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International Symposium on Multiple-Valued
Logic for 1971-1991

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Profiles of Topics and Authors of the International Symposium on Multiple-Valued Logic for 1971-1991*

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Abstract

We consider the growth of multiple-valued logic over the 21 year period from 1971 through 1991, as indicated by papers in the International Symposium on Multiple-Valued Logic. Of specific interest are 1) trends in research topics. This includes patterns of growth and decline. We also consider 2) the demographics of the contributing authors. This includes the distribution of authors by country, the percentage of authors who are new, percentage of new authors who return, and the distribution of authors by affiliation (academia, industry, and government). To derive these statistics, we developed a database of papers, authors and topics. This can be used, for example, to do library searches or to assign papers to referees.

1. Introduction

It has been thirteen years since the last analysis of papers in the *Proceedings of the International Symposium on Multiple-Valued Logic (ISMVL)*. In 1979, Ginzer and Butler [2] presented an overview of the first eight years of this symposium. They discussed the international composition of the organization and percentage of first-time authors. We are now able to examine the first 21 years of ISMVL. The present wide availability of database programs allows us to collect and present data in ways that were impractical thirteen years ago. With these tools, we investigate the growth and vitality of multiple-valued logic (MVL) and examine whether ISMVL is serving the needs of its members.

2. Profile of Papers in ISMVL

A simple but effective way to measure growth is to

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count the number papers published per year. This ranges from a low of 18 in 1971 and 1972 to a high of 68 in 1989. A general upward trend in the number of papers is shown in Fig. 1.

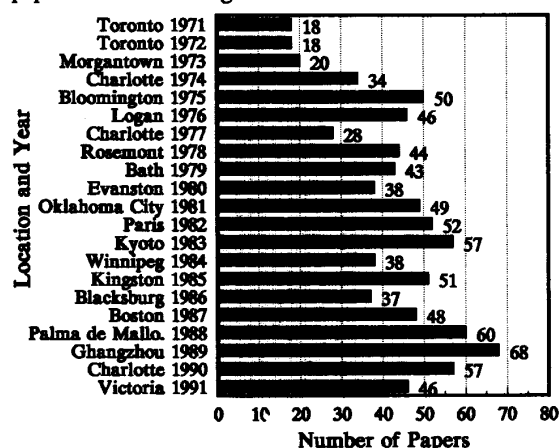


Figure 1. Number of Papers Per Year of ISMVL.

Growth in a discipline is also measured by an increase in the number of areas in which it is applied. Therefore we analyze papers by topic. Papers are first categorized by *major topic*. There are eight major topics, each analogous to a general session category given in the Proceedings. Fig 2. shows numbers of papers in each major topic by year for the past 21 years. A second type of topic is the *minor topic*. The minor topic represents specific areas within a major topic. While the major topic provides a unique classification that tracks broad areas, the minor topic is more specialized and is not unique. Minor topics can span major topics. For example, the minor topic "minimization" occurs under the major topics of fuzzy logic, logic design, and circuits. Every paper is assigned at least one and up to four minor topics. Minor topics are also the best indi-

