

INDIAN STATISTICAL INSTITUTE

FIFTYSEVENTH ANNUAL REPORT

April 1988—March 1989



203, BARRACKPORE TRUNK ROAD
CALCUTTA-700 035

INDIAN STATISTICAL INSTITUTE

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O. INTRODUCTION¹

It is a pleasure to begin this year's report with a record of some exciting discoveries made by our Geological Studies Unit. In the course of looking for clues for the causes of global mass extinction 65 million years ago, an exciting development in geological research has taken place. Exploration conducted by the Geological Studies Unit has led to the discovery of the last remains of the flesh-eating dinosaur, tyrannosaur, in Jabalpur from a limestone bed which is 65 million years old. The Unit has also succeeded in finding quartz crystals showing features of shock metamorphism from a sandstone layer in the same place. The sandstone occurs above the tyrannosaur-yielding limestone and immediately below the Deccan Trap lava flows. If it is proved that the shock-metamorphic features in the quartz crystals are due to the effect of a very high pressure impact, then its presence indicates that the enormous lava flows in the Deccan plateau 65 million years ago perhaps had been triggered off by the impact of a huge meteorite. The resulting atmospheric pollution was of such a scale that it caused a global environmental crisis leading to the sudden and massive extinction of a large number of organisms, including the dinosaurs, all over the world.

These major discoveries are the joint work of a team consisting of Dr. D. K. Rudra and Sri P. K. Mazumdar of the Geological Studies Unit and Dr. S. Chatterjee and Dr. A. R. Basu of the U.S.A. Dr. Chatterjee is a former student and faculty of the Institute. It should be mentioned here that the Institute was the first to discover remains of dinosaurs in the Indian subcontinent. The dinosaur reconstructed out of fossilized bones and named *Barapasaurus tagorei*, has now found a place in many text books.

Among other major events during the year are two international conferences to honour the memory of Professor Raj Chandra Bose, a famous statistician and combinatorial mathematician, who had been closely associated with the Institute. The first, entitled Raj Chandra Bose Memorial Conference on Combinatorial Mathematics and Applications was organized jointly with Calcutta Statistical Association and held in Calcutta during 14-16 December, 1988. The second, entitled Raj Chandra Bose Symposium on Probability, Statistics and Design of Experiments was jointly organised with Delhi University and Indian Agricultural Statistics Research Institute and held in Delhi University during 27-30 December, 1988. Both the conferences were well attended by participants from India and abroad.

In this connection it should be pointed out that the Institute has remained very active in combinatorial mathematics and design of experiments. A monograph on Optimal Designs, which has been co-authored by Dr. B. K. Sinha of the Division of Theoretical Statistics and Mathematics has been accepted for publication by Springer-Verlag.

¹ Based on the Annual Review presented by the Director at the twentythird convocation of the Institute held on 24 January 1989.

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An important result in combinatorics, obtained recently in the Institute, is described below :

A unital of order s is a Balanced Incomplete Block Design with $v = s^2 + 1$, $k = s + 1$ and $\lambda = 1$. A classical construction due to R. C. Bose gives a unital of order s which is naturally embedded in a projective plane of order s^2 , for each prime power s . It was conjectured by D. R. Hughes and F. Piper that unitals exist only for prime power orders. Dr. Bhaskar Bagchi and Dr. Sunanda Bagchi of the Institute recently constructed a unital of order 6 disproving this conjecture. Efforts are now being made elsewhere to see if this unital could possibly be extended to a projective plane of order 36 . It may be recalled in this context that, till now, projective planes are known only for prime power orders.

Another significant theoretical result obtained by a young colleague, Dr. R. Bhatia, deserves to be mentioned. A significant improvement of existing results on perturbation of roots of polynomials has been obtained in collaboration with L. Elsner and G. Krause. In 1950, A. Ostrowski had obtained an estimate which roughly says that the distance between the roots of two polynomials of degree n is bounded by $(2n - 1)$ times a certain measure of the distance between their coefficients. In 1981 Elsner had improved this by showing that $(2n - 1)$ here could be replaced by n . Now it has been shown that n can be replaced by a constant smaller than 4 for polynomials of any degree. This result has significant applications in numerical analysis.

The Institute organized a Indo-U.S. Workshop at Bangalore, sponsored jointly by the D.S.T., the National Science Foundation (U.S.), and the Indian Econometric Society. The theme of the workshop was Bayesian Statistics and Econometrics, an area of research on foundations and new tools which remain largely neglected in India. The workshop was very successful, thanks to the efforts of Professor N. S. Ivengar, who is currently the President of the Indian Econometric Society, and other colleagues at I.S.I., Bangalore. In the last report, reference was made to a volume of radical essays on foundations by Professor D. Basu, which was edited by Prof. J. K. Ghosh for Springer-Verlag. The monograph, which came out in the summer of 1988, will also act as a catalyst in the spreading of Bayesian ideas.

The Institute, along with other organisations, is preparing to hold an Asian Congress on Quality and Reliability in October, 1989. The Prime Minister has been kind enough to agree to inaugurate the Congress and the Ministry of Industrial Development has promised substantial financial support. Much of the work for this Congress is being done by the Division of Statistical Quality Control and Operations Research.

The Institute will start a new two year M.Tech. programme in Quality, Reliability, and Operations Research from the next academic year. The programme, which will prepare students from two streams, namely, engineering and statistics, was approved by the Academic Council and the Council recently. It is hoped that students out of the course will have a strong background in both engineering and various aspects of quality, reliability and operations research. The course will meet a well felt need in Indian industries,

For the academic session 1988-89, a total of 9515 candidates applied for admission and were called for written selection tests for the courses offered by the Institute. A total of 5456 candidates appeared for the admission tests and out of them about 271 candidates were selected for admission to the various courses of the Institute. One

scholar from Egypt and one scholar from the USSR have undergone advanced studies in Statistics for a year under the Indo-ARE Cultural Exchange Programme and Indo-Soviet Cultural Exchange Programme respectively. Three (2 in Calcutta, 1 in Bangalore) research students and one outstanding M. Stat. II year student of the Institute have been awarded the National Board of Higher Mathematics Scholarship.

During the period under review, the International Statistical Education Centre, which started functioning in 1950 under the auspices of UNESCO and the Government of India, conducted the Regular Course of the 42nd term with 26 trainees from different countries in South and South-East Asia, the Middle East, the Far East and Commonwealth Africa. The Government of India have awarded fellowships to 21 foreign trainees—3 under the TCS of the Colombo Plan, 10 under Special Commonwealth African Assistance Plan (SCAAP) and 7 under ITEC. Two Indian trainees, and one trainee from Sierra Leone are supported by their respective governments.

The publication of all issues in the Fiftieth volume of Sankhyā is nearly complete. The first volume of Professor C. R. Rao's selected papers is almost ready.

The Institute's expertise has been sought by agencies. The World Bank, which is advising the Chinese Government on major price reforms, has sought the help of our colleague in Planning Unit, Delhi, Professor V. K. Chetty. Professor Chetty's expertise in price controls in India is well-known.

Several important projects have been taken up at the request of different agencies.

The Reserve Bank of India has entrusted the Institute with a project on the Long-Term Forecasts of Requirements of Fresh Notes and Coins. One has to develop a model for determining the demand for currency in our country—both the aggregate demand as well as the demand for different denominations of currency. The study is being carried out jointly by the members of Economic Research Unit and Computer Science Unit.

'Differential Impact of Modern Rice Technology on Favourable and Unfavourable Production Environments' is a research project sponsored by Rockefeller Foundation as a part of the network study undertaken in several Asian countries and co-ordinated by the International Rice Research Institute, Manila. The general objective is to examine and to measure, in the context of the rice-based farming system in West Bengal, how and to what extent technological change in rice production is accepted by the people, and how it affects their well-being under different production environments. Government clearance has been obtained very recently. The preliminary investigations have been completed, and the stage is set for the first phase of data collection at the village level.

Recently, the National Sample Survey Organisation (NSSO) has conducted a pilot study on household income, expenditure and savings to see if any meaningful estimate of household income could be found through household enquiries. The Institute is collaborating with the NSSO in processing and analysis of the data collected through sample survey.

Last year it was mentioned that the Applied Statistics, Surveys and Computing Division has undertaken the development of a software package for editing data collected by NSSO through their surveys. The package, now in the final stages of development, provides for a simple English-like language for the user to specify the

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required consistency checks. The package has been implemented and thoroughly tested on our computers. It is now being implemented on the NSSO computer at Baranagar.

A collaborative work with Gesellschaft für Strahlen und Umweltforschung (GSF), Munich, and our Electronics and Communication Sciences Unit, has developed some important quantitative methods of diagnosis of stratified epithelia in pathology for computerised detection of pre-cancerous and cancerous lesions of varying grades. The work was carried out by Dr. B. B. Chaudhuri of the Institute and Dr. K. Rodenacker and G. Burger of GSF. They developed image analysis and pattern recognition techniques of selected tissue areas in the sections based on the minimal spanning tree (MST) and the zone of influence (ZOI) tessellation graphs.

The Institute, which maintains a branch at Giridih has recently initiated action on a few important socio-ecological projects centred in and around Giridih.

The DOE/UNDP sponsored Nodal Centre started functioning as a Centre of Advanced Study in Fifth Generation Knowledge-Based computing with Professor R. Dutta Majumder as the principal co-ordinator. About twelve academic and industrial R and D groups in the country will be collaborating and using the expertise generated in the Centre.

After some unavoidable delay, the Institute has installed the VAX 8650 computer system. It is a modern system with complete interactive facility. It is supported with 16 Megabytes of main memory and more than 2000 Megabytes of on-line disk storage facility. About 50 terminals and PC's would initially be connected to the system. In addition, two Micro VAX satellite systems would also be connected to the main VAX 8650 system. Apart from standard language compilers and other utilities, the system would also provide specialized software packages for Graphics, Simulation, Image Processing, Numerical and Statistical Analysis.

Considering the growing importance of computer oriented activities, a separate Computer and Statistical Service Centre has been formed in the Institute in accordance with the Council decision of February 5, 1985. Apart from routine operational and management activities, this Centre would also provide statistical and computational consultancy to its users, would organize specialised trainings and would be responsible for the development of software and data archival service. A Policy Advisory Committee (PAC) and a Technical Group (TG) have been constituted.

Construction of Senior Students Hostel in Calcutta has been completed. In Delhi the Guest House has been extended substantially and a deep tubewell has been sunk to prevent water scarcity on campus. In Madras no construction could be undertaken since the land on which construction was to be made has been encroached upon by a group of unauthorised persons. Attempts are being made to evict the encroachers through usual legal processes.

Part I. Teaching, Training, Research, Projects and Publications

1. TEACHING AND TRAINING

Degree and Training Courses

During the academic session 1988-89, 9515 candidates applied for admission and were called for written selection tests for the courses offered by the Institute viz., B. Stat. (Hons.), M. Stat. (M-stream and S-stream), M. Tech. in Computer Science, One-year Post-Graduate Diploma in SQC and OR (Calcutta), Part-Time Certificate, Diploma in SQC and OR (Bombay and Madras), Research fellowships in Statistics, Mathematics, Economics, Computer Science, Theoretical Physics, Physics, Anthropology and Geology; One-year Evening Course in Statistical Methods and Applications and the course on Operation of Automatic Data Processing Equipment. Admission tests were conducted at 14 centres all over the country. A total of 5456 candidates appeared for admission tests and a total of 376 candidates were called for interviews and 271 candidates offered admission to various courses during the academic session 1988-89.

Four foreign applicants who applied directly for admission to our courses were given special admission tests conducted through the Indian High Commission or Embassies in Paris, Los Angeles, Colombo and Dhaka.

The annual examinations for the B.Stat. and M.Stat. courses were held in May/June 1988. The 1988-89 academic session commenced on 4 July 1988.

One hundred and eleven candidates received their degrees and diplomas at the Twenty-third Convocation of the Institute held on 24 January 1989. Ninety-seven candidates who passed the various regular courses of varying duration (one year or less) received the certificates during the year. Seven candidates were awarded Ph.D. degree of the Indian Statistical Institute.

Four trainees in Engineering from Banaras Hindu University received six-week practical training in the Electronics and Communication Sciences Unit and the Electronics Unit.

The Council on the recommendation of the Academic Council, decided to introduce a new course—the M.Tech. programme in Quality, Reliability and Operations Research from the academic session 1989-90.

A new specialisation course on 'Advanced Probability and related topics' for the M.Stat. II year has been finalized. This will be introduced from the academic session, 1989-90.

It was also decided to start a One-year Evening Course in Statistical Methods and Applications at Hyderabad. The course will start from the academic session, 1989-90.

A revision of the syllabi and course structure of the B.Stat. and M.Stat. programmes was undertaken by a committee constituted by the Academic Council. The new syllabi were introduced from the academic session 1988-1989.

A new selection test centre has been decided to be opened at Sambalpur (Orissa) for admission to the courses during 1989-90.

The number of candidates admitted to the different degree, diploma and training courses during 1987-88 and 1988-89 and the results of the examinations held during the period are given on the following page :

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**NUMBER OF STUDENTS ADMITTED AND PASSED IN DIFFERENT COURSES
APRIL 1988—MARCH 1989**

Courses	Number of students			
	enrolled in 1987-88	as on November 1987	passed in annual examina- tion in 1988	enrolled in 1988-89
	(1)	(2)	(3)	(4)
1. <i>Courses leading to a Degree in Statistics</i>				
1.1 Bachelor of Statistics with Honours B.Stat. (Hons.)				
1st year	26	21	21	16
2nd year	12	12	11	21
3rd year	16	16	16	12
1.2 Master of Statistics (M.Stat.)				
1st year (M-stream)	14	14	12	7
1st year (S-stream)	40	40	38	30
2nd year	45	45	42	52
1.3 Junior and Senior Research Fellows, Visiting Fellows in the following areas*	61	61	00	80
2. <i>Specialised Courses in Applied Statistics leading to Diplomas</i>				
2.1 Statistical Quality Control and Operations Research (One-year)	10	10	5	13
3. <i>Courses in Statistics for persons in Employment (jointly with C.S.O.)</i>				
3.1 Junior Certificate Course in Statistics (September-February)	9	9	9	21
3.2 Indian Statistical Service Probationers' Training Courses (October-December)	18	15	15	—
4. <i>Evening Course</i>				
4.1 Statistical Methods and Applications Calcutta	35	27	9	27
4.2 Two year Post-Graduate Diploma in Statistical Quality Control and Operations Research (Bombay and Madras)				
Bombay—1st year	5	4	2	4
2nd year	3	2	2	2
Madras —1st year	7	5	4	—
2nd year	5	3	2	—
4.3 Six-months Evening Course in Statistical Quality Control (Bangalore) Bangalore-January-June 1988	20	20	9	—
5. <i>Computer Courses</i>				
5.1 M.Tech. in Computer Science				
1st year	21	19	19	17
2nd year	14	14	14	19
5.2 M.Tech. by Dissertation	—	—	1	—
5.3 Intensive Course on Programming and Applications	28	28	28	23
5.4 Course on Operations and Automatic Data Processing Equipment				
1st year	13	12	11	13
2nd year	14	12	12	10
6. <i>Associatehip in Documentation and Information Science</i>				
1st year	7	6	6	7
2nd year	8	8	8	6
Grand Total	428	404	295	380

*Statistics, Mathematics, Economics, Theoretical Physics, Communication Sciences, Anthropometry and Human Genetics, Computer Science, Embryology, Geology/Biometry, Chemistry, Physics, Leaf Protein and 2 CSIR Fellowships in Theoretical Physics. The figure includes 16 Research Fellows and Associates at Delhi Centre and 4 at Bangalore Centre.

