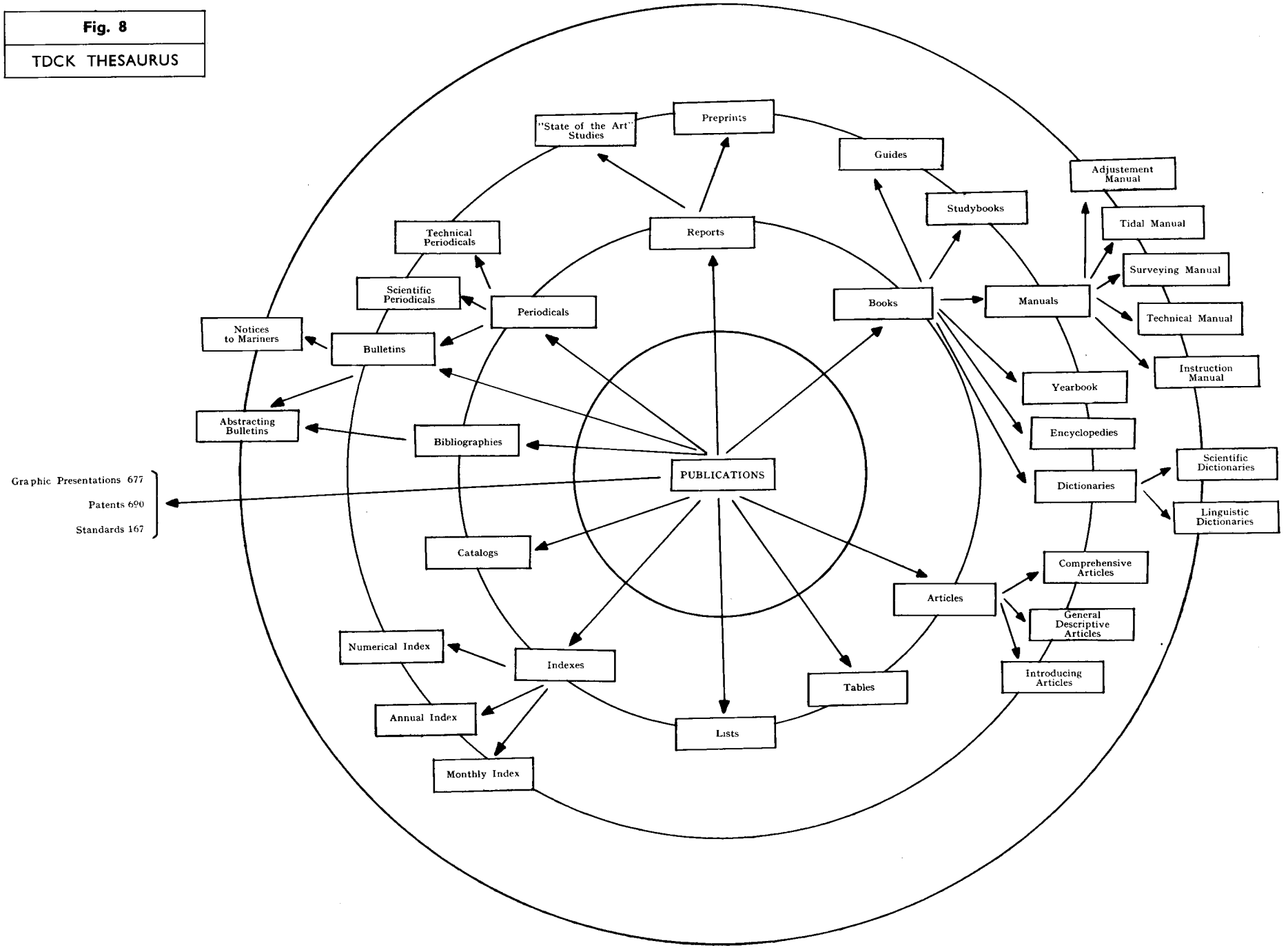