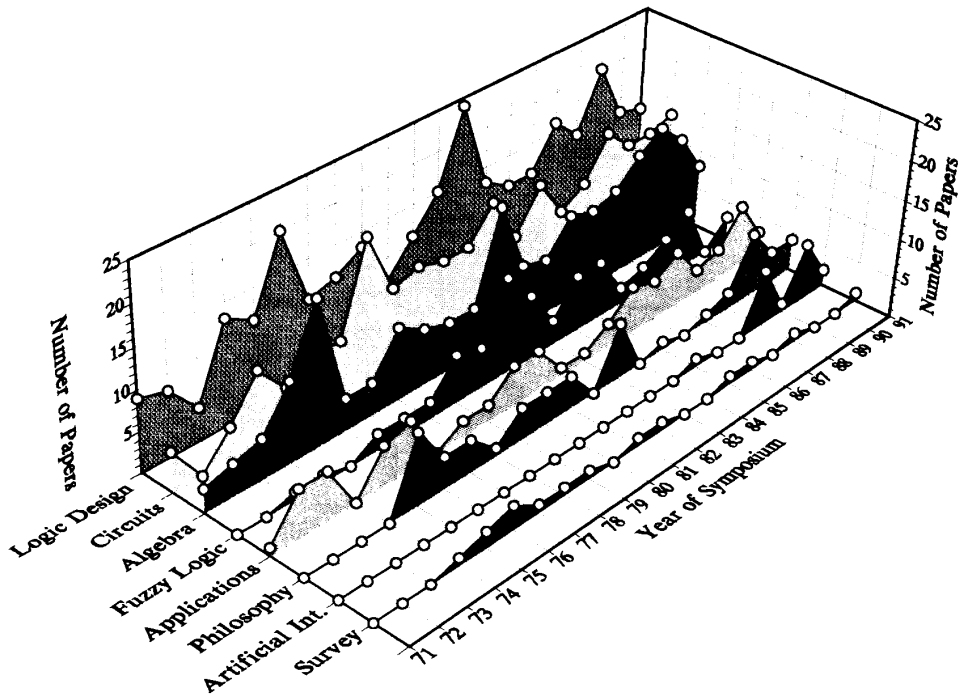


Figure 2. Number of Papers by Major Topic by Year.

cators of increasing breadth, as researchers explore new areas, integrate MVL into other disciplines, and carry theoretical results into practical applications. Appendix I lists the 416 minor topics. Some such as "completeness" cover many areas and are widely used. Others such as "Oracle" occur in only one paper, but enable researchers to easily locate such papers. Minor topics serve to index the database used to generate the data presented here; the database contains 902 papers, 732 authors, and 1600 author/paper pairs.

Fig. 3 shows the number of papers per year in selected minor topics. We chose these specific minor topics because each one represents a special characteristic, for example, an increase or decrease in research interest. As an illustration, in "approximate reasoning" eight of the nine papers have been published in the last seven years. Similarly, over half the papers on "clones" and "expert systems" have been submitted in the last five years. These represent growing areas on interest. Biological computing has entered the list of minor topics in the last four years and illustrates a new area.

Our results also show topics that experienced a loss of interest. For example, "hazards" and "microprogramming" have seen a decline. For both topics, no paper has been published in the last five years, and there has been diminishing interest in the years just prior to that.

Some topics, such as fuzzy (logic), illustrate another characteristic. Certain topics exist as both major and minor topics. That is, a topic may be the subject of a paper that falls primarily into another major category. For example, an application or circuits paper, may utilize fuzzy logic although not making a direct contribution to it. Another measure of health is the diversification of MVL theory in practical applications. We measure this in two ways, the number of applications papers and the number of different applications topics that MVL papers address. We note from Fig. 2, that there are a substantial number of applications papers. A total of 68 applications papers have been published. These papers cover approximately 50 distinct topics, including, for example, document retrieval and security.