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International Statistical Education Centre (ISEC), Calcutta

A brief report on activities of the International Statistical Education Centre during the year 1988-89 is as follows :

It may be recalled that the Centre was opened in 1950, and is operated jointly by the International Statistical Institute and the Indian Statistical Institute, under the auspices of the UNESCO and the Government of India. The Centre functions under a joint Board of Directors. The Directors represent International Statistical Institute, Indian Statistical Institute and the Govt. of India. Professor P. C. Mahalanobis was the Chairman of the Board of Directors since its inception in 1950 until his death in 1972. Since then National Professor C. R. Rao has been the Chairman of the Board.

The Centre provides training in Theoretical and Applied Statistics at various level to selected participants from the countries in the Middle-East, South and South-East Asia, the Far East and the Commonwealth countries in Africa, sponsored by respective Governments. Major training programme of the Centre is a 10-month Regular Course. In addition, Special Courses of varying duration are also organised. Facilities exist for research work and advanced study by senior statisticians from abroad. Since inception, the Centre has provided training to 1111 trainees from 52 countries.

Two trainees of the 41st Term attended Special Course of two months duration in Advanced Data Processing ; one of them enjoyed ITEC fellowship and the other was supported by her Sponsor.

A total of 60 candidates from 17 different countries were nominated by respective Governments for admission to the 42nd Term of the Regular Course of this Centre. Of these 60 candidates, 32 were offered admission and 26 participants from 11 countries joined. Twenty trainees were supported by fellowships awarded by the Government of India under the Technical Cooperation Scheme of the Colombo Plan, Special Commonwealth African Assistance Plan, and Indian Technical and Economic Cooperation Scheme. Of the remaining 6, three from People's Republic of China enjoyed UNDP fellowships. 3 received support from respective employers and Governments.

Fiftyfour teachers of Calcutta, Bangalore and Delhi Centres of the Indian Statistical Institute and 40 Officers of the Government of India participated in teaching the Regular Course during the year. One trainee went to Bangalore Centre of ISI to undergo specialization in SQC and OR and 5 trainees to Delhi Centre to undergo specialization in Economic Planning.

All the Special Course trainees completed their training programme successfully. All the 26 Regular Course trainees have been recommended for the award of Statistical Training Diploma.

The officials of the International Statistical Institute maintained their cooperation and interest in the matters relating to the Centre. The members of the Board of Directors have shown their continued interest in ISEC Teaching programme, and particularly Professor J. K. Ghosh, Director of the Indian Statistical Institute, has lent his constant guidance and has shown active interest in smooth functioning of the Centre.

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Professional Examinations in Statistics

During the period under report, the Statistical Assistantship Certificate, Junior Diploma in Statistics and Senior Diploma in Statistics Examinations were held at Bangalore, Bombay, Calcutta, Delhi, Hyderabad, Lucknow and Madras Centres during April 1988 and October 1988 terms respectively.

The total number of candidates registered, appeared and their results for April 1988 and October 1988 terms are shown below.

Examination	Number of candidates					
	Registered		Appeared		Passed*	
	April	October	April	October	April	October
1. Statistical Assistantship Certificate	33	32	16	15	7	3
2. Junior Diploma in Statistics	26	40	17	19	7	8
3. Senior Diploma in Statistics	12	13	10	10	2	7

* Passed in one or more papers only—not necessarily completed the examination.

The total number of candidates who have qualified for the award of the Certificates and Diplomas in the Professional Examinations in Statistics including the results of October 1988 term are 481 and 245 respectively.

2. RESEARCH WORK

A brief account of the progress of research in different divisions and units of the Institute is given below :

Theoretical Statistics and Mathematics

The division has the major part of the responsibility of teaching theoretical statistics and mathematics in the B.Stat., M.Stat., and other courses of the Institute. The Division also conducts a course, lasting 12-18 months, at an advanced level for research scholars enrolled for the Ph.D. degree of the Institute.

Calcutta

Main topics of Research

Asymptotic Theory in Statistics, Decision Theory, Statistical Inference. Inference in Stochastic Processes, Sequential Analysis and Inference, Multivariate Analysis, Discrete Multivariate Analysis, Robustness, Linear Models, Constructional and Combinatorial Aspects of Designs, Optimality Theory of Designs, Sampling Theory and Surveys, Ergodic Theory, Stochastic Processes, Markov Processes, Stochastic

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Models, Characterizations of Distributions in Statistics, Limit Theorems in Probability, Inequalities, Application of Statistics in Geology and Human Genetics, Statistical Computations, Statistical and Quantitative Economics.

Descriptive Set Theory, Graph Theory, Combinatorics and their Applications to Social Sciences, Functional Analysis, Geometry of Banach Spaces, Measure Theory, Harmonic Analysis, Analysis on Lie Groups, General and Algebraic Topology, Differential Topology, Automata Theory, Computational Complexities, Complex Analysis and Moduli Problems, Complex and Hypercomplex Manifolds, Binary Codes and Finite Geometries, Classical Finite Simple Groups, Sediment Transport and Theory of Dispersion.

Nature and description of research work done during the current year :

1. *Probability Theory and Stochastic Processes* : Relations between Crossings and Sojourn times for continuous local martingales were studied. A semi-martingale is associated with Crossings of an interval by a martingale and their local times were described. These are used to discuss Levy's down crossing theorem and some ratio limit theorems. An extension of Levy's Characterization of Brownian motion using Hermite Polynomials was obtained. Simple Markovian motions of a particle with Velocities 0 or 1 were studied.

Prediction process for jump processes were obtained. Their Levy systems were derived and applied to get a Markovian Proof of Davis' result on martingale representations and also a formula for compensations of jump Process. A Conjecture of Frank Knight regarding jump type process was settled.

2. *Inference* : Results were obtained on the topics. Stopping rules, permutation invariance and sufficiency principle, bounded risk estimation of a finite population mean, optimal strategies, sequential methods for finite populations, consistency between model and design-based estimators in survey Sampling. Local asymptotic minimax estimation in Non-regular case. Asymptotic optimum properties of Rao's test in one and several parameter cases when the observations are dependent and asymptotic properties of Durbin-Watson test, properties of Stein's two stage procedure for point and interval estimation were investigated. Results on Edgeworth expansions, estimating change points in a failure rate, etc. were obtained.

3. *Designs and Analysis of Experiments* : Optimality properties of 3-concurrence most balanced designs, New concepts in factorial designs (admissibility efficiency-consistency) were studied and a monograph on the Calculus for Factorial arrangements was prepared. Optimality results in experimental designs (efficiency balanced rotatable designs, bio-assay designs) were obtained. Statistical problems of the estimation of optimal strategies with reference to Inventory models under risk were investigated.

4. *Multivariate Analysis* : In Discrete Multivariate Analysis, fraction selection problem was investigated. Concepts of regression and Correlation and corresponding inference problem for Circular data were discussed. The basic problem of ordering multivariate distribution was undertaken. Some general results on multivariate ordering and multivariate majorizations have been obtained. The problem of directional majorizations have been considered in detail. The concept of differential effect of a drug has been posed and the inference problems have been dealt with. The

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classification problems when the feature variables are subject to error have been considered and certain results on the effects of the noise distributions have been obtained.

The estimability problems in product multinomial sampling including connections with fractional factorial plans have been studied. Optimal multivariate designs for incomplete observable vectors have been studied. Characterization problems of distributions, Symmetrical directional distributions in relation to multivariate inference problems have been studied.

5. *Survey Sampling* : Certain problems connected with the allocation of sample size to strata have been solved and the technique of regression estimation was revisited and the exact and asymptotic properties were established. Much of the research concentrated on practical problems such as utilisation of additional resources in sampling, randomized response techniques, non-negative variance estimation, small area estimation, crop forecasting and other estimation techniques in agriculture with special reference to India.

A study was initiated regarding the inferential aspect of Social network. In this, one is primarily interested in estimation of the total number of "Symmetric ties", A simple sequential strategy was shown to have better performance over the conventional strategy based on simple random sampling. Certain probability inequalities for probability proportional to size without replacement (PPSW OR) sampling were established which were quite useful for the choice of "preferred samples" and to derive the non-negativity of various estimators.

6. *Combinatorics, Graph theory and Theoretical Computer Science* : Significant work has been done on existence and non-existence of certain special series of t -designs, those which occur classically in conjunction with finite simple groups, groups and strong regular graphs, biplanes, inversive plane.

Measures of reciprocity in social networks have been studied by considering both simple networks as well as those with multiple arcs and the results have been applied to sociology, demography, trade Statistics etc., giving interesting results. Interesting results on strongly regular totally super compact self complementary graphs were obtained. Results on in the fields of Data structures and efficient algorithms NP completeness, were obtained, generalized t -array trees were introduced and those which minimise various path lengths were characterized, using these results parallel-comparison complexities of searching problems and t -array search algorithms were determined. Studies on transportation problems, unions and common complements of subspaces were made.

7. *Descriptive Set Theory* : Random analogues of some results in Topology (eg. Tietze extension theorem, Urysohn theorem etc. ...) have been proved. Several random fixed point theorems with stochastic domain are obtained. These results significantly generalize various known results.

Structure properties of hyper-arithmetical sets of ambiguous classes were obtained. A new characterization of $Q_{\aleph+1}$ under PD was obtained. Simple proofs of invariance of Borel point classes were given. Applications of selection theorems to parameterization problems were made.

8. *Analysis, Geometry and Topology* : The work on the Pompein problem has given rise to certain unified treatment of the main problem in Euclidean spaces as well as in symmetric theory of the compact and non-compact type. In the context of operator algebras, kernel function Hilbert spaces associated with domains in C^n and their relation to Cowen-Douglas operators, Halmos' conjecture concerning complete boundedness, representation of some semi-simple lie groups and their symmetric domains, were investigated.

Several studies have been made on the area of Moduli problems on Riemann surfaces and Riemann surfaces in string Physics, embedding of homogeneous space in the universal Teichmüller spaces with applications in string theory. Homotopy studies on the classification of locally stable sections, contact structures on closed manifolds were made. Banach spaces with MIP, CI properties were studied. Intersection properties of balls and a 'dual' decomposition property were studied for injective and projective tensor products respectively of Banach spaces, leading to an interesting characterization of L^1 -preduals. The investigation of another intersection property (due to Behrends), with particular emphasis on the space of compact operators, yielded several new examples of a Banach spaces that answered in the negative several questions raised originally by Behrends. Also studied was the relationship between the finite intersection property and the property of being 'Constrained' in a dual space.

In the area of differential topology, the Gromov theory on the homotopy classification of certain types of sections of a smooth fibre bundle was extended by replacing the hypothesis that the domain of the sections be a non-closed manifold by a technical condition called "local stability". A conjecture of S. S. Chernoff on contact structures on manifolds was verified. In point set Topology an elementary construction of a regular space that fails to be completely regular with the additional property that it does not support any non-constant continuous function was given, and investigation of certain problems of a topological-cum-measure-theoretic nature is continuing.

In studying the spectrum of ergodic transformations, a question of Banach and Rokhlin, viz, whether there are measure-preserving transformations with finite Lebesgue spectrum, a particular result, obtained in 1984, was generalised and related results published.

Bangalore

Main topics of research : Theory of Large deviations, Information theory, Probability theory on infinite dimensional vector spaces, Stable and semistable probability laws, Diffusion processes, Sample Surveys, Large sample theory, Bayesian inference, Reliability theory, Functional analysis — Geometry of Banach spaces, Operator theory and Operator algebras, Harmonic analysis, Topology, Differential geometry and topology, Finitely additive measure theory, G -inverses.

Delhi

The broad areas of research in which the faculty members of the unit have worked are :

Probability theory, Quantum stochastic calculus, Semi-martingales, Cohomology and quantum fields, Stochastic processes, Filtering theory, Finitely additive probability,

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Estimation of Common mean, Parametric and non-parametric inference, Diffusion processes, Strongly p -mixing in stochastic processes, Bootstrapping, Permanents in probability and statistics, Mathematical statistics, Linear Algebra and matrix inequalities with applications to order statistics, Generalised inverses of matrices, Cost optimal integration of surveys, Operators in Hilbert spaces, Spectral theory of operators, Schrodinger operators, Distance between roots of polynomials of degree n with applications to numerical analysis, Topology, applications of topological and Geometrical methods to perturbation of eigen-values, Coincidence point theorems, Combinatorics, Game theory, P -matrices and the linear complementary problems.

Nature and description of research work done during the current year :

A significant improvement of existing results on perturbation of roots of polynomials has been obtained in collaboration with L. Elsner and G. Krause. In 1950, A Ostrowski had obtained an estimate which roughly says that the distance between the roots of two polynomials of degree n is bounded by $(2n-1)$ times a certain measure of the distance between their coefficients. In 1981 Elsner had improved this by showing that $(2n-1)$ here could be replaced by n . Now it has been shown that n can be replaced by a constant smaller than 4 for polynomials of any degree. This result has significant applications in numerical analysis.

Unbiased estimation of a parametric function of scale parameters of two gamma distributions with known shape parameters and its application to Olkin-Pratt estimator of intra-class correlation and common-mean problem, extensions and unification of existing results on improved estimation of a common mean in non-normal set ups have been obtained.