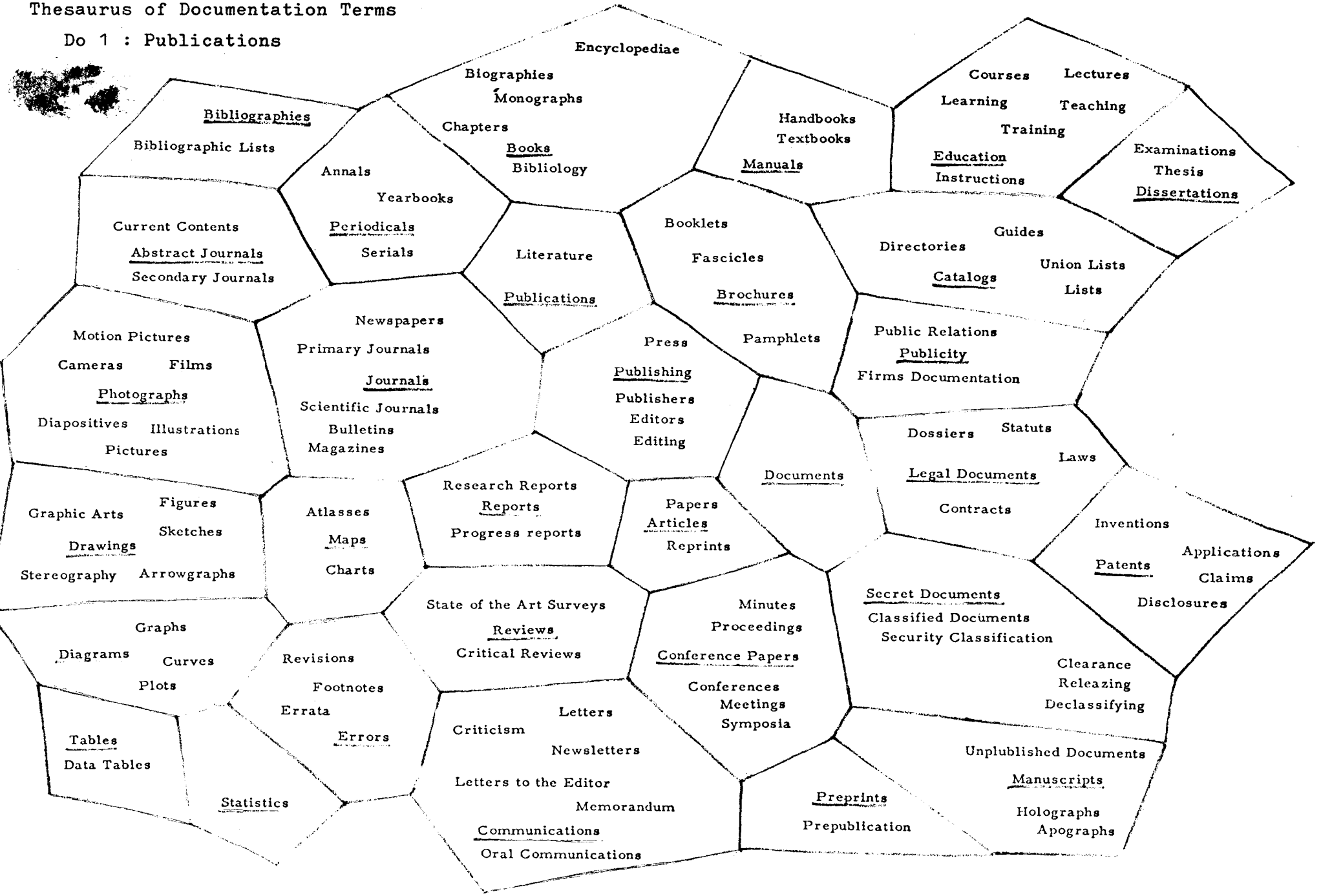