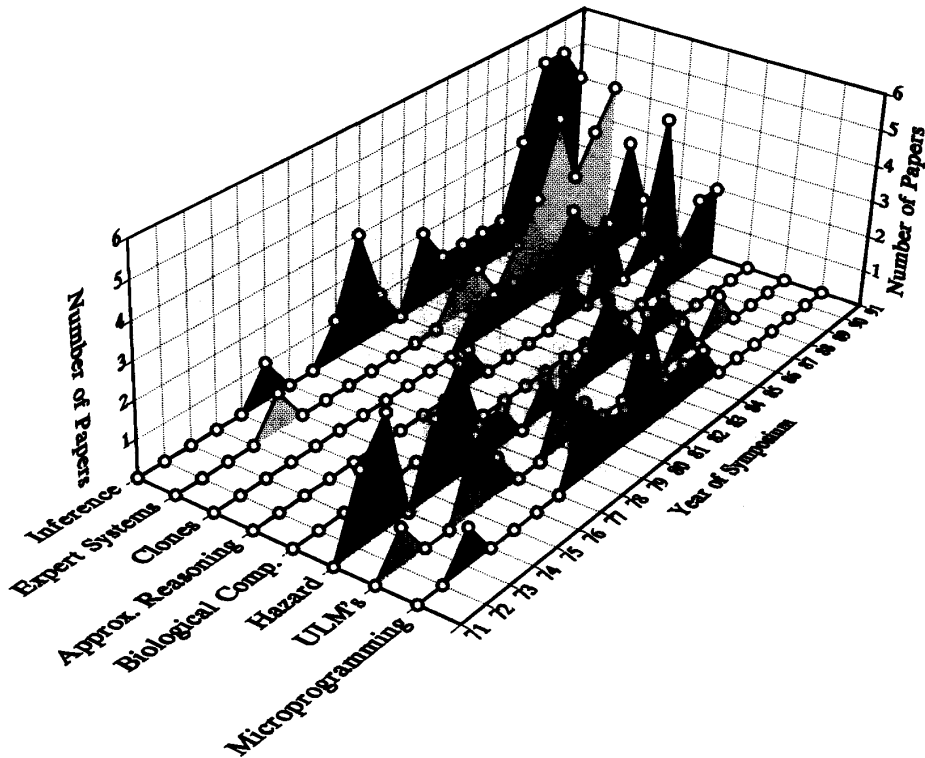


Figure 3. Number of Papers Per Year in Selected Minor Topics.

3. Profile of ISMVL Authors

We next consider the contributors. Fig. 4 shows the number of authors per year. We note that there has been an upward trend over the past 21 years.

Of special interest is the number of researchers who contribute a paper to the ISMVL for the first time. The ability to attract new researchers is an important measure of the vitality of any discipline. Fig. 4 shows the number and percentage of all authors who were new contributors for each year. For the first symposium, 100% of the authors are new. The percentage of new authors in the second through fifth ISMVL's was between 64% and 71%. For succeeding symposia, this percentage decreased slightly, but has remained generally high. The lowest percentage was in 1977 at 37% and the high was 59% in 1988, with an overall average of about 50%. Related to the new author issue is the ability of the symposium to retain the interest of these first time authors. We, therefore, examined the number of such authors who contributed a paper in some subsequent year. Fig. 4 also shows this data. The largest number of returnees occurred from 1983. Of the 54

new authors, 25 returned in later years. The next largest number, 19, occurred from 1971. As expected, the percentage of new authors who return drops for more recent symposia, since there are fewer opportunities for attendance. The overall average, 32%, shows a healthy continuing interest in MVL.

Fig. 5 shows a histogram of productivity of ISMVL authors. Counting authors with many papers gives a sense of how many have a strong commitment to MVL. In the past 21 years, 23 authors have contributed more than 10 papers each, and one author has contributed 32. As expected, many authors, 481, have contributed just one paper.

Fig. 6 shows an interesting, related trend. Plotted here is the number of authors divided by the number of papers per year. This is not the average number of authors per paper because of authors who have more than one paper that year, but it is close. There is a general upward trend. As multiple-valued logic has matured, there are fewer single authors and more group activity. The passage of time has allowed the formation of research partnerships, assimilating new authors into

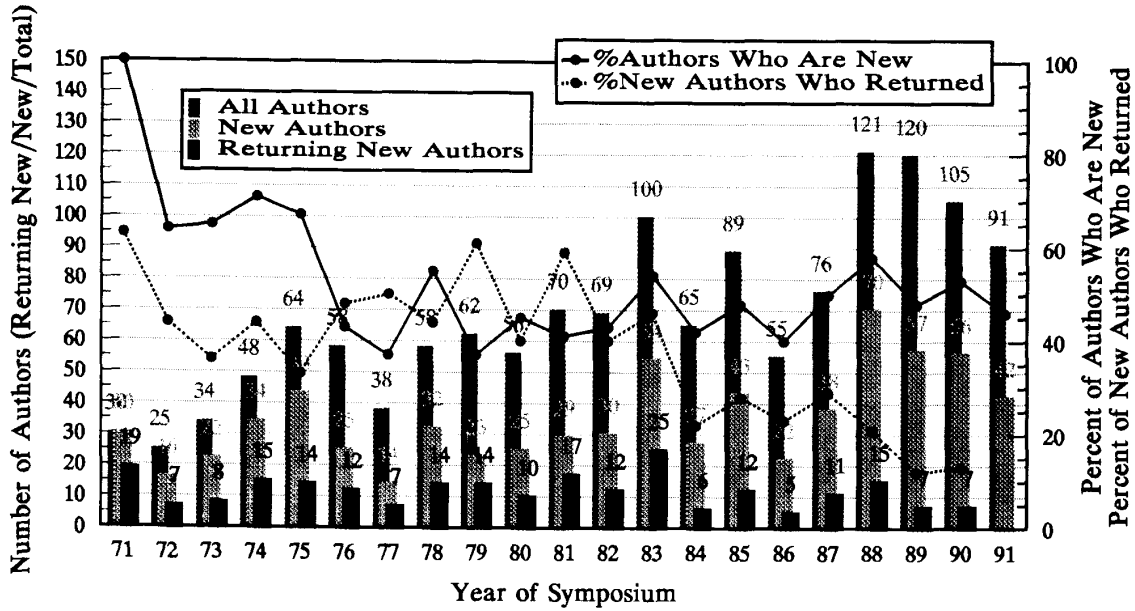


Figure 4. Number of Authors and Number and Percentage of New Authors.