In the paper "Majorization and Singular Values II" a unified treatment of several majorization results concerning eigenvalues and singular values is given. The starting point of the theory is a classical result of Schur which asserts that the eigenvalues of a symmetric matrix majorise its diagonal elements. Several generalization of this result were then given by different authors using Hadamard products and diagonally equivalent matrices. The result of the present paper captures all the known results in this direction.

In the paper "Permanents in probability and statistics" several areas in probability and statistics are considered in which the theory of permanents can be fruitfully employed. These include multinomial and related distribution, order statistics, sequential experiments with feedback and sampling. It is shown that the Alexandroff inequality for permanents can be used to demonstrate that certain sequences arising in probability and statistics are log-concave. This is a completely new area, except for some scattered examples found earlier in the literature.

The following matrix programming problem has been solved. Given the diagonal blocks C_1 and C_2 of a matrix

$$C = \begin{pmatrix} C_1 & ? \\ ? & C_2 \end{pmatrix}$$

to determine the off-diagonal blocks so that rank of C is minimum subject to the conditions that the column span of C is contained in that of a given matrix

$A = (A_1^T, A_2^T)^T$ and the row span is contained in that of another given matrix $B = (B_1, B_2)$. For a matrix C so determined, $A-CB^T$ is a common solution of minimum possible rank for a pair of equations $A_1 X B_1 = C_1, A_2 X B_2 = C_2$.

Matrix partial orders for complex matrices can be induced by the classes of minimum norm g -inverses and the least squares g -inverses. Shorted matrices have been studied in terms of these partial orders as well as a star order of Drazin.

A coincidence-point theorem has been proved for certain classes of maps of manifolds with boundary. To a special case one can obtain an algebraic topological method of counting the number of fixed points of a generic class of maps in the interior of a manifold with boundary. No such homological counting procedure seems to appear in the literature.

Notions of cohomology have been introduced in the semigroup of finite subsets of a set under union and utilised to construct a whole family of quantum fields connecting the free boson and free fermion fields. Quantum stochastic differential equations are solved in the framework of Maassen's kernel calculus in Fock space.

A remarkable class of Martingales called Azema martingales has been realised as solutions of appropriate quantum stochastic differential equations and their chaos completeness established.

Quantum Ito's formula has been established when filtration is described by a continuous spectral measure in the time axis.

Geometric characterization of P -matrices due to Gale-Nikaido is well known. A similar characterization for N -matrices—these are matrices in which all the principal minors are negative—has been given. This result has been used to give another characterization using Linear complementarity problem.

The law of iterated logarithm for fluctuations of posterior distributions for a class of diffusion process was obtained and a sequential test of power one for testing the drift coefficient is derived. Bounds for the equivalence of the Bayes and the maximum likelihood estimators were obtained for such processes. Bootstrapping technique is applied for obtaining the first passage distribution of a finite state Markov chain. Minimax linear estimator of the trend parameter in random fields was studied. A new notion of "mixing strongly" is introduced for stochastic processes and its properties were investigated. Methods of statistical inference from sampled data from stochastic processes were studied both in the parametric and the non-parametric framework. It was shown that the kernel type density estimator is inconsistent for exchangeable sequences. A new class of Gallon-Watson type processes (branching processes with continuous state space) is introduced and non-parametric estimation of characteristic function of "offspring" distribution for such processes is studied. Inequalities of Chernoff-type for stochastic integrals were derived.

Research on the spectral theory of operators, particularly Schrodinger operators, is continuing in collaboration with Professor von Ammon of Geneva and his student from Sambalpur University, Orissa. In particular, a theory of resonances is being developed.

Study of the theory and application of quantum stochastic processes has reached an interesting stage with our discovery that every classical Markov Chain can be thought of as an appropriate quantum diffusion. An attempt to give a

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dynamical theory of the celebrated 'collapse postulate' of quantum mechanics based on q.s.d.e. is currently on. An interesting extension of Ewawo-Hudson theory of quantum diffusions has been obtained.

Applied Statistics, Surveys and Computing

The Applied Statistics, Surveys and Computing Division consists of two units : Computer Science Unit and Biometry Research Unit. Research activities in the Division include both theoretical investigation of methodology and application of existing methods to the solution of practical real life problems. The scope of the Divisional research work is broadly in the areas of applied statistics, computer science and biometry. In addition, Computer Science Unit has the responsibilities of management of in-house computer system of the Institute.

Research Activities in Computer Science Unit

Sample Survey : Area 1 : *Sample Survey* : Optimal sampling strategies under super-population models are derived based on suitably procured randomized response ; variance estimators in this context are also examined.

Superiority to Hansen-Hurwitz strategy of Horvitz-Thompson procedure based on a particular IPPS scheme is established and existence of non-negative variance estimator for the latter is established.

Asymptotically optimal sampling strategies are found under correlated super-population models. Combinatorial methods applied in construction of IPPS scheme of sampling.

Area 2 : *Life testing and reliability* : Alternative estimators for the shape parameter of the Weibull distribution are demonstrated to be more efficient than the existing ones ; Appropriate significance levels of the test involved in estimation are derived according to minimax regret, average regret and other criteria. Testimators are also derived for Inverse Gaussian distribution.

Combinatorics and Design : A Steiner design $2-(288, 8, 1)$ has been constructed. Optimality of nested multiway designs has been studied. A class of designs, called λ -designs, has been studied with a view to settle the λ -design conjecture. It is shown that the conjecture holds if every λ -design has a point, all blocks through which have the same size. A new method, called the method of sum and differences has been developed and used for constructing strongly balanced uniform repeated measurements designs. An algorithm for constructing group divisible designs has been developed and 5 new GDD's are constructed.

Methods of constructions of balanced weighing matrices and generated Hadamard Matrices have been developed and their interrelationships with orthogonal factorial plans and symmetrical Group Divisible Designs with dual property have been investigated, yielding some new series of such designs.

Econometrics : Research activities have been carried out relating to the estimation of different indices used in Econometrics. Work has also been carried out on relevant statistical problems relating to equality measures and indices of growth.

Parallel Processing, Fault diagnosis, Parallel architecture : The fastest diagnosis algorithm (IEEE Trans. on Computer 1984), for the system level fault diagnosis, has

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the complexity $O(n^{2.5})$, where n is the total number of processors in the system. Based on some theoretical work, the diagnosis algorithm is expected to have a complexity $O(n^2)$. The algorithm has been modified to that extent for all examples now at hand.

Investigation has been continuing for the design of fault-tolerant pipeline processors which continue to give uninterrupted service even when a segment of the pipeline fails.

Image Processing : Several algorithm for object extraction and edge detection have been developed. One of the algorithm is based on an ideal digital image model. This method uses only global information but produces results even better than some local information based methods. Some of the segmentation techniques use the χ^2 statistic, the edge detection algorithms fuzzy set. Unlike other methods, this is not sensitive to the direction of edges. Work is in progress to define higher order entropy of a fuzzyset which can give a measure of the average ambiguity present in any arbitrary subset of a fuzzy-set. This measure will have application in different decision making problems.

Software Design and Developments : The applied statisticians and the software specialists of the Division have successfully collaborated in developing a software package for editing NSSO survey data. The package is designed so that specification of the edit requirements may be made in an English-like language requiring no knowledge of Computer Programming. The package has been tested with live NSSO data on ISI computer system. It is ready for implementation on NSSO hardware.

The Division has been developing microcomputer-based statistical package which should meet the data analysis requirements of biologists, hydrologists and environmental scientists.

Linear Models : Explicit algebraic formulae are derived for recursive estimation and testing in general linear models (with possibly singular design and dispersion matrices). Their application to regression diagnostics is demonstrated.

Applied Multivariate Analysis : The work on estimation and testing hypothesis of patterned covariance and correlation matrices continued during this year. A new algorithm for the analysis of patterned correlation matrices by maximum likelihood procedure was developed. Various models for centrosymmetric covariance and correlation matrices were proposed in terms of autoregressive processes and repeated measures designs and problems of identification, maximum likelihood estimation and testing hypothesis were solved. Estimation and testing problems of circumplex covariance structures have also been solved. Some applications of these techniques in psychometric problems have been made.

Psychometry : A technique based on canonical correlations was developed for the construction of Attitude Scales. This technique was successfully applied to measure attitudes towards air pollution in Calcutta, based on the data from the survey on attitudes to air pollution.

Statistical Pattern Recognition : Continuing the earlier work on pattern recognition with imperfect supervisors, the problem of stochastic supervision was

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considered, motivated by applications in remote sensing and medical diagnosis. Two models were proposed for stochastic supervision—a beta model and a logistic-normal model—and the Efron efficiencies of the supervisors were derived and computed for various parametric values to understand the effect and worth of stochastic supervision compared to deterministic and perfect supervision.

Projects

(a) Internally funded project :

(i) *Attitudes of scientists and professionals towards environmental pollution :* The study aimed at determining the nature and extent of concern on the part of scientists and professionals about the present state of environmental degradation in Calcutta. Using a sample of 100 scientists who volunteered to fill in the pre-coded questionnaire developed for this pilot study, an attempt was made to analyze the experienced or anticipated environmental stress of air and water pollution along some principal cognitive dimensions, e.g., awareness, knowledge, concern as well as attitudes and values.

Although the present study is based on 'soft data' connected with scientists' attitudes, beliefs, opinions and suggestions, the findings emerging from it will have a great bearing upon policy decision-making and socially imposed change. The technical suggestions solicited from the scientists, for example, for the abatement of air and water pollution in Calcutta can be very useful to governmental agencies dealing with environmental protection.

A semantic differential scale has been developed to measure indirectly one's attitude towards air pollution.

(ii) *Survey on a Socio-economic classification of medical engineering and post-graduate students, Calcutta-1986 :* A stratified sample of 877 students of the final years of various university departments, medical and engineering colleges in Calcutta and Siligore has been surveyed. SRSWOR's were taken from 13 strata composed of students of various corners cutting across the affiliating bodies. Only theoretical innovation consists in trying qualitative and quantitative techniques for randomized references on confidential issues. The report writing has been completed and is in the press.

(iii) *TV Viewership Survey, Calcutta, 1987 :* The field work covering 496 households and 1214 viewers was over by May, 1988. Data entry to the computer systems is complete for 316 household schedules and 778 viewers' schedules. Consistency checks are over for 57 household schedules and 202 viewers' schedule. The tabulation process is to be completed and the programmes for the computation of estimates are to be tested on the computer.

(iv) *A survey of cancer patients in and around Calcutta 1987-88 :* Schedules collected from about 350 patients suffering from oral cancer were scrutinised and samples of the schedules were resurveyed for verifying the correctness of the data already collected. The data were particularly analysed and some of the findings obtained.

(v) *A study of Domestic Tourism in Orissa :* The objective of the study of domestic tourism is to collect and analyse data on domestic tourists and tourism

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infrastructure to discover basic parameters for the purposes of proper and realistic planning and promotion of domestic tourism.

All domestic tourists travelling in Orissa during a one-year period is the population for the purpose of this study. Domestic tourists at each tourist spot is considered a sub-population.

In this scheme, the sample is one of the tourist days, and parameters related to total number of tourist days can be estimated from this sample. For the purpose of estimating the total number of domestic tourists in Orissa during the year and other parameters related to number of tourists as opposed to number of tourist days, a subset of this sample has to be used. This subset will consist of these tourists in the sample whose first (or last) place of visit in Orissa is the particular town, where he is residing at the time of interview. A new sampling plan to choose a tourist from a selected accommodation (say, a hotel) has been developed. From the information of number of rooms and their respective capacity, a sequence of rooms (identified by their capacity) for each sampled accommodation has been prepared. From this list the rooms are taken sequentially and checked whether there is any occupant. If not, the next room is taken from the sequence. This procedure is such that each person has equal chance to be chosen.

The field work for this survey started in August 1988 and was completed in July 1989. The data was collected through repeated visits of hotels, dharamsalas and other places where domestic tourists stayed in selected towns of tourist interest in Orissa. A type study was also conducted at Railway and Inter city Bus Station at Puri to cover departing tourists. Another type study was also conducted near the Jagannath Temple and the sea beach at Puri.

A complete report on the survey is expected to be ready by the end of 1989.

(b) *Externally funded projects :*

(i) *ISI-ONGC Collaborative Research Project :* Faculty members of the Division participated in this inter institutional collaborative project. Aggregated econometric models for the discovery and production phenomena restricted to a basin level were already developed for Cambay basin, for which the relevant part data were available adequately. A stochastic model for discovery, preserving the probabilistic nature and discreteness of each discovery involved and its associated impact in future decision making has been developed. A simulation package has been constructed based on the model, which has also been verified on the test data obtained from Cambay basin. Also another simulation package has been developed aimed at pragmatic optimization, giving the product and cost profiles for different feasible investment strategies proposed to be followed in different basins of the country. Along with the expected returns in future the models also estimate the extent of random fluctuations to which they may be subjected for a given strategy of investments. The packages are more or less at a final shape and are being checked with the test data available. The reports on these packages are under preparation.

(ii) *Differential Impact Study of modern rice technology on favourable and unfavourable production environments :* The project is sponsored by Rockefeller

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Foundation and coordinated by International Rice Research Institute and forms a part of a network study undertaken in several Asian countries. The general objective of the project is to examine, and to estimate, in the context of the rice based farming system in West Bengal, how and to what extent technological change in rice production affects the well being of people under different production environments. There are proposed to be two broad phases of the study : Phase 1 constitutes the extensive study based on the aggregate data to be collected at the village level. Phase 2 will focus attention on the complete village economy, subject to the basic scope of the project. The required data for Phase 2 at the household level will be collected from some of the selected villages already covered in phase 1.

After receiving the clearance of the Government of India on the subject, a project team was formed by the Director including some faculty members of the Division as well as a few scientists from Kalyani University, in October 1988.

After a preliminary assessment of the situation from the district level data available from secondary sources, the phase 1 of the study was initiated. The selection of districts, blocks from the districts and villages from the blocks selected was completed, capturing the extent of agro-environmental variation prevalent in the state as far as practicable. The village level data were collected. Some analysis have been made and the results have been recorded. The preparation of the questionnaire for the second phase of the survey is in process at present. A work schedule has been prepared. The household survey constituting phase 2 of the project is expected to commence in early December 1989, the reference period for which the data are proposed to be collected being the Kharif season, just concluded.