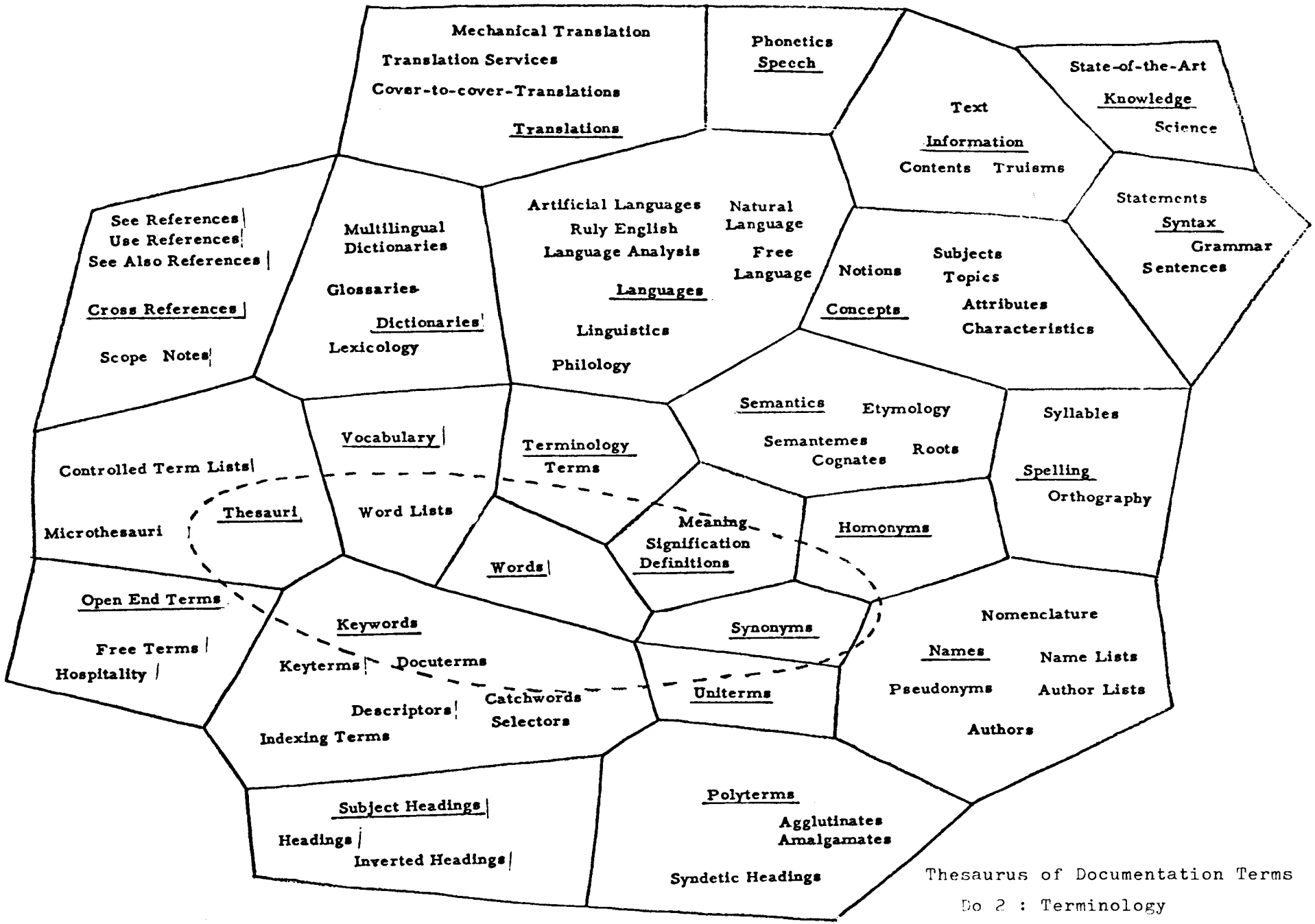
A P P E N D I X

THESAURUS OF DOCUMENTATION TERMS