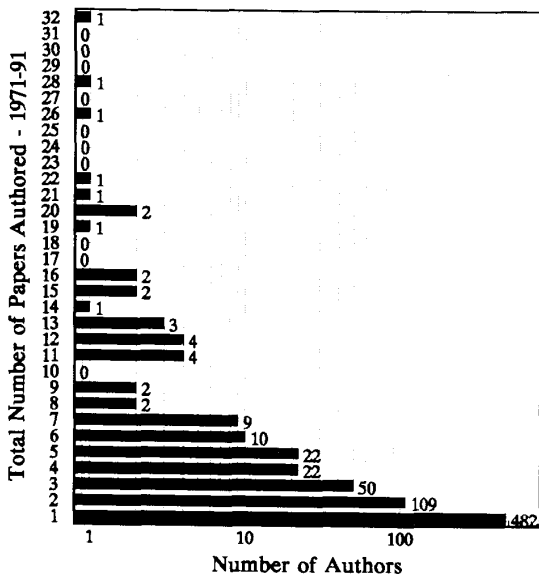


Figure 5. Histogram of Paper Productivity.

the research community. We believe this is another indicator of growth and evolving author participation.

Fig. 7 shows the distribution of papers by number of authors for the past 21 years. The vertical axis shows how many authors collaborated on a paper, while the horizontal axis shows how many papers there are with

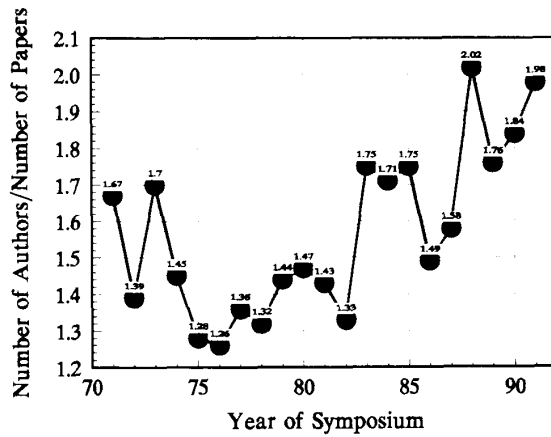


Figure 6. Number of Authors/Number of Papers.

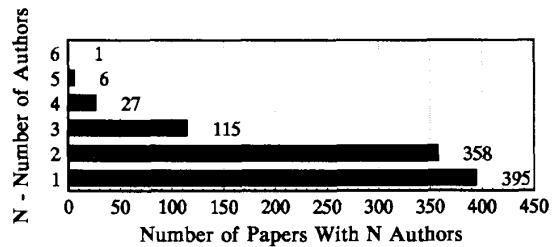


Figure 7. Histogram of Author Multiplicity.

Country	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total	
Algeria														1									1
Argentina										1											3		4
Australia																				1		1	2
Austria											1	2					2						5
Belgium					2	2	2	3	3			1											13
Brazil												2										3	5
Canada	5	3	6	10	12	12	8	4	5	4	6	6	8	10	11	8	6	14	13	15	17		183
Chile	1	1	2	3	1											1							9
China								1		1	3	3	10	7	17	7	7	15	47	9	2		129
Denmark												1											1
Ecuador										1	1	1	1										4
England				1	4	4		1	12	2	5		2	3	1	2		2	1				40
Finland		3	2	1																			6
France	1		2	2	2	3	4	3	3	4		2		3	4		4	1			3		41
Germany					1	1	3	2	2	1	2	3		2	2	1	4	2	5	4	4		39
Hungary												2	3	3						1	1		10
India				2									1	1									4
Iran																						1	1
Iraq								2				2			2								6
Israel				2	3								1		1								7
Italy												2	3										5
Japan	3	2	3		3	8	7	7	9	8	11	8	39	13	18	10	17	22	23	18	30		259
Korea																					1		1
Mexico																	1						1
Netherlands							1			1	3	2	3		3	2	2	2			2		21
Nigeria										1	1												2
Poland			1	1	6	1	1					2	3	2		2	1				2	2	24
Portugal																						2	2
Saudi Arabia										1	2												3
Singapore																					4		4
South Africa											1												1
Spain						2	2	4	2	2	7	5	1		3	2		26	6	2	4		68
Switzerland				1																			1
Taiwan											1		1										2
USA	20	16	17	25	29	25	10	31	26	29	26	21	24	19	27	20	31	35	18	36	29		514
USSR					1							3								1			5
Yugoslavia														1			1	2	2		1		7
Unknown			1									1							2				4
Total	30	25	34	48	64	58	38	58	62	56	70	69	100	65	89	55	76	121	120	105	91	1434	
Year	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total	