(iii) *A Pilot Study of Social Attitudes Towards Air Pollution in Proper Calcutta* (funded by the Department of Environment, Ministry of Environment and Forests, Government of India): The main purpose of the above mentioned study was to obtain general and specific data concerning the level of awareness and knowledge of the sample residents regarding air pollution in Calcutta and their attitudes towards the quality of air and atmosphere of the locality where they presently live. The study also aimed at investigating into the people's perceptions of the effects of air pollution, their opinions regarding the possibilities of combating it and their willingness to pay for its abatement. Using a two stage probability sampling procedure, data have been collected on the basis of personal interview from a total of 1724 respondents living in 56 different NSS blocks of Calcutta proper which were selected randomly in the first stage.

The results of the survey clearly indicate that about 78 percent of the residents of Calcutta proper are quite aware of the air pollution problem.

The survey reveals that feeling of attachment with one's stay in a particular locality is associated with the expressed concern for air pollution. The more involved or identified the persons are with Calcutta, the more concern they tend to express with air pollution as a community problem. In other words, concern with air pollution in Calcutta proper does not apparently stem from, or lead to, or express itself in terms of generalized negative feelings towards or rejection of the locality as a place to live. On the contrary such concern appears to grow out of widespread feelings of community identification and to lead to ameliorate the situation.

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Further analyses are in progress for examining the role of length of residence as well as various social and demographic variables in determining one's concern with and attitudes towards air pollution. A Draft report is being prepared for the sponsoring agency.

(iv) *Study on per acre yield of FFDA/Non-FFDA water areas* : The field work has started in the districts of Burdwan, Bankura and Nadia.

Research Activities in Biometry Research Unit

Analysis of biochemical results on the onset of diabetes from etiological point of view indicate some geographical variation of immunoglobulin (M) particles of serum of diabetic people located with oral anti-diabetic drugs for a short period. This may raise serious doubts about the long-standing hypothesis that natural immunity is an almost stable and invariant character.

Studies on the dietary influence on the synthesis of cholesterol in human body have revealed that the pure carbohydrate food does not produce hyper-cholesterolemia whereas hutter or any food that contains saturated fatty acids of animal origin is hyper-cholesterolemic.

A study is in progress on the role of biological, immunological and genetic variables in malaria. Another study has been undertaken to investigate the different sub-units of genetic markers in tissues of Indian freshwater carps.

Projects

(a) *Internally funded project :*

(i) *Impact of common oral antidiabetic drugs at the immunoglobulin levels of diabetic people* : Short term and long term effects of common oral antidiabetic drugs at the immunoglobulin and protein level of maturity onset diabetic people were studied. The immunoglobulin, Igm behaves peculiarly in the short term treatment. This is very important finding and further studies continued.

(ii) *An investigation into the young insulin dependant Diabetic people* : The possible role of 'stress factor' on diabetic mellitus is the objective of this study. Data has been collected from the Industrial area of Jamshedpur, rural and urban area of Calcutta and tribal people at Giridih. One paper has been published and another is under preparation.

Mal-nutrition related diabetic patients are found to possess increased serum lipid levels along with high levels of IgG. This shows that there is some abnormality in the metabolic functions of lipids. Work on some immunological parameters in such patients reveals that the problem needs greater attention on the immune system of the body.

(b) *Externally funded projects :*

Pilot survey on the determination of survival, growth and reproduction rates of fresh water Indian carp with reference to bundh-bred, hatchery and riverine sources : Some of the physical parameters such as length, weight etc. and a few biochemical parameters

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were measured of carp seeds from different sources such as Hatchery, Chaba, bundh and river. Work has been completed and a final report will be submitted to the Directorate of Fisheries, Government of West Bengal.

The Computer and Statistical Service Centre (CSSC)

Following the recommendations of the Indian Statistical Institute (ISI) Review Committee and a decision of the ISI Council, the CSSC was set up by Dr. J. K. Ghosh, the Director of the Institute by his office order No. D.O./6358 dated 2nd December, 1988. A Technical Group (TG) to examine technical matters relating to the centre and a Policy Advisory Committee (PAC) to formulate overall policy regarding the utilisation of the services of the CSSC have also been constituted. Until permanent arrangements are made, Dr. J. Roy, Chairman of the TG will be in charge of administration of the CSSC.

The Computer and Statistical Service Centre (CSSC) will be responsible for operation and maintenance of the computer system allocated to the centre to provide the following services to users with special arrangements for students : (a) Statistical and computational consultancy ; (b) Assistance in choosing and using software available at the centre ; (c) Assistance in computer programming and debugging of programs ; (d) Training in systems software, application packages and programming languages ; (e) Bulk data transcription service and (f) Data archival service.

The CSSC will be equipped with VAX 8650 system of Digital Equipment Corporation, USA, Configuration of the system is given below :

Hardware :

VAX 8650 CPU with 16 MB memory
5 × 456 MB Fixed Disk (RA81)
Two 8" Floppy Disk Drives (R X 21 — BN)
Two 1600/6250 BPI Tape Drives (TU 81 — AB)
One 800/1600 BPI 9 track tape Drive (9300-F)
Twenty Video Display Terminals (VT 320)
Eight 240 CPS Dot Matrix Printers (LA 240-AA)
Two 600 LPM line Printers (B — 600)
One Laser Printer (LN03 — AE)
Two Desktop color Graphics Terminal (Tektronics model 4209)
Two 36" × 48" Graphics Tablet (Tektronics model 4958)
Two Ink jet Color Copier (Tektronics model 4696)
One ZETA — 8 plotter, 8 pen
There will be two MICRO VAX — II systems of the following configuration attached to the main system.
Micro VAX II (VS 460 — D3) with 4MB memory, 42 MB fixed Disk and One 5.25" FDD 1.2 MB Capacity
19" Graphics Terminal (Resolution 1024 × 864)
Corporate Mouse
Micro VAX-VMS operating System with FORTRAN and PASCAL Compilers.

Software :

- (a) VAX/VMS Operating System Ver. 4.7
 - BASIC
 - C
 - COBOL
 - FORTRAN
 - PASCAL
 - Computer Aided Instruction
 - DB (Relational Data Base Software)
 - WPS Plus (Word Processing Software)
 - LISP
 - QUINTUS PROLOG
- (b) Ultrix Operating System with FORTRAN, PASCAL, C, FRANZ LISP
- (c) The following program packages will be available under VAX/VMS
 - IMSL (International Mathematical and Statistical Library)
 - SPSS (Statistical Package for Social Scientists)
 - GPSS (General Purpose Simulation System)
 - ACSL (Advanced Continuous Simulation Language)
 - PLOT 10 Interactive Graphics Library (SIGGRAPH/ACM)
 - BMDP
 - NAG

The CSSC will maintain a Data Archive consisting of data tapes from the National Sample Survey Organisation, and also of other important surveys, which may be made available to the CSSC.

The CSSC conducted a Course on Word Processing for scientific workers of ISI, 23 participants attended the Course. The centre also conducted a two weeks course on "Programming in BASIC" for Technical Officers of SQC/OR.

The CSSC will soon announce refresher and orientation courses for computer professionals of ISI, and others.

Physical and Earth Sciences

CHEMISTRY

Research Activities

1. *Study of Soil Rhizospheres* : Plant roots being the habitate for the development of symbiotic and non-symbiotic micro-organisms the soil rhizosphere permeated by them is the zone of vigorous activity. This attributes to the rhizospheres properties and composition different from those in the bulk soil. A comparative investigation was undertaken (to understand the biochemical and microbiological pathways) of humus formation through measure of physico-chemical parameters at root-zones and away. Significant difference in humus composition and soil physical properties have been observed.

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2. *Colloid chemical behaviour of clays and related minerals* : Adsorption and desorption of organic and inorganic ions on fine-grained rocks, feldspars, quartz and clays have been measured to understand the growth of surface area and exchange capacity during the soil development. Relative flocculation—sedimentation characteristics of organo-mineral substances are being employed to develop a possible method of isolating individual mineral from their complex mixtures in soils.

ELECTRONICS

A. *Digital Systems Research* :

1. *Parallel Algorithms and Parallel Architectures* : Design of efficient parallel algorithms and their implementation on suitable systolic architectures for different numeric and graph problems like binary multiplication, all pairs shortest path generation in a graph etc. have already been completed. Significant results on these areas have already been published in different international journals of repute. Extension of the earlier algorithms and architectures for fault-tolerant binary multiplication and division are currently under study. Studies on efficient parallel algorithms for ternary arithmetic and their implementations on systolic architectures have also been undertaken for the current year.

2. *Network Topology* : Studies on suitable topologies for computer networks in order to have a network with low diameter, low number of communication links, incremental extensibility and fault tolerance have already been carried out and significant results on these areas have also been published. Recently we proposed to undertake a program to study the reliabilities of different network structure and hence to devise certain algorithms for designing a suitable topology with a given reliability under the constraints of a given maximum number of edges and a minimum value of the diameter.

3. *Some Studies On Interconnection Networks* : Different types of full-access, unique path multistage interconnection network (MIN's) have been studied extensively. The problem of partitioning a given permutation into an optimal number of compatible subsets, such that each subset may be passed through the MIN simultaneously, has been solved for a definite class of permutations. To resolve the same problem for any arbitrary permutation is under development. A new mathematical representation of MIN's and to determine the equivalence of different MIN's using this representation are under study.

4. *BENES Network and Its Fault-tolerance* : Benes network being a rearrangeable MIN, can realize any arbitrary permutations in single pass. It has been observed that it also possesses a high level of fault tolerance without any extra stage. It can tolerate any single fault with a very simple rerouting. Its fault-tolerance and routing in presence of multiple faults have also been found. New designs for fault-tolerant non NXN's having $\log_2 N$ stages introducing minimum redundancy are currently under study.

5. *Synthesis of MIN's from Some New Consideration* : Some new design methodologies for the MIN's are under development. Design of an NXN with near-optimum hardware that will realize a given set of permutation in a single pass is

under study. Synthesis of an $N \times N$ MIN when N is not a power of 2 covering a wider spectrum of application area will be developed.

6. *Testing and Fault Tolerance of Interconnection Networks* : The versatility of MIN's have led to widespread use of these networks in multiple processor and communication systems. As a result, testing of the MIN is becoming a topic of increasing interest and research. Fault tolerant design schemes for a class of MIN's implemented with 2×2 switching elements have been obtained. These schemes tolerate only control element faults. But the novelty of the scheme is that they do not use any multiplexures of any special type of elements but only some additional stages of switching elements and they cover a large number of multiple faults as well.

7. *System Diagnosis* : Work is in progress to develop an efficient algorithms for diagnosis faulty units in a multiprocessing environment. Graph theoretic modelling is adopted and several interesting results have been obtained. A new algorithm has been proposed whose performance is currently being estimated.

8. *Delay Fault Analysis* : The detection of delay faults is an important area of concern to any VLSI designer. Effects of logic partitioning on the behaviour of delay faults are investigated. Attempts would be made to devise methodologies for designing circuit with guaranteed performance.

9. *VLSI Layout Design* : In hierarchical design of VLSI chips, a floorplan is often obtained as a rectangular dual of a given graph depicting topological neighbourhood among functional modules. The area and shape constraints for each module are also given. Since it is advantageous to generate sliceable floorplans, an investigation of the graph-theoretic conditions under which a given graph has a sliceable dual has been done and method to construct it has been devised. A polynomial-time algorithm has been developed for transforming a given nonsliceable floorplan to a sliceable one, with changes in aspect ratios of minimal number of models. Further work includes decomposition of nonsliceable floorplan from the connectivity consideration of channel graph and to find an efficient algorithm to break all cycles in the channel graph with minimum number of channels. This will greatly enhance to routability on the chip.

B. Theoretical Physics

1. *Holomorphic Quantum mechanics and conformal geometry* : The internal symmetry of hadrons has been investigated from the point of view of holomorphic quantum mechanics and conformal geometry.

2. *Stochastic field theory and thermo field dynamics* : Thermo field dynamics has been formulated on the basis of the finite temperature stochastic field theory. The equilibrium and nonequilibrium states in quantum statistical mechanics has then been studied on the basis of this formalism.

3. *Stochastic field theory and supersymmetry* : The realisation of supersymmetry from stochastic field theory both at $T = 0$ and $T \neq 0$ has been investigated. Supersymmetry has also been investigated utilising the techniques of holomorphic quantum mechanics in an interacting theory.

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4. *Stochastic quantisation and Berry phase* : Stochastic quantization in Minkowski space-time has been studied taking into account a complexified space-time. It has been shown that this formalism leads to a gauge theoretical extension of a relativistic particle which gives rise to Berry phase in the sharp point limit.

5. *Superstring and Ising model* : The relationship between nonlinear σ -model having a Wess-zumino term with a Polyakov fermionic string and three dimensional Ising model has been investigated.

6. *Quantum gravity and supergravity* : The role of microlocal structure and geometry in gravitational phenomena has been investigated. It has been shown that quantum gravity and $N = 1$ supergravity may be represented by the forstan term in Einstein-Castan action which can be formulated in terms of SL (2,C) gauge theory.

7. *Geometrical and topological features of quantum field theory* : The role of non-hermitian operation and complex manifold has been investigated to study the topological aspects of quantum field theory. It has been shown that the topological aspects of a fermion help us to avoid the chiral anomaly.

8. *Quantum field theory and quantum mechanics* : Supersymmetry breaking has been studied in a number of models. Finite temperature effects on strings in flat as well as curved space have been studied. Some studies on Kaluza-Klein theory has also been made. Gaussian analysis of several field theoretical models have been performed. Existence of solitons at finite temperature has also been studied using this approach. Presently this method is being used to study models in curved space and nonlinear models.

In quantum mechanics exact solutions of a number of non-exactly solvable problem have been found using super symmetric quantum mechanics. The problem of partition algebration is under study at present.

The shift $1/N$ expansion technique for relativistic equations, namely, the Dirac equation has been developed. The method is general enough to be applied to any potential and the cases that have been treated includes scalar and vector potentials. Further development of this method and related methods are currently under study.

9. *Plasma physics* : Ion accoustic solitary wave equations have been studied extensively. Double layer formation in both magnetized and unmagnetized plasma has been studied. These problems have been treated using the pseudo potential approach.