Thesaurus of Documentation Terms

Do 1 : Publications





Thesaurus of Documentation Terms

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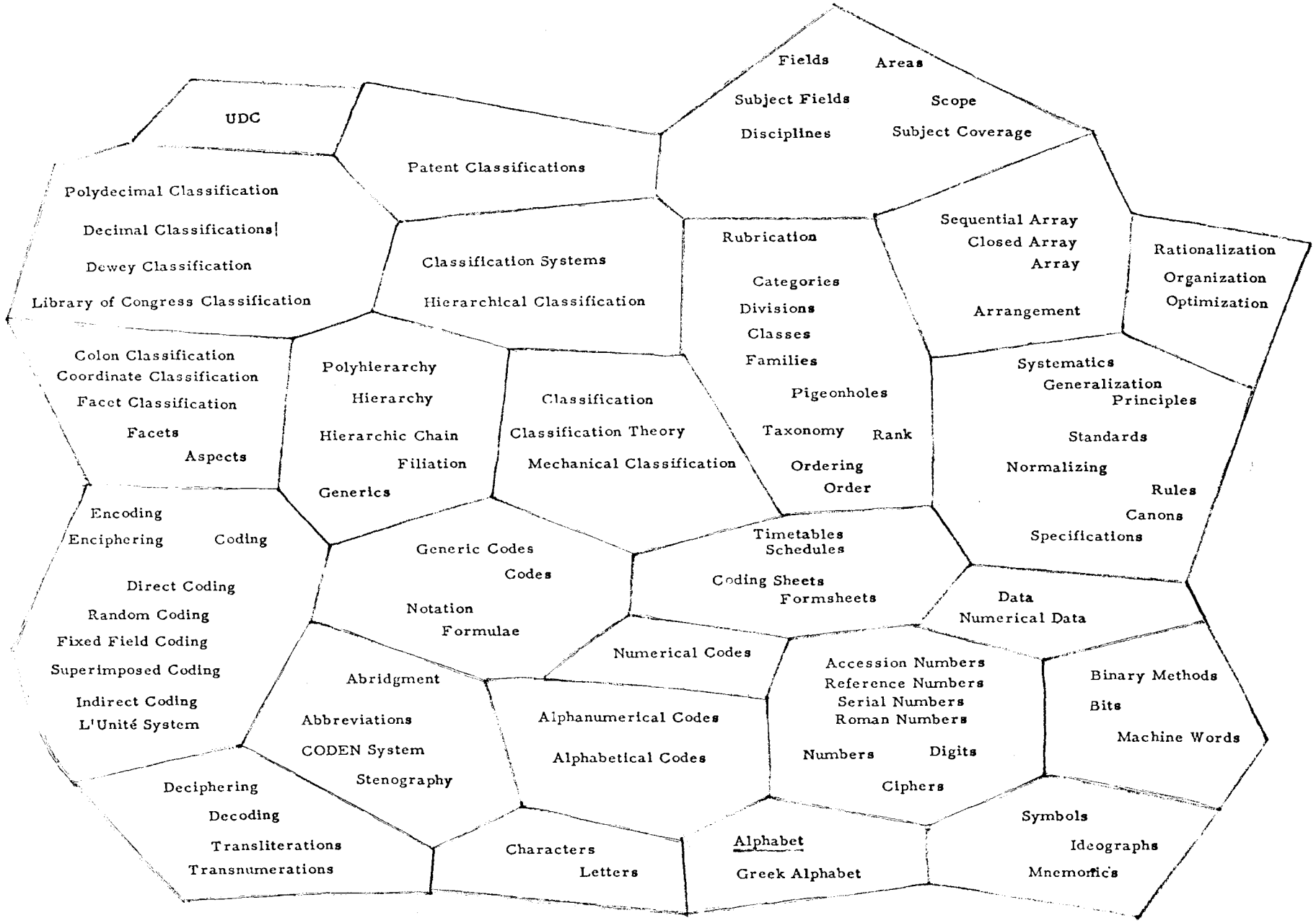
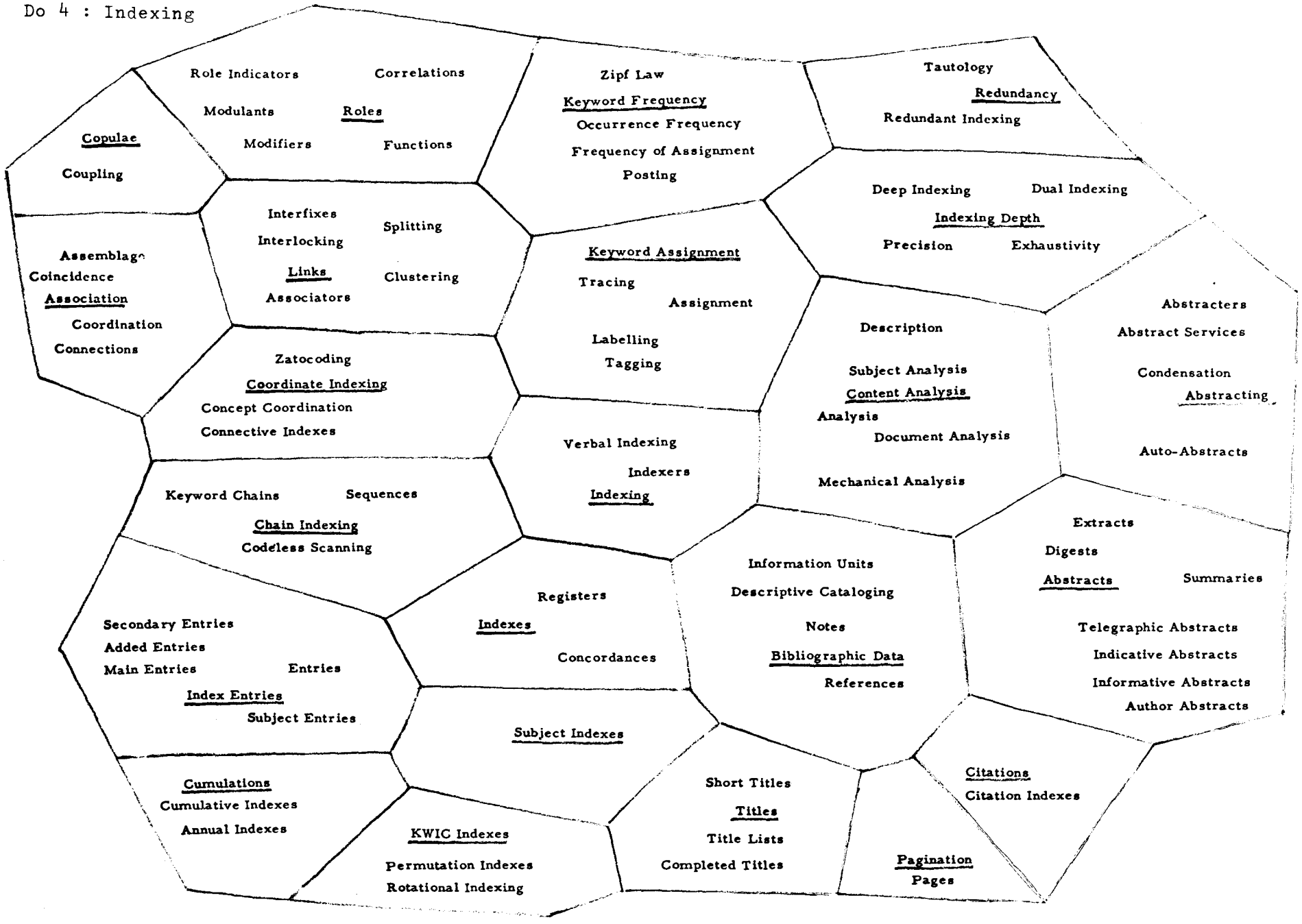