Figure 8. Number of Authors by Year by Country.

that many authors. Single-author papers are the most common, with two-author papers a close second.

4. Profile of the Symposium

From the first symposium in 1971, internationalism has been a hallmark of ISMVL participation. In 1971, authors from five countries (Canada, Chile, France, Japan, and the U.S.) on four continents participated Fig. 8 illustrates the continuing geographic spread of interest, as a distribution by author's nationality. Some interest-

ing observations can be made. In 1971, 67% (20) of authors were from the U.S., with Canada as the second most prolific contributor. In 1991, authors came from 10 countries world-wide. Japan has taken the lead with 33% (30) of the authors, while the U.S. is a close second with 32% (29). Fig. 8 shows the number of authors contributing according to country over the 21 year history of the ISMVL.

A related factor is symposium location. We consider how the location of a conference affects the retention

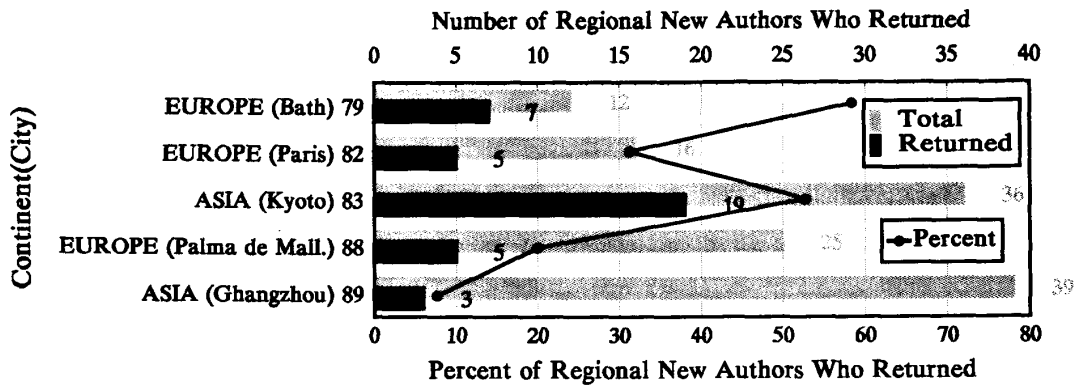


Figure 9. New Author Continuation Data for ISMVL Outside North America.

rate of new authors. Five symposia have been held outside North America - Japan (1983), People's Republic of China (1989), France (1982), Spain (1988), and England (1979). For analytical purposes, we consider the continent of both symposium and authors. At the symposium held in Japan, there were 54 new authors, of which 36 were from Asia. Of these new Asian authors, 19 or 53% have contributed a paper to at least one subsequent symposium. For the conference held in France, there were 30 new authors, 16 of whom were

from Europe. Of these, 5 later returned, a retention percentage of 32%. Fig. 9 shows results for all symposia held outside of North America. Although the results are not as clear for the '88 and '89 ISMVL, because of the lack of time an author has had to return, we believe this data shows there is a benefit to the wider geographical distribution of ISMVL.