10. The worker has been continuing his researches in the field of Ultrahigh Energy Physics with an aim at understanding the nature of the collisions of the particles and also the structure of the particles as well. The researches in the final analysis are motivated to suggest and/or build up an alternative basis of particle structure and particle collision.

11. The investigation of a quantum particle with random background field is studied using the cluster expansion technique. A generalised master equation is derived

similar to that for a particle interacting with a thermal bath. This has profound significance in the theory of measurement process in quantum mechanics. The decay of quantum coherence and the Feynman paths due to this background field are still under investigation. The random background field can be shown to generate the confining potential for quark and gluon. This random background field induces the fluctuation of the space-time metric or vice-versa.

12. The fluctuation of space-time metric raises a small but finite cosmological constant in Einstein equation. The creation of particles and other cosmological scenario can be studied within this framework. The nontrivial space-time objects like warm holes and other foundational problems are also under investigation considering the fluctuation of the space-time metric. Moreover, the Finslerian structure of manifold and related gauge fields can be studied taking the probabilistic structure of geometry.

13. The ultrahigh energy Cosmic Ray and its galactic origin are also under investigation.

C. *Fluid Mechanics*

1. In statistical methods, as applied to geophysical turbulence problems, often the gradient diffusion assumption is made regarding transport of mass, energy or other properties within the flow. Appropriate formulation of the associated turbulent transport coefficient or spectral eddy-viscosity is of considerable importance in such an approach. The spectral eddy-viscosity for the case of a stratified turbulent flow without shear has been worked out. Such calculation for the case of stratified turbulent flow with shear is under progress.

2. *Blood flow in cardiovascular system* : In the cardiovascular system the normal blood flow is sometimes disturbed by some unnatural growth (medically called stenosis) formed in the lumen of an artery. The important flow characteristics, such as velocity, wall shear stress, pressure, etc. which have medical significance are also disturbed and reveal some alteration in the flow caused by stenosis.

The effects of stenosis on the one-dimensional flow field of viscoelastic fluid in a rigid tube have been studied. The present investigation is going for examining the stenosis on the flow characteristics for two-dimensional flow in a rigid tube.

3. *Thermocapillary flow phenomena and formation of surface waves* : The unsteady flow of a liquid film on a cold rotating disk is analyzed by means of matched asymptotic expansion and the velocity field, film thickness, temperature and the rate of heat transfer are determined. A zone S , bounded by a curve in the r - z plane may be delineated such that the temperature is minimum on this curve. Thus, heat flows from the disk to the fluid inside the zone S and in the opposite direction outside S .

Theoretical study of this problem is a first step towards the understanding of the complicated effect of heat and mass transfer on spin coating problem.

4. *Effect of a strong vertical vortex on the sandy bed in a river* : Experiments have been carried out in our laboratory by creating a vertical vortex by rotating a hollow and perforated circular cylinder in a water reservoir with a bed of sand.

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Boundary layer in a conical scour hole has been studied for one phase flow and vertical velocity distribution in the solid body vortex calculated. An electronic instrument for measuring accurately the speed of rotation of the vertical cylinder has been constructed.

5. *Scour Near bridge piers* : An approximate model incorporating horse-shoe vortex as well as vertical wake vortices has been drawn up to explain the flow field around a bridge pier. Experiments have been conducted at the laboratory of Civil Engineering Department of I.I.T., Kharagpur.

ELECTRONICS AND COMMUNICATION SCIENCES

Activities of the Unit include (i) investigation for the methodology and algorithms development of the various problems in the application area of computer and communication sciences (ii) teaching some of the courses in M.Tech. (Computer Science), B.Stat. and M.Stat. programme of the Institute and conducting vocational training to engineering students of different universities and I.I.T's and (iii) carrying out external project work.

During the period April 1988 to March 1989 research work was directed in the following areas.

1. *Development of methodologies for Image Analysis, Shape Analysis, Image understanding System and Computer Vision Technology* :

Major contributions in this field may be enunciated as follows :

(a) A unified approach to pattern recognition, image processing, computer vision and artificial intelligence in the light of knowledge based computer systems technology for future generation computer systems has been formulated and published in international journals.

(b) Some important development in respect of image segmentation using visual response system and a new coding scheme has been developed for two tone image contours and published, which is being extended for gray tone images.

(c) A methodology and software for 3-D shape analysis has been tested with generated image data and important contribution in the field of shape analysis from the point of view of robotics and computer vision was recognising and locating partially occluded objects applying some methods of differential geometry was completed and published.

2. *Studies on Pattern Recognition/Classification, Feature Evaluation, Learning Algorithms and Parallel Processing Algorithms including Neural Computing* :

(a) In the field of cluster analysis and non-parametric pattern recognition an estimation procedure was developed on the basis of minimal spanning tree for three different classes, viz. compact region, bounded line classes and bounded mixture classes. An intelligent search method for clustering using artificial intelligence technique was also developed. All these are being applied in image processing problems.

(b) In the field of fuzzy mathematics and its applications a group of generalised fuzzy operators were developed and published along with a method for computing

bounds for membership functions to be used in real life problems. A group of optimal fuzzy measures were developed for decision making purposes when the patterns are incomplete and ill defined. Fuzzy transforms for colour image enhancement and segmentation were developed.

(c) In the field of statistical pattern recognition theoretical property of the Bhattacharyya coefficient as a feature evaluation criterion and looseness of error bounds provided by the generalised separability measures of Lissack and Fu has been developed and published.

(d) A fractal based criteria was developed to evaluate the performance of digital image magnification techniques as a measure to compare the performances of different techniques. Fractal dimensions were applied to different landsat TM images and are found to be an attractive measure for such comparison since they are not only data structured depending but also invariance to scale changes to original data. Experiments confirmed that bilinear interpolation preserves the fractal dimension upto eight times magnification while bicubic interpolation preserves it upto four times.

(e) A parallel architecture for spatial aggregation which is an important psychophysical attribute were suggested and a simulator for Hopfield type neural network is under development for pattern recognition and visual image processing.

3. *Digital Communication, Signal Processing, Microwave Propagation and Atmospheric Studies :*

(a) Studies on the properties of Tropospheric propagation over the coastal region of eastern India : Investigation of the propagation of Bangladesh TV signal transmitted from Satkhira centre, in the fringe region of reception has been completed. Analysis of some of the data recorded simultaneously at three stations at Channel VII-189 MHz provided some interesting results specially during the presence of atmospheric irregularities and also at atmospheric disturbances. These results have been reported and published in different journals and conference proceedings.

We are planning to relate these propagation characteristics with the boundary layer behaviour prevailing at that time. To get informations regarding the earth's diffraction and scattering in well beyond the radiohorizon, we are extending these observations to another Bangladesh TV centre Khulna, which is far from Calcutta and also transmits in higher frequency.

(b) Observations and Studies on the Atmospheric behaviour by Sodar within 1 km range : The atmospheric characteristics as thermal plumes, nocturnal inversion, turbulences etc, have been extensively investigated over this region through the continuously operated Sodar (indigenously developed at ISI). Huge amount of data collected from the system has been in the analysis stage and some of the results are going to be published in the journal and conference proceedings (already accepted).

Literature survey on the studies on aerosol, acid-rain, and other pollution effects are going on. Planning of a pilot survey on this study and also selection/development of necessary system for monitoring them is under consideration.

(c) On Instrumentation work for communication network : Instrumentation works on μ -processor based interfacing system in dealing vast amount of propagation

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data are in progress. Some suitable algorithms for processing of these data have been developed. μ -computer based data acquisition system with on-line digitization facility and storing of VHF/atmospheric signal data for further analysis and processing are under consideration.

4. *Automatic Speech Recognition, Music Analysis and Speech Processing System Development :*

(a) Acoustic phonetic study of Bengali speech sound : A detailed study of Bengali vowels has been completed and the results are accepted for publication. Analysis of spectrograms of about 300 Bengali words uttered individually by 6 male and female speakers have been completed.

Phonetic transcription of 30K Bengali words have to be computerised and some progress has been achieved in phonetic transcription and computerisation. For handling these large data for lexical analysis some software packages development have been completed. In the areas of existing ambiguities, a standard for pronunciation has to be developed.

Study of the properties of large lexicon to develop efficient organisation and management of data-base has been in progress. A knowledge-base for key-syllable/key-word related statistics and coherency statistics for various distinctive features at the phonetic level are under consideration for development and would be used in developing knowledge-based lexical expert system.

(b) Statistical studies on North Indian classical music (Gharana) : To discriminate gharanas (say, Agra, Jaipur and Bishnupur) 'strutis' play an important role. Hardware and software system development for acquisition and processing of of these ragas are going on. Statistical and fuzzy-based methodologies are proposed for the analysis of data for all these three gharanas in collaboration with SRA. Cues of nasality in musical sounds for establishing an objective measure of degree of nasality is also undertaken.

(c) Development of voice-interactive Knowledge-Based Computer System : An expert system model for limited vocabulary isolated word recognition has already been tested. The syntactic and semantic relations for processing of Bengali language is being completed. Development of a lexical data structure with morphological base has already been undertaken. Synthesis of speech is under consideration. The overall programme is a part of the project jointly undertaken by six different Institutes including ISI.

5. *Indepth Studies on Cybernetics, System Theory and Artificial Intelligence (AI) :*

(a) Procedural Knowledge and Logic Programming : A theory and method to synthesise Logic Programs from the structured algorithmic specification programs has been in progress. For primary investigation a subset of specification language containing only simple input/output, assignment, conditional and loop statements has been considered. Arrays and more complicated data structure would be considered afterwards for implementing machine independent Logic Programming synthesis algorithms based on structured algorithmic language and standard PROLOG semantics.

(b) Natural Language Understanding specially of Bengali Natural Language : It is one of the important topics of AI by which computer understands natural language by Expert System approach and the ultimate objective is to have a fullfledged working system with Bengali sentences as accepted inputs and produces representations of knowledge carried by the sentences. Inherent formalisms of standard 'sadhu' Bengali Language has been identified with a word grammar for common Bengali verbs on a possible structuring of Lexicon. Knowledge representation scheme compatible with other standard KBS (as vision and speech understanding systems) are in consideration.

Future plan of works consist creation of a reasonably large lexicon of common words, formation of grammars for different word classes/parts of speech and extraction of word-analysed sentences from the semantic information.

(c) Studies in Knowledge Representational methodologies for recognition of partially occluded objects and 3-D computer vision : A new method has been proposed to recognize and locate partially occluded 2-D and 3-D rigid objects from an initially generated set of local features of shapes using the concept of differential geometry. For the best possible recognition, a computer vision scheme based upon the matching of local features with that of models of cognitive data-base are considered.

Development of 3-D vision knowledge representational scheme including frame-line representational language, a resolution theorem prover and an interactive man-machine interface is going on. The suitability of logic programming for 3-D knowledge representation has been studied and experimented with a small scale system designed to test some of the 3-D vision paradigms in the block-world.

6. *Development of AI Methodologies in building Expert Systems for different application :*

(a) Artificial Intelligence in developing Expert System : Development of expert system using AI for the application in field of speech and language processing, image processing and biomedical engineering field has been under processed. A scheme for an expert system in vision research has been developed. 'Association of Experts' have tested satisfactorily and the development of primitive expert (module P'EX) is being continued. Based on total energy profile, primary labelling (a part of P'EX) and ultimately lexical expert (module LEX) would be undertaken.

(b) Fuzzy Expert System in management of Uncertainty : Extraction of informations from incomplete data-input and knowledge-base would be possible through those parameters of fuzzy expected value, fuzzy expected interval and fuzzy relations to design Compiler, Inference-Engine and Question-Answering programme. Algorithms have been developed to handle hand-written character and speech recognition problems to facilitate natural language processing and communication between man-machine at faster rate.

(c) Expert System for Hand-written character recognition : Development for the methodology for recognition of well formed hand written isolated alphabumeries have been continued. In the subsequent phases of work development of hardware facility for reading documents in the formatted version of Zip-code, Bank-cleques

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would be undertaken so as to automatic reading of the programme/data sheets by the systems would be possible. To model the system as an expert one, development provision for recognition of well formed hand-written documents has to be incorporated.

7. New Computer Architecture for Signal Understanding, Intelligent Interface towards Knowledge-Based Computer Systems (KBCS) in FGCS :

The National Centre for Knowledge-Based Computing with Prof. D. Dutta Majumder as Principal Co-ordinator is engaged in active research and developmental work in the field of pattern recognition, image processing, computer vision and artificial intelligence in connection with the Future Generation Computer Systems (FGCS/KBCS Programme) development. The chief activities of the centre are as follows :

(a) Development of a Simulator for a Multi-layered Parallel and Distributed Systems to implement low level visual processes : For syntactic and semantic validation of user-supplied network description and function definition, a data validator has been developed along with softwares for network definition file and function files. A pseudo-parallel simulator is being implemented under UNIX environment.

(b) Neural computing for pattern recognition and computer vision : Since for non-existence or rarity of efficient conventional algorithms for solving complex visual pattern recognition, neural computing paradigms are thought of. Artificial neural network functioning as an Associative memory or Optimisation network may solve those problems. Analog network model with dynamic behaviour and with well defined, regular attractor basins has been developed to facilitate automatic and efficient synthesis of the network for a given visual pattern recognition problem. Implementations of artificial neural network as an alternative architecture for vision computing in possible circuit theoretic application is under consideration.

(c) Parallel architecture for Spatial Aggregation : Spatially apart objects can be grouped into a single entity to extract underlying arrangement within them may be possible by spatial aggregation. To handle this problem an effort has been made to design an SIMD architecture with a massively parallel PE plane. Design, allocation, and possible reduction of plane size for PE is in progress.

(d) Recognition of Partially Occluded objects and knowledge representation scheme for high level computer vision : Work is in progress to recognize and locate partially occluded 2-D rigid objects, the local features of its shape is generated using differential geometry concept. Based on matching local features of the objects in a scene, a computer vision model has been developed. Model matching has been done by a scheme for hypothesis generation and verification.

The software for different functional modules with incorporation of high level visual knowledge in the network has been in nearing completion.

(e) Remote Sensing application : Localization and registration of satellite images with topomap, algorithm development for geometric correction of remotely sensed data and principal component analysis for developing prototypes of rocks, classification of densely vegetated and water-body regions have been done.

Testing of supervised classification techniques over a restricted terrain for detecting/identifying different rock types using gray values of pixels (4 bands of MSS data) are going on with development of algorithms for interpolating/growing regions expertly covered by homogeneous rock types.