Thesaurus of Documentation Terms

Do 3 : Classification

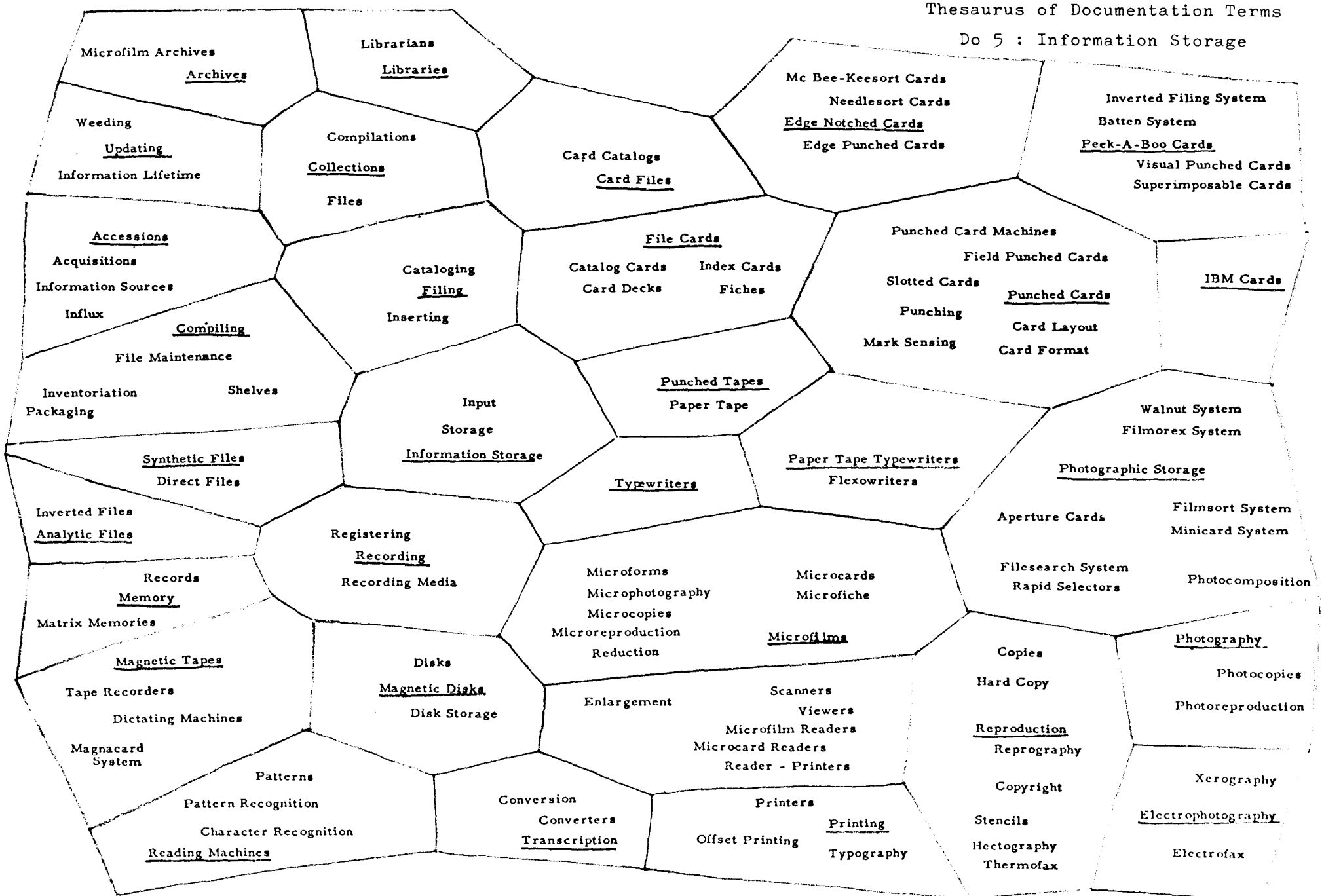
Thesaurus of Documentation Terms

Do 4 : Indexing



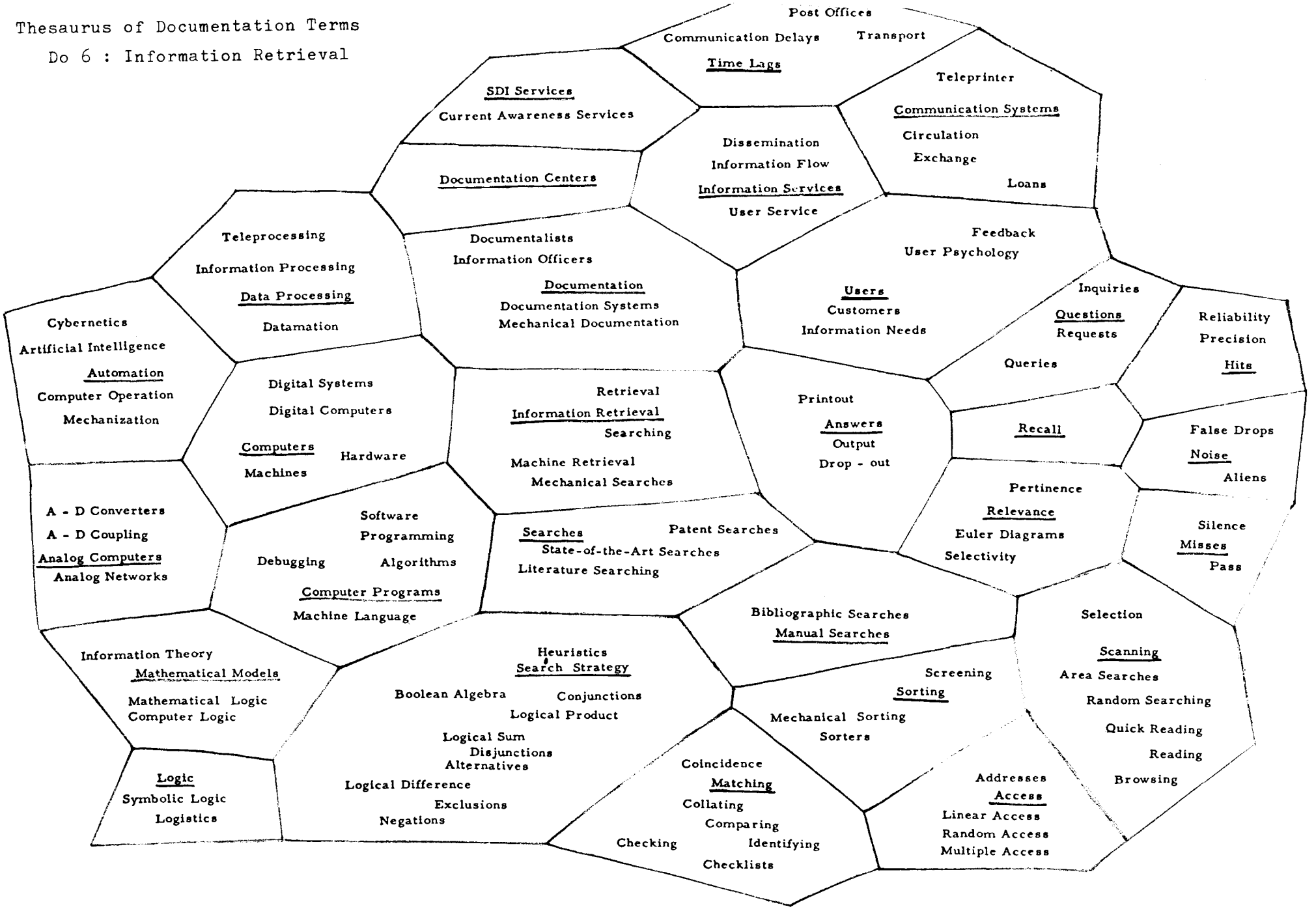
Thesaurus of Documentation Terms

Do 5 : Information Storage



Thesaurus of Documentation Terms

Do 6 : Information Retrieval



04 ABSTRACTING
04 ABSTRACTS
03 ABBREVIATIONS
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05 ACCESSIONS
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03 ALPHABETICAL CODES
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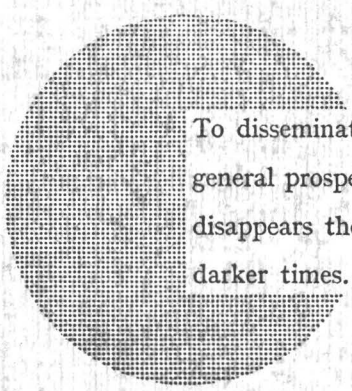
03 UDC
02 UNITERMS
05 UPDATING
06 USERS
02 VOCABULARIES
02 WORDS

THESAURUS OF DOCUMENTATION TERMS

KEYWORD LIST

L. ROLLING - EURATOM

SEPTEMBER 1964



To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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