As another measure of vitality, we consider whether ISMVL attracts researchers from industry and govern-

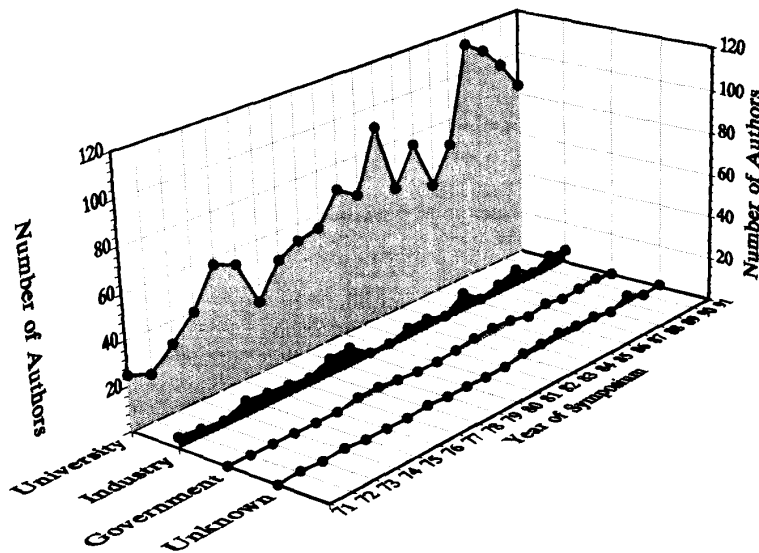


Figure 10. Distribution of Authors by Affiliation.

ment, the primary users of technology, and from academia, the primary source of theoretical advances. Fig. 10 shows the distribution of authors by affiliation. Here, the result is less encouraging. Participation by government and industry averages slightly less than 10% of university participation. This identifies one area where efforts can be made to attract researchers.

5. Concluding Remarks

Our analysis shows both topics for which interest is decreasing, as in "hazards", and those for which it is increasing, as in "expert systems" and "clones". Any growing and evolving discipline will demonstrate both these attributes, as areas cease to be fruitful and new areas of exploration arise.

Over the 21 year history of the symposium, approximately 50% of each year's authors are first time contributors. This was a surprising result of the study of the first eight years; it is still surprising. We also considered the retention rate, an average 32%, as significant and positive.

We investigated to what extent the location of the symposia affects attendance. We expected that a conference in a location tends to attract authors from that location, but questioned whether this would stimulate ongoing interest in ISMVL. Our results show, in varying degrees, an increase in follow-on attendance by these authors. Our results also show the need to attract researchers in industry and government.

The overall conclusion of this study is that multiple-valued logic and the ISMVL which serves as its forum, remain healthy. There continues to be a balance between new authors and long-time contributors. There is progress toward practical applications, and there is a harvesting of the benefits of world-wide locations.

Acquiring the Database

The database is available upon request. It is formatted in DataPerfect, a companion database to WordPerfect. To obtain a copy, send a blank high density 3.5" to either author with a self-addressed flopper mailer envelope. No warranty is made on this database.

Acknowledgments

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entering the data into the database and to Henry Ayling and K. Wayne Current for making it possible to finance the project. The authors also express thanks to Robert Brandewie, Deputy Director of DMDC, and Michael Dove, Division Chief, for a leave of absence that allowed the first author to collaborate on this paper.

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APPENDIX I: LIST OF MINOR TOPICS