Project Work

Externally Funded Collaborative Projects

Ongoing Projects

1. Collaborative research project on '*Hindusthani Raga Sangeet and Indian Stringed Instruments*' between ISI and Sangeet Research Academy (SRA) has been continued during the period under review.
2. The joint project entitled '*Statistical Studies on the Tropospheric Preparation for VHF/UHF and Microwave Link*' amongst ISI, IRI'E—Calcutta University and B. E. College has been continued and is on the stage of completion. Now the work on multi-sodar and Doppler Sodar system is under processing. This project was funded by the Department of Science and Technology (DST). Final Technical Report containing the interesting and fruitful results have already been sent.
3. Project funded by Electronics Commission entitled '*Application for Pattern Recognition and Image Processing Techniques to Geological Mapping and Mineral Detection*' is completed. On successful applications of supervised classification technique small area containing dense vegetation and water-body and its rock types can be identified and subsequently a geological map of them can be developed.
4. Defence Grant-in Aid Scheme project entitled '*Systems and Algorithm Development for Pattern Recognition and Shape Analysis for object of Defence Interest*' is under progress. Using principal component analysis, various filtering techniques and applying different transformation, effective storage and segmentation of images can be performed in a result-oriented fashion.
5. The collaborative research work on '*Intelligent Robot Fabrication*' with Birla Industrial & Technological Museum (BITM) is continued.
6. National Knowledge-Based Computer System (KBCS) has been established with Prof. D. Dutta Majumder as Principal Coordinator-cum-Project Director in the field of Pattern Recognition, Artificial Intelligence, Image Processing and Computer Vision for Fifth Generation Computer Systems (FGCS) Programme of UNDI and Govt. of India. A part of the Project on '*Some Applications of Artificial Intelligence in Developing Expert System*' is under Progress.

Geological Studies

Research :

Research was undertaken in the following broad areas during the year (1988-89) :

Tectono-stratigraphic studies of the Delhi Supergroup, Rajasthan ; Tectonics, stratigraphy and sedimentation of the Proterozoic rocks of the Pranhita-Godavari

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Valley ; Gondwana geology and palaeontology of the northwestern Pranhita-Godavari Valley ; Studies on late Cretaceous dinosaur fauna from the Lametas in Maharashtra ; Ultra-structure and SEM studies on dinosaur egg shells from central India ; Evaluation and description of late Cretaceous fish faunas ; Fossil amphibians of the Satpura Gondwana basin ; Stratigraphy, fossil and geological relationship of the Lameta beds, Jabalpur ; An empirical statistical study of preferred orientation of line in 3-dimensional space—applications in geology ; Experimental study on the development of large-scale vertical scour holes through action of stationary vortex.

Significant progress that has been achieved in certain broad areas of research is given below :

Delhi Supergroup : The Delhi Supergroup of central Rajasthan has been interpreted as shallow water deposits younging away from the contact with the basement complex. The complex set of thermo-tectonic events in these rocks has been interpreted in terms of two broad tectonic episodes, interspersed by a phase of thermal high.

Proterozoic geology of the Godavari Valley : A history of multiple rifting in an intracontinental setting for the evolution of the basin in-fill, erosional remnants of which constitute the Proterozoic sequence of the eastern Proterozoic belt of the Godavari Valley has been suggested. There is an indication of considerable shortening across the basin strike, raising the debate about a palinspatic collisional suture along the *Godavari join* between two cratons.

The different sedimentary units in the southwestern Proterozoic belt of the Godavari Valley can be grouped into three assemblages, each having a distinctive depositional framework. It is suggested that there is a successive change through time from shallow marine to deep marine to continental regime under tectonically unstable conditions, perhaps related to development of the rift valley basin.

Gondwana stratigraphy and palaeontology : The vertebrate faunal studies of the late Triassic Maleri and Dharmaram Formations recognise three replacement events which may coincide with the base of Carnian, Corujan-Norian boundary and Rhaetic-Liassic transition, respectively.

Mesozoic fish faunas and dinosaur egg shells : New material of Eoserranid fishes, represented by 3-D skull material and parts of body, collected from late Cretaceous sediments of central India are under examination. Screening of the matrix has revealed additional new micro-vertebrates, as fish teeth and scales.

Results of the work on dinosaur egg shells, including ultra-structure examination under SEM, conducted jointly with Laboratoire de Paléontologie, Montpellier, France, and Centre for Advanced Study in Geology, Chandigarh, throw light on the last of the dinosaurs in India and their European contemporaries.

Lametas, Jabalpur : Exploration in the late Cretaceous Lameta beds in Jabalpur has resulted in the exciting discovery of the last remains of the flesh-eating dinosaur, from a 65 million year old limestone bed. Some quartz crystals showing features of shock metamorphism from a sandstone layer overlying the limestone bed and immediately underlying the widespread Deccan Trap lava flows have also been

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recovered. The discovery of tyrannosaur and the shock metamorphosed quartz, if indeed the shock metamorphism is proved to be induced by the very high pressure impact of a huge meteorite, may lead to an important understanding of a global problem. With regard to the mass extinction as well as the triggering off mechanism of the enormous volcanism that occurred in the Deccan plateau 65 million years ago.

Quantitative geology : Variation in the nearest neighbour density estimates in C-axis fabric in some quartz tectonics has been investigated. An exponential function apparently compatible with monoclinic point group symmetry has been and is being examined for its suitability in describing observed preferred orientations in natural samples.

Teaching and Training :

Members participated in teaching geology in the B.Stat. (Hons.) Course. Several members participated in the teaching programmes of other universities and institutions, viz., M.Sc. course in Geology, Calcutta University, B.Sc. (Hons.) and M.Sc. in Applied Geology, Jadavpur University.

Physics

1. *Research Activities :*

The research activities of the Physics Unit have been on problems of 'Bioengineering and Medical Physics' and during the period April 1988—March 1989, the Unit worked mainly on the following.

(i) Electrical properties of the horny layer of the skin such as the determination of high frequency electrical conductance, the state of hydration and the sorption-desorption experiments to evaluate the boundary function of the skin.

(ii) Measurement of transepidermal water loss—normal and pathological—and correlation with hydration state and the electrical conductance.

(iii) Design and development of an instrument for measuring the coefficient of skin friction and its changes with hydration and such diseased processes as psoriasis and ichthyosis vulgaris.

PROJECT WORK

Ongoing project :

The only ongoing project of the Unit is entitled '*Thermal and Electrical Properties of Skin*' which is a logical extension of the previous completed project '*Mechanical Properties of Skin*'.

In short, the project aims at, among others,

(a) quantitative measurement of cutaneous thermal sensory thresholds, loss and recovery

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(b) determination of skin surface pH—normal and pathological and at different environmental conditions

(c) evaluation of skin surface hydration, sebum excretion rate, electrical impedance, transepidermal water loss, skin friction etc. to characterise the quality of the skin

(d) studying the phenomenon of heat transport in skin and subcutaneous tissue.

Progress of the project : The project is almost at the completion stage. An electronic device has been developed to measure cutaneous thermal sensory thresholds (TST). The TST'S of 200 normal and many groups of pathological skin have been determined and their changes with age, sex, locations, humidity and ambient temperature etc. studied by multivariate analysis and their correlations determined. It has been found that TST could be used as 'aging index' of the skin.

Studies of sensory loss in leprosy patients of various types—indeterminate to lepromatous—have been made on about 250 patients. In a large number of cases, the recovery of loss on treatment have been evaluated by follow-ups.

A complete mapping (pH-mapping) of skin has been made by determining the surface pH of skin at 21 cardinal points in all age groups. The interaction of skin pH with the distribution of sweat glands, sebaceous glands and the normal flora has been established.

Sorption-desorption studies of skin by measuring the skin impedance, hydration state and the transepidermal water loss have thrown light on the hygroscopicity and the water holding capacity—the two competitive processes—of the skin and also in the barrier function of the skin.

Iontophoretic application of drugs on certain skin disorders (e.g. hyperkeratosis) has shown spectacular results and is being continued.

Teaching activities : The Physics Unit was engaged during the year under reference in giving one full semester course to the Second Year B.Stat. Honours students. The course contents included, as in last year : Thermodynamics, Statistical Mechanics, Relativistic Mechanics and some selected topics of Atomic and Nuclear Physics.

Flume Project

The uniformity of velocity distribution in the flume both in vertical and lateral directions has been made by setting two honeycombs, one in front of jets and other at the source.

Data obtained so far from flume experiments conducted at Uppsala and ISI Calcutta, and also from natural environments have been analysed for interpretation of grain sorting.

Biological Sciences

AGRICULTURAL SCIENCE

Research Activities

With a focal theme on improving productivity through efficient water management and cropping systems under 'Rainfed farming', field based trials were undertaken at

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Giridih Experimental Farm, Bihar. During the period studies have indicated a few interesting results listed below :

- (i) Cropping Sequence studies in High land indicated barley, mustard and linseed to be particularly suitable as winter crops capable of giving moderate yield with residual soil moisture. This indicate the possibility of introducing double cropping without irrigation in a monocropped region.
- (ii) Intercropping studies revealed the possibility of increased productivity in high and medium land with maize in combination with groundnut, soyabean and green gram.
- (iii) Of the different crops/varieties tried in the farm pigeonpea, groundnut and maize in the Kharif season and mustard, barley and linseed in the rabi season seem to be most suitable in medium to high land situation including 'tanr' which mostly remain fallow throughout the year.
- (iv) Collaborative long term studies with IRRI, Manila and Calcutta University initiated from June, 1988 on P adsorption in acid lateritic rice soils have shown marked increase in rice yield with rock phosphates. This is suggestive of usefulness of rockphosphates in acid soils.

Morphological and anatomical studies :

- (v) In exploratory work on Palmae, anatomical studies on 10 species of palms were completed. In levo and dextrorotatory plants studies were also made to find out the anatomical differences and possible causes of these characteristics.
- (vi) Adaptability trials on coconut and oil palm in saline regions of Sundarban are in progress with periodical data collection on morphological characters.
- (vii) In studies on mangrove vegetation, palynological work on 12 species were completed along with epidermal structural studies of 20 sp. Anatomical investigation on roots, stems, leaves and tracheary elements are in progress.

ANTHROPOMETRY AND HUMAN GENETICS

Research activities

1. Human Adaptability Programme :

The 6 projects undertaken under its Human Adaptability Programme aim at a *comprehensive* study of human adaptation to environmental stresses, including biocultural interaction and the chances of, and strategies for, survival of disadvantaged groups. These studies, taken together, may provide important clues to *promotion* of the chances of survival and well-being of these groups. They may also lead to development of new statistical tools for measuring the level of well-being, relative effects or various environmental stresses, and so forth, and thereby enrich both Statistics and Human Biology. Specifically, the following results are obtained :

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- (i) *Health Status and Labour Productivity* : The results show no relation between the labourers health status and their productivity, implying the wide range of adaptability of the human biological system.
- (ii) *Effects of Micro-environmental factors on Health in Rural Populations* : A repeat (demographic) survey has been conducted in a West Bengal village after 10 years. The results are likely to provide insights into the factors affecting fertility, mortality, migration and family structure at the micro-level. These insights may have important applications in population planning.
- (iii) *Psychological Stress and Health of Mother and Child* : The data on working status of women, their anxiety level and physical/physiological health status themselves and their children, collected so far, will have important implications planning middle class women's outdoor employment with minimal health hazards.
- (iv) *Socio-cultural characteristics and community Health Status of the Lepchas of Darjeeling district, West Bengal* : No field work could be undertaken due to political disturbances in the Darjeeling area. The results obtained from earlier data have already been reported.
- (v) *Impact of Altitude on Human Population, Phase II, Determinants and Consequences of Human Health and Activity Patterns in the Mountain Ecosystem* : No field work could be undertaken due to political disturbances in the Darjeeling area. The results obtained from earlier data have already been reported.
- (vi) *A study on the Determinants of Fertility and Mortality in an Urban Setting : An Anthropological Perspective* : Field work has recently been started in a slum in central Calcutta. No results have been obtained yet.
- (vii) *Biostatistical study in Vitiligo : a skin disease* : On this study, epidemiological data were gathered from 15,685 individuals. Data on 298 families, each ascertained through a single affected individual were also gathered. A genetical model is found to provide a good fit to family data on vitiligo. Serological and biochemical analyses of blood samples were also done.

2. Genetic Epidemiology Programme :

There is a growing awareness among the people about the risk factors for diseases. Some diseases are purely genetic in origin (haemophilin) and some are purely environmental (diarrhea). It is now wellknown that the manifestation of some diseases are due to the action of both genetic and environmental (hypercholesterolemia). The cause of essential hypertension is still not well understood. There is opinion that it may be the result of a large number of factors—both genetic and environmental ; and genetic factor may be due to single gene or polygenic, and the environmental factors may be many. It would be interesting to study and identify the determinants of blood pressure and to measure the magnitude of the risk factors involved.

Rheumatoid disease is a crippling disease and produces a large number of orthopedically handicapped persons every year. Genetic influence, environmental

conditions, psychological stress etc., have been said to be the causative factors for this disease, and it is relevant for Rheumatoid arthritis disease to study (i) prevalences of the diseases, (ii) nature of inheritances, and (iii) risk factors. For both the studies a family will be treated as a sampling unit.

(i) *Genetic Epidemiology of Blood Pressure* : Analysis of data of the study already conducted on blood pressures it reveals : (a) Some anthropometric variables have low but statistically significant correlation with adult blood pressure ; (b) influences of anthropometric variables alone can predict blood pressure ; (c) education appears to be the only significant predictor of systolic blood pressure.

Further 20 Marwari families living in Calcutta were screened for (i) blood pressure, (ii) physiometry, (iii) anthropometry, (iv) clinical, (v) social and cultural informations. Out of the total 80 families screened for the above purpose, blood samples were collected from 5 families comprising about 280 individuals for following biochemical tests in collaboration with the Post-graduate Institute for Medical Education and Research, Calcutta : (i) Glucose, (ii) Urea, (iii) Creatinine, (iv) Triglyceride, (v) Total Cholesterol, (vi) HDL Cholesterol, and (vii) Blood groups etc. The blood samples are under analysis.

3. *Population variation Programme* :

The programme aims to understand (i) nature of distribution of various biochemical, serological markers, Hb types, gamma globin groupings etc. in the endogamous population groups ; (ii) immunoglobulin level (IgG), populations ; (iii) genetic variation within and between population groups based on a large number genetic loci ; (iv) measuring the distance between population groups and to build up phylogenetic tree ; (v) quantifying the extent of various ethnic components in the population groups and (vi) genetic relationship between genetic proximity and genetic distances of the populations.

(i) *Genetic survey of some endogamous groups of Eastern India* : From two major studies already completed in Assam, Manipur and West Bengal the important findings are (i) very high prevalence of Haemoglobin E gene in North Eastern India, particularly, highest in the world amongst the Kacharis of Assam (0.645) as well as in the Deshis of northern West Bengal (0.612) which have drawn the attention of clinician, geneticist and public health workers. Subsequent screening of Thalassaemia amongst the HbE gene carrier populations in northern West Bengal (in collaboration with Dept. of Haematology, School of Tropical Medicine, Calcutta) have not revealed the presence of any HbE That Gene in the populations, (ii) genetic study in Assam populations have identified the existence of two major racial groups—Mongoloid and Caucasoid, where as in West Bengal three major cluster have been observed as Mongoloid, Caucasoid and Proto-Austroloid.

(ii) *Genetics of Dermal ridges among some castes and tribes in India* : Dermatology in population genetic based on their ethnographic and geographic proximities : the obtained results confirm the general presumptions (a) that dermal traits in general and palmar characters, in particular, do help in understanding the biologic/ethnic affinities among different groups both at macro and

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micro levels and (b) that different types of traits, which are likely to be influenced by different genetic and/or environmental factors give rise to different clustering patterns.

- (iii) *Study of Physical Growth of the Bengali Children* : (a) A cross-sectional growth study of 25 anthropometric characters was undertaken on 825 Bengali boys aged 7.0 to 16.0 years in Calcutta. The methodology was followed according to the recommendation of International Biological Programme (IBP 1969). Results show that attainment of peak adolescent growth in 12.5 years for a large number of linear and skeletal dimensions including height. The results thus generated for the first time a base line growth data on the Bengali boys not given by ICMR (1972) which could be used as a reference population data when required. In addition, the results also show the influence of different socio-economic and demographic factors influencing the growth variables in varying magnitudes. Finally, multivariate factor analysis applied on these anthropometric data showed four important factors namely (1) linear, (2) transverse, (3) cephalofacial and (4) fatness responsible for determining size and shape during the growing years of 7.0 to 16.0 years. These four factors together explained 77% of the total variance.

A cross-sectional growth study of 7 anthropometric characters was undertaken in 715 Bengali girls aged 5 to 18 years in the suburbs of Calcutta. Peak annual increments for height (6.7 cm/year) occurs among them between 9-10 years, while for weight the peak growth (4.47 Kg/year) occurred between 12-13 years. Moreover, a significant difference was observed in growth of size, mass and subcutaneous fat between menarcheal and nonmenarcheal girls. Both these studies thus give an idea of the growth status of the contemporary Bengali children in relation to the children from other parts of the country. The earlier onset of adolescent growth of the Asiatics than U.S. and European children has also confirmed by the results obtained.

For the first time a family study of 28 anthropometric characters was undertaken on 110 rural endogamous Mahisyas families of South 24 Parganas district of the state of West Bengal (N = 540). Results have generated for the first time the inheritance pattern of a large number of anthropometric characters in this population. Preliminary analysis of data show parent offspring correlations to be of high order for linear and skeletal dimensions, while circumferences and fatness revealed a moderate order.

4. *Genetic survey of some endogamous groups of India* :

Central India was chosen as the field of the study as it is inhabited by large number of tribes having various ethnic and cultural back ground, and a survey was conducted amongst the following 16 tribal groups during January—March 1969, in collaboration with the Dept. of Human Biology and Anthropology, Bremen University, Bremen, W. Germany; and the Dept. of Anthropology, Sambalpur University, Orissa. Madhya Pradesh : Maria, Muria, Bhatra, Halba, Dhurwa; Orissa : Kisban, Binjhal Deshi Kondh, Rajgond, Savara, Kuvikondh, Konda Dora, Parojn, Gadaba; Maharashtra : Raj gond, Maria gond. About 1700 blood samples were collected (100 individuals from each tribe) from the tribes which are under laboratory tests for the following markers : Blood groups—A₁BO, Rh system, MNSs, Kell, Duffy, Diego; serum groupings—Gm Inv. (gamma globulin groupings); serum polymorphism-Haptoglobin, ceruloplasmin, Albumin by gel electrophoresis, Transferrin, α_1 -antitrypsin

and group specific components (GC) by LEF electrophoresis ; enzyme polymorphism- Acid phosphatase, Estrase-D, glucose-6-phosphate dehydrogenase, G-phosphogluconate dehydrogenase, Glyoxalase, Lactate dehydrogenase, Adenosine deaminase, Carbonic anhydrase (I and II), and Haemoglobin pattern. Besides, estimation of Hb level, blood pressure, tests for G-6PD deficiency were performed. The data are under analysis.

BIOCHEMISTRY

Main topics of research :

1. *Distribution of intestinal parasites in West Bengal :*

The proposed study is designed for intestinal diseases taking into consideration of the variation in ecological ethnic, dietary and socio-economic patterns of the populations from different regions in West Bengal. Data generated from this study would constitute the basis of an epidemiological background which may ultimately help in the eradication programme.

Analysis of previous data has been done, and some more informations about depth of tube well for collection of drinking water and its distance from sea are to be collected.

2. *Genetic epidemiology of Blood pressure :*

To study of relative influence of the determinants of hypertension along with anthropological and demographic data, different biochemical parameters on blood/serum with special reference to lipid metabolism are being estimated among affluent, vegetarian population in the first stage.

So far about 300 blood samples have been estimated. The study is being done in collaboration with Department of Biochemistry, Post Graduate Medical Research, S.S.K.M. Hospital.

3. *Cancer Chemoprevention : An approach towards cancer control :*

The goal of cancer research is to reduce the morbidity and mortality that is associated with the disease which can be achieved either by prevention or through cure. The concept of cancer 'Chemoprevention' referred to the prevention of cancer by the use of pharmacologic agents to inhibit or reverse the process of carcinogenesis. The current proposal has the following approaches :

1. Folic and in cervical preneoplastic and neoplastic diseases.
2. Development of *in vitro* model for human uterine cervix.
3. Dietary 'risk factor(s)' in cervical preneoplastic and neoplastic diseases.
4. Cancer prevention with nutrient intervention.

Uterine cervix cancer is number one female cancer in India. However, epidemiologic information for its various 'risk factor(s)' remain largely unknown. The

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present study would constitute the basis of the nutritional epidemiologic data base. Furthermore, these studies would constitute the basis for a Chemoprevention intervention clinical trial which is the ultimate goal.

EMBRYOLOGY

Main topics of research

1. *Biochemical Embryology :*

Various biochemical and physiological processes during embryonic development have been the long-term subject of research in this Unit. *Limnaea* (mollusc) has been the most studied system. Recently the Mediterranean squid and local squid at Digha have been studied on a year round basis depending upon its availability.

Microinjection of ^{14}C -amino acids into *Loligo* embryonic yolk has shed light on the problem of embryonic nutrition in the cephalopod. At a certain stage of development of the embryo, a new lipid arises in the embryonic tissue (which till that time resembled yolk lipid pattern). With micro-injection of ^{14}C -acetate this and other lipids can be studied. In *Limnaea* lipid biosynthesis peaks at trochophore stage and then again declines. These have been studied by fractionation on TLC and counting with LSC. Inhibitors like actinomycin and cerulenin used in earlier investigations in the Embryological Laboratories may be used to study the course of biosynthesis.

Further work on adhesion and deadhesion in molluscan cells will be carried out, for this is a fundamental process which makes morphogenesis possible.

2. *Mathematical and stochastic modelling of cellular growth, differentiation and morphogenesis during embryonic development and the mechanism of carcinogenesis :*

Mathematical investigation of cellular differentiation, morphogenesis and self-organization in biological systems with the help of advanced mathematical tools, such as, catastrophe theories, bifurcation analysis, control theories, stochastic processes etc. is the principal object of this project. The mechanism of controlled cellular growth during embryogenesis involving morphogenesis and pattern formation is a very important and interesting subject of investigation both in the experimental and mathematical fields. There exist many hypothetical theories of morphogenesis and differentiation. Mathematical studies along with simultaneous experimental verifications may shed new light on the mechanism of the epigenetic system more perfectly. These studies may ultimately lead to the revelation of the underlying mechanism of carcinogenesis which is, in fact, a process of unregulated random growth of undifferentiated cells. The present project involves the studies of these complex biological mechanisms at the molecular level. Mathematical and stochastic models of the epigenetic mechanism during embryonic development have been further developed and analysed in the light of nonequilibrium thermodynamics. Spontaneous emergence of a spatially dissipative structure far from the thermodynamic equilibrium has been observed in the model biological system. The results have been published in standard international journals. New methods have been explored to analyse the nonlinear multiple-loop biochemical control network models of the epigenetic system. Stochastic models of the reaction-diffusion system have been further developed and analysed both by analytical and numerical method. The formation of the primary layer of

differentiation, e.g. ectoderm, mesoderm and endoderm have been mathematically exhibited with the help of nonlinear diffusive models. Multidimensional nonlinear mathematical models have been further developed and explorative studies on these models with the help of advanced mathematical tools have been carried out. The results of all these studies have been published in standard international Journals. A Ph.D. thesis has been submitted to the Jadavpur University.

3. *Intercrop interaction—A mathematical study on Agricultural ecology :*

It has long been observed by many agricultural scientists that some crops influence the yield and vegetative growths of other crops in mixed cultivations. This influence may act in different ways. The growth and yield of one crop may be (i) activated or (ii) inhibited or (iii) remain uninfluenced by another crop. Apart from competitions between different crops for the same sources of food, light etc. there seems to exist another factor in each crop—a chemical component which comes out inside the soil as root exudate. This component may be an activating or inhibiting catalytic agent which activates or inhibits the growth and yield of the other crop growing in the vicinity of the former crop. The transport of this catalytic component from one crop to another is supposed to take place by a process of diffusion through the soil. The existence of such root exudate, although not yet experimentally established, has been proposed by many workers. The academic interest of the present study is to investigate both mathematically and experimentally into the existence and properties of such catalytic root exudates and the mechanism by which the intercrop interaction takes place whereas the practical object of this research is to maximize the yield of grains and fodder per unit area of land with minimal investment by well-designed mixed cultivation.

Intervarietal interaction between two varieties of wheat and between two varieties of rice were conducted at the ISI experimental farm at Giridih. The intervariatal interactions in these cases result in macroscopically significant increase of yields and growth of each variety at a particular spacing. The results also indicate the existence of a growth promoting (sometimes inhibiting) factor which comes out from the plants into the soil as root exudate and diffuses through the soil with a wave like propagation.

Externally Funded Project :

1. *Chemical communications in mammals through non-volatile molecules :*

This is a multidisciplinary subject and is being studied in a project funded by DOEN, Govt. of India.

Many samples of the semiochemicals in the tiger have been studied with GLC, and a GCMS (at IISC, Bangalore). The most notable indication is the presence of 2-methoxy-propane as a semiochemical. If confirmed in further samples with GCMS run, this would be a very remarkable finding in a biological sample. Further comparisons have been made between the musky odour of tiger and 2-acetyl-1-pyrroline, the principle of fragrant rice.

Observational data on marking in tiger have also been accumulated.

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ENTOMOLOGY

1. *Influence of some physical factors in the swarming of mosquitoes* : As the date of commencement of the project is 1989-90, certain preliminary observations on the size of swarm in relation to swarming site has been made. The swarming of this species takes place during late winter and spring.

LEAF PROTEIN

The Leaf Protein Research Unit, conducting agronomical, biochemical, nutritional and microbiological studies on a large number of crop plants, have established certain optima in these areas for maximizing economic leaf protein production, which is advocated for food/feed use as alternative protein and β -carotene source. Again microbiological investigations carried out by this unit, indicated the possibility of introducing cheaper microbial growth media with immense potential to agricultural and pharmaceutical industries.

1. *Screening and agronomic studies of various plant species including fodder crops, weed and tree leaves* :

(a) The objective is to screen and select hopeful water weeds and semiaquatic weeds, cole crops, tree and shrub leaves for multipurpose uses with the aim of exploiting their potential for better and efficient nutritional value. Thirty one tree species from Ranaghat (West Bengal) and an adjoining area were screened for protein extraction. Leaf protein concentrate from *Samanea saman* showed best nitrogen percentage (9.95%), the leaf protein concentrate from *Gliricidia sepium* gave highest *in vitro* digestibility (50 to 25%). Lowest percentage of free polyphenols (2.17%) was found in the leaf protein of *Albizia procera*. Besides above, parameters like mineral contents, available lysine and carotene and antinutritional substances like oxalates, nitrates, alkaloids and antitrypsin is being initiated. (b) Eight varieties of sugar beet were grown in the field and data were collected at the interval of 20 days starting from 75 days upto 150 days of the crop. Highest root yield observed at last harvest i.e. 150 days and highest shoot yield dry matter and protein yield observed at 115 days of the crop,

2. *Microbiological aspects of leaf protein* :

The feasibility of LP by-products for biomass and metabolic production is the aim of the investigation. A number of fungal isolates were identified during the microbiological food study of the deproteinized leaf juice as *Penicillium notatum*, *Aspergillus nidulans*, *Sporotrichum xylophila*, *Alternaria tenuissima*, *Alternaria alternata*, *Curvularia* sp, a number of Cellulose degrading strains isolated from fibrous residues when the residues were mixed with diluted soil sample. The isolates are known as *Aspergillus* sp LP-50, 52, 53 Actinomycete SB₁, SB₂, SB₃, SB₄. The strain has been used for quicker decomposition of the organic wastes. The cellulolytic activity of the strains were measured in terms of reducing sugar (0.450-1.400 mg of glucose/ml culture filtrate). Chemical analysis of 25 fibrous residues have been worked out chemical composition as follows :

Ash 5.3-15%, Nitrogen-2.5-4.25%, Lipid-4.7-16%, Holo-cellulose 36-60%.
Pentosan-6-16%, Pectin-1-12%, Modified Acid Detergent fibre 35-55%

3. *Studies on aquatic weeds :*

(a) Based on their chemical analysis, twelve plants were found to have potential for direct utilization as a feed source.