A/D CONVERTER	COMPRESSION	FORMAL LANGUAGE	MAJORITY FUNCTIONS	PROBABILISTIC	SYSTEMS DIAGNOSIS
ABELIAN	COMPUTER DESIGN	FOURIER	MAJORITY VOTER	PROBABILITY	SYSTOLIC
ABNORMALITY PREDICAT	COMPUTER SCIENCE APP	FUNCTION DERIVATION	MANAGEMENT ANALYSIS	PROCESSORS	T-NORMS
ADDERS	CONDITIONAL	FUNCTIONS	MARKOV	PRODUCTION	TABLEAU
AGGREGATION	CONNECTIVES	FUTURE DIRECTION	MASS MEMORY	PROGRAMMING	TARSKI
ALGORITHMS	CONSISTENCY	FUZZY	MATRICES	PROGRAMMING THEORY	TAUTOLOGY
ALU	CONTAINMENT	GAAS	MEDIUM ALGEBRA	PROLOG	TAYLOR
AMBIGUITY	CONTRADICTIONAL	GALOIS	MEDIUM LOGIC	PROPOSITIONAL	TEMPORAL
ANALOG	CONTROL	GANGED-LOGIC	MEMORY	PROTOCOL	TESTING
ANALYSIS	CONVERTERS	GATE ARRAY	MESFET	PSEUDORANDOM NUMBER	THRESHOLD
APPLICATION	COPULAS	GAUSS	MICROPROGRAMMING	Q-ALGEBRAS	TOPOLOGICAL
APPROX REASONING	COST	GENTZEN	MINIMAL	Q-FUNCTIONS	TRANSITIVITY
ARCHIMEDEAN	COSTTABLE	GEOMETRIC	MINIMIZATION	QUANTIFICATION	TRANSMISSION
ARCHITECTURE	COUNTER	GRAPH THEORY	MINKOVSKI	QUANTIFIERS	TRANSMISSION GATES
ARITHMETIC	CRYPTOGRAPHY	GROUPOIDS	MIX-RADDX	QUASI-TRANSITIVE	TRANSPORT EQUATIONS
ARRAYS	CURRENT-MODE	GROUPS	MIXED-VALUE ALGEBRA	QUERY LANGUAGE	TREES
ARTIFICIAL INTEL	CURVE GENERATION	HAMMING	MODAL	QUOTIENT ALGEBRAS	TRIANGULAR NORMS
ASSOCIATIVE MEMORY	CYCLIC CODES	HARDWARE DESIGN	MODEL THEORY	RACES	TRUNCATED DIFFERENCE
ASSOCIATIVITY	D-FUZZY	HARMONIC ANALYSIS	MODELLING	RAM	TTL
ASYNCHRONOUS	DATA BANK	HARR	MODSUM	RANKING	ULM
ATOMIC ALGEBRAS	DATABASES	HASHING	MODULAR DESIGN	REAL-TIME	UNANIMITY
AUTO TEST GENERATION	DE MORGAN	HAZARD	MODULAR LATTICE	REASONING	UNARY
AUTO THEOREM PROVING	DEBUGGING	HEDGE-ALGEBRAS	MODULAR REDUNDANCY	RECURSION	UNATE
AUTOMATA	DECIDABILITY	HEIGHT CLASSIFICATION	MODULE	REDUCIBILITY	UNDECIDABILITY
AUTOMATED DESIGN	DECISION ALGEBRAS	HEYTING	MODULO-ALGEBRA	REDUCTION	UNIFORMITY
AUTOMATED REASONING	DECISION CIRCUITS	HILBERT	MODUS PONENS	REDUNDANCY	UNIVERSAL
AUTOMATIC CONTROL	DECISION DIAGRAM	HOMOMORPHISM	MOLECULAR COMPUTING	REED-MULLER	VARIABLE VALUED
AXIOMATIZATION	DECISION THEORY	HORN	MONOTONIC	REGISTERS	VECTOR
AXIOMS	DECISION-MAKING	HYPERREALS	MOS	REGULAR FUNCTIONS	VENN DIAGRAM
BALANCED GATES	DECISIVE	HYPERPLANES	MOAICS	REGULARITY	VLSI
BARREL SWITCH	DECODERS	IDENTITY	MULTIPLEXERS	RELIABLE	VOLTAGE-MODE
BELNAP	DECOMPOSITION	IMAGE PROCESSING	MULTIPLIERS	RESIDUE NUMBER	WALSH
BETA-RESOLUTION	DEDEKIND	IMPLICATION	MVL HISTORY	RESOLUTION	WAVEFORM
BI-DIRECTIONAL	DEDUCTION	IMPRECISION	NATURAL LANGUAGE	RESONANT TUNNEL DIOD	ZIANG-HARTLEY
BI-POLAR	DEGREES OF TRUTH	INCOMPLETELY SPECIFI	NEGATION	RHO-VALUED	ZORN
BIBLIOGRAPHY	DELTA FUNCTIONS	INDIA	NETWORK	RINGS	5TH GENERATION
BINARY	DEMOGRAPHICS	INDISTINGUISHABILITY	NEURAL	ROBBINS	
BIOLOGICAL ALGEBRA	DEMORGAN	INDUCTION	NMOS	ROM	
BIOLOGICAL COMPUTING	DETACHMENT RULE	INFERENCE	NON-MONOTONIC	ROOTS	
BLOCK FUNCTIONS	DETERMINISM	INFINITE-VALUED	NUMBER SYSTEM	RULE-BASED	
BOCHVAR	DIAGNOSIS	INFORMATION THEORY	OCKHAM	SATURATION	
BOOLEAN	DIFFERENTIAL CALCULU	INSTRUCTION SYSTEMS	OMEGA LOGICS	SCHMITT	
BOOLEAN DIFFERENCE	DIGITAL SIGNAL PROC	INTEGRAL CALCULUS	OMEGA VALUED	SECURITY	
BOOTH	DIRECTED SEARCH	INTERCONNECTION	OPTICAL	SELF-CHECKING	
BOUNDARY-SCAN	DISCRETE FUNCTION	INTERMITTENT FAILURE	OPTICS	SELF-DUAL	
BUS	DISJOINT	INTERRUPTS	OPTIMIZATION	SELF-TESTING	
CAD	DISSOLUTION	INTUITIONIST LOGIC	OPTOELECTRONICS	SEMANTICS	
CAM	DISTRIBUTED SYSTEMS	INVERSES	ORACLE	SEQUENTIAL	
CANONICAL FORMS	DIVIDERS	INVERTERS	ORTHOGONAL	SET LOGIC	
CAPACITOR	DOCUMENT RETRIEVAL	INVOLUTION	P-ALGEBRAS	SETS	
CARNAP	ECL	ION IMPLANTS	PARADOX	SHALLOW FUNCTIONS	
CARRY-LOOK-AHEAD	EMBEDDING	ISOTONIC	PARALLEL PROCESSOR	SHEPPER	
CASCADES	ENCODERS	ITERATION	PARALLEL PROGRAMMING	SHIFT NETWORKS	
CCD	ENTROPY	I2L	PASS-TRANSISTOR	SHIFT REGISTERS	
CELLULAR ARRAYS	ENUMERATION	JAPAN	PATTERN GENERATOR	SIGMA ALGEBRAS	
CELLULAR AUTOMATA	EQUALITY	JOSEPHSON	PATTERN RECOGNITION	SIGNAL	
CHARGE-CONTROL	EQUIVALENCE CLASS	KARNAUGH MAPS	PERFORMANCE EVAL	SIGNAL PROCESSING	
CHINESE PHILOSOPHY	ERROR CORRECTING	KLEENE	PERMUTATIONS	SIGNED DIGIT	
CHIP ARCHITECTURE	ERROR DETECTION	KNOWLEDGE-BASED	PHI-ALGEBRAS	SIMULATION	
CHIP LAYOUT	EXCLUSIVE OR	LAKOFF	PI-LOGIC	SINUSOID	
CHRISTENSON	EXPERT SYSTEMS	LAMBDA RESOLUTION	PIPELINED	SOCIAL SYSTEMS	
CIRCUITS	EXPERT-SYSTEMS	LAMBDA-RULES	PLA	SOCIETY DIAGNOSIS	
CLEFTS	FAIL-SAFE	LATCH	PLAUSIBILITY	SOLITONS	
CLONES	FANOUT-FREE	LATTICE	PLAUSIBLE REASONING	SPECTRAL	
CLOSURE	FAST FOURIER TRANSPO	LEARNING	POSETS	STONE	
CMOS	FAULT DETECTION	LEGAL DECISION MAKIN	POSSIBILITY THEORY	STORAGE	
CODES	FAULT DIAGNOSIS	LINEAR CODE	POSSIBLE WORLD THEOR	STUCK-AT	
COGNITIVE PROCESS	FAULT MODELLING	LINEAR TREE	POST	SUM-OF-PRODUCTS	
COMBINATIONAL	FAULT TOLERANCE	LINEARLY SEPARABLE	PRE-PRIMAL	SWITCH-LEVEL	
COMPACTNESS	FIBEROPTICS	LINGUISTIC	PREDICATE CALCULUS	SWITCHED CAPACITOR	
COMPAR. LOOK-AHEAD	FIBONACCI	LIPSCHITZ	PREDICATE LOGIC	SWITCHING	
COMPARATIVES	FIELD EFFECT TRANSIS	LITERALS	PREFERENCE RELATIONS	SYLLOGISMS	
COMPARATORS	FILTERS	LOCAL AREA NETWORKS	PRENEXATION	SYMBOLIC LOGIC	
COMPLETENESS	FLIP-FLOP	LOGIC DESIGN	PRESUPPOSITION	SYMMETRIC	
COMPLEX NUMBERS	FLOATING GATE	LSI	PRIMAL	SYNCHRONOUS	
COMPLEXITY	FLOWCHARTS	LUKASIEWICZ	PRIME IMPLICANTS	SYNTHESIS	