(b) The seasonal changes in the chemical composition of four, edible, aquatic plants namely, *Allmania nodiflora*, *Enhydra fluctuans*, *Ipomoea reptans* and *Morsilea quadrifolia* were studied and were found to be promising when compared to other plants commonly used as green vegetables.

(c) The possibility of extracting leaf proteins from aquatic plants were also assessed. In animal experiments, supplementation of wheat flour diets with small amounts of leaf proteins (30%) prepared from *Pistia stratiotes* and *Lemna minor* considerably improved the quality of cereal based diets.

4. *Acceptability trials of leaf protein in poor rural and lactovegetarian sector :*

The Leaf Protein Research Unit is conducting the efficiency of leaf protein as human food and for its acceptance by adults of tribal and non-tribals of lactovegetarian groups as cheap and good protein source. The project is mainly formulated to transfer the technology from lab to land and to convince the Government and public about its feasibility and merits.

The first group, the tribals particularly live in isolated groups and are economically downtrodden. They are basically dependent on forest resources because cultivation also is not possible due to lack of arable lands in their vicinity. The second group is not so poor like 1st group but they are purely dependent on vegetable and are deficient in protein intake mainly because of ignorance. In the light of the above situation L.P.R.U. conducted acceptability trial on school children of target groups. Two main points which emerge from past researches are (i) Given the freedom, children might not have accepted it and (ii) Acceptance by adults has not been tried. A pilot survey was carried out on the Bauri's of Bansgram, Vill. Bero, Dist. Purulia, West Bengal on social economic and nutritional status.

5. *Total utilization of sugar beet (Beta vulgaris L.) mainly sugar product from root and LP from tops :*

(a) Effect of nitrogen, harvesting time of the crop and method of cultivation. 4 N doses were 60, 120, 180 and 240 kg/ha. Harvesting stages were 80, 100, 120 and 140 days after sowing. Method of cultivations were earthing-up and non-earthing-up.

(b) Studies have been carried out on the following aspects : (i) Yield of sugar t/ha at different level of fertilizer. (ii) Yield of LP and fibre kg/ha from the tops at different stage of growth. (iii) Comparison of efficiency of *Saccharomyces cerevisiases* and *Zyomonas mobilis* for conversion of sugar to ethanol. (iv) Extraction of pectin. (v) Conversion of cellulose and hemicellulose to sugar and ethanol. (vi) Comparison of various types of fermentation technology.

After harvests analysis are being carried out.

However previous experiment showed highest sugar yield of 5.42 t/ha at 140 Kg N/ha level with earthing up method of cultivation. Again LP production was maximum (6.5 Kg/ha/day) when harvested at 100 days with treatment at 180 Kg N/ha.

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Social Sciences

ECONOMIC RESEARCH

The Unit continued to be engaged in teaching and training at various levels and in research work covering different areas of theoretical and applied economics and econometrics.

Research Activities :

The research activities of the Unit during the period under review covered fields like economic theory, national and regional economic planning, issues in development economics, level of living and poverty in India, besides works in applied economics and methodological studies in econometrics.

1. *Economic Theory* : Research work has been going on over the past several years on the history of economic thought and on various areas in economic theory. Investigations has continued on social choice theory and game theory, covering topics like measures of industrial concentration, welfare economics etc. Another study is attempted to present a macro view of administered prices and deficit financing.

2. *Economic Planning and Development* : One study develops a planning model for railway network expansion. The method is first to estimate the total cost, which is the sum of current cost and capital cost, for a number of alternative expansion programmes and then to select one with the minimum cost. An application of cluster analysis has been attempted in a paper on the basis of time series data for defining agricultural regions in West Bengal.

3. *Income and Level of Living* : Various aspects of income and level of living have been examined in a number of studies. On the basis of a sample survey, a study attempts to assess the level of income and inequality in income among different occupation groups. Attempts have also been made to study empirically the intertemporal variation in the real wage rate of agricultural labourers in India. A theoretical-cum-empirical model has been developed to analyse the intertemporal variation in the incidence of poverty in rural India.

4. *Agricultural Economics* : The Unit has a continuing interest in studies on various aspects of agricultural economics, like marketable surplus and size classes of holdings, changes in cropping pattern, marketing of agricultural products and its efficiency etc.

5. *Econometrics* : A considerable amount of research has been done in various topics on econometrics, e.g. (i) problems relating to multicollinearity in misspecified models, (ii) estimating Box-Cox models with non-spherical disturbances, (iii) Bayesian estimation and comparison of expenditure model with additive or multiplicative heteroscedasticity etc.

Project Work :

The members of the Unit have undertaken a number of projects. These projects are described below in brief.

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(a) *Intra and Inter-Occupational Differentials in Income and Level of Living :*

So far as income and expenditure are concerned, a great deal of economic inequality is observed between occupation groups as well as within such groups in India and this is the subject matter of the present study. For this purpose two important occupation groups, namely supervisory and clerical office workers in a number of employing agencies, e.g., Banks, the Life Insurance Corporation, Central Government service, West Bengal State Government service, the organised private sector and the unorganised private sector, have been selected. The data needed for the study have been collected through a sample survey covering sample earners and their households. To keep the scale of the field work within manageable limits, the survey has been confined to the Calcutta Municipal Corporation Area. The field work is already over and a number of working papers have already been prepared. A comprehensive report covering all the selected employers is proposed to be prepared during the next financial year.

(b) *Investment Planning for Iron and Steel Sector :* An alternative approach to measure the capacity utilisation of 'Blast Furnace' and 'Steel Melting Shops' in Integrated Steel Plants has been developed. Using this measure, capacity utilisation of Blast Furnace and SMS of all the integrated Steel Plants of India for the recent years have been assessed. The performance of precise technological variables responsible for under-utilisation in respective Plants has been identified.

Sixth Plan Technical Note prepared by the Planning Commission, Government of India provides 89×89 Input-Output tables for India for the year 1979-80. This table has been aggregated to a 13×13 table retaining the 4 sectors of steel as it is, while the other 85 sectors have been aggregated to 9 sectors. Implications of alternative growth scenarios in terms of variations in the relative sectoral weights in the growth of final demand categories on the requirement of each product of steel have been examined. Based on the same 89×89 transaction flow for 1979, 13×13 allocation coefficient matrix is also constructed. A simulation exercise is also carried out to see the behaviour of technical coefficients of steel sectors when allocation coefficients of the same steel sectors are kept unaltered and the output vector have been made to change.

Steel sector should have a further breakdown into at least 8 subsectors so that it will help to make possible more thorough understanding about the demand forecasting of steel. Attempts are made to have an extended I-O table of 17×17 with 8 steel sectors and 9 non-steel sectors entirely with the help of secondary data available from NCAER, MECON and SAIL. Though a tentative 17×17 I-O table is constructed where all flows for steel sectors to non-steel sectors and those from all non-steel sectors to steel sectors are all physical flows, and only flows between non-steel and non-steel sectors are in value terms, it has not been still now possible to arrive at a balanced value I-O table probably due to lack of consistency in the valuation procedure. Efforts are on to obtain a 17×17 balanced value I-O table with 8 steel sectors and 9 non-steel sectors.

(c) *Linguistic Analysis of the Complete Works of Rabindranath Tagore Based on Complete Statistical Counts :* The Institute for Study of Languages and Cultures of Asia and Africa (ILCAA), Tokyo, has been transcribing Tagore's works on magnetic

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tapes for computerized processing supplying word counts and other results to the ISI groups for further linguistic and statistical analysis. Three poetical works—*Gitanjali*, *Sandhya Sangeet* and *Prabhat Sangit*—have been taken up for analysis. Certain types of analysis, e.g., studies of compound verbs, are being carried out directly from the texts themselves.

(d) *Long-Term Forecasts of the Requirements of Fresh Notes and Coins* : The Unit is currently engaged in a study sponsored by the Reserve Bank of India (RBI) on the long-term forecasts of the requirements of fresh notes and coins in India. The study is going to be based mainly on the secondary data available from the RBI. However, some data had also been collected through a modest-sized surveys of currency transactions of commercial banks in and around Calcutta (such an area for survey was chosen mainly because of its proximity to the Institute). The study is expected to be divided into two interrelated parts. First, it would try to forecast the required amount of the total currency. Secondly, it would attempt to estimate the necessary amount of currency required of each denomination, by figuring out the 'right' denominational mix.

(e) *Modelling for Estimation of Discovery and Production Costs of Hydro-carbon in India* : The ISI-ONGC Collaborative project on the estimation of Discovery and Production Cost is nearing completion. Earlier, members of the project team made a number of presentations at Tel Bhavan, ONGC, Dehradun on the Discovery Cost model developed by the ISI scientists. A methodology for estimation of production Cost has also been proposed by the ISI scientists and a paper has been prepared for presentation at Dehradun.

Teaching and Training Activities :

Members of the scientific staff shouldered the responsibilities of teaching economics, economic statistics and econometrics in the degree, research courses in economics and other courses conducted at ISI, Calcutta. Several faculty members participated in the teaching programmes of other Universities.

PLANNING (DELHI)

Research Activities :

The members of the Unit continued research in a number of fields in both applied as well as theoretical economics, regional planning and analysis of social movements. Research in applied economics included diverse topics such as planning, problems in estimation of poverty, estimates of labour force and unemployment, foreign trade and economic development, health and family planning, amongst others. Work was continued on the development and application of macroeconomic models for analysing policy issues (such as dual pricing and quantity rationing). Research in economic theory revolved around game theory and its applications, economic inequality, industrial organization, models of unemployment and the design of contracts and mechanisms.

Project Work :

Various members of the unit have been working on a number of projects. Topics covered include (4) A study of provision of basic social service in rural areas of

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Haryana and Rajasthan, (ii) Conflict, structure and change, (iii) Autonomy-seeking movements in Punjab and Darjeeling, (iv) Resource Inventory for planning (v) Perspective Plan Model for Economic Development of Assam, (vi) Family Planning awareness, attitudes and practices among members of Parliament, (vii) Family Planning among workers of Hindustan Latex Limited, (viii) Disparities in household income and level of living within and between various occupation groups in Delhi.

ECONOMIC ANALYSIS (BANGALORE)

Research Activities :

During the period under review, the Unit continued its research activities and published major results in econometric theory and its applications. One study concentrated on the Intra- and Inter-sectoral Decomposition of Consumption at all-India level. Another study went into the question of heteroscedasticity in the estimation of additive Engel Curves. A Bayesian approach was used in yet another study involving additive and multiplicative heteroscedasticity. On economic theory, one study focussed on the generalized Henry George Theorem as applied to interregional equity. A significant contribution was the evolution of a new concept of poverty based on nutrition, and its evaluation through the Bayesian methods. A comprehensive survey of the literature on Indian poverty was prepared and the major conceptual and statistical gaps were identified.

Projects work :

Work was continued on the two following ongoing projects during the period under review under the direction of Professor Iyengar : (a) Studies on Poverty and Inequality : Regional Dimension, (b) Summer Course in Quantitative Techniques in Economics.

The project entitled "Studies in Poverty and Inequality : Regional Dimensions" made further progress with the collecting of nearly 600 articles in the area of income distribution, poverty and inequality with reference to India. Nearly 600 articles relating to levels of living, poverty in other countries and consumer expenditure are being collected. A comprehensive review was prepared. This formed the basis of the Presidential Address at the Twenty-sixth Indian Econometric Conference in Bombay in January 1989 by N.S. Iyengar. An edited version entitled : "Recent Studies in Poverty in India : A Survey" of this Address will appear in the July 1989 issue of the *Journal of Quantitative Economics*.

Two other methodological studies are under way : (a) A regional study of consumption of milk and milk production, (b) A study of the impact of pay revisions on the distribution of incomes of salaried workers.

Preliminary work on the second project namely, Summer Course in Quantitative Economics began and the necessary circulars calling for nominations to the Course, were sent to universities in March 1989.

LINGUISTICS

During the period April 1988 to March 1989, the programme of research in the areas of Fundamental and Applied Linguistics was continued. The Units' research projects may be grouped under three main headings, namely

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I. Studies on the phonetic structures of major Indian Languages and application of the results in the areas of :—(a) Speech Pathology ; (b) Second Language Acquisition ; (c) Cultivation of Mother-Tongue.

II. Studies on acquisition of language and bi-lingualism.

III. Application of statistics in linguistic problems.

I. *Fundamental research* : A survey of the articulatory and acoustic structure of the Oriya language is in progress. Research on the suprasegmentals of Oriya has been commenced. Statistical processing of data on the frequency of occurrence of Oriya phonemes will be carried out.

Research on the suprasegmentals of Hindi, Telugu and Bengali was continued throughout the year.

Applied research : Studies are in progress on : (a) Development of speech sounds articulation during the period of language acquisition in the pre-school age child. (b) Measurement of the threshold of Bilingualism. (c) Academic achievement of hearing impaired children attending general schools with normal hearing children. (d) Comparative intonation patterns of Indo-Aryan and Dravidian languages as well as languages within the broad Indo-European group. Studies on pitch and intensity patterns are being carried out, utilising the Visi-Pitch.

POPULATION STUDIES

Research Activities :

1. *Some Determinants of Child Mortality and the Latter's Impact on Fertility* : The main objective of the study is to understand the phenomenon of high infant/child mortality and its effect on fertility through a comprehensive study of level of living including dietary habits and nutrition, education, fertility, morbidity, access to medical facilities etc. in rural and urban areas of Hooghly District, West Bengal.

The transfer of data from field schedules to computer tape is complete for the urban sector of the survey area while some progress is being made in respect of rural sector data. Some tabulation work with urban data is being undertaken.

2. *Education Development Survey in Rural area around Patna* : This survey has been taken up to study the educational development and other socio-demographic aspects of the rural population around Patna.

One report based on the household data and four other technical papers have been prepared. The preparation of a consolidated report on the survey is undertaken.

Education and literacy status changes between father and son were studied over different time periods using birth cohort approach. It was revealed that upper caste and other Hindus possessed higher education and literacy mobility than that of scheduled caste Hindus and Muslims. Scheduled caste Hindus showed slight trend of development. Downward trend in education and literacy of daughters over their

educated mother was observed for the Muslims in the study area. Higher net upward education and literacy mobility was found among population of the study area, especially among upper caste and other Hindus in comparison with that for the population in rural areas of the district around and away from Calcutta. The occupational mobility analysis indicates a significant improvement in the employment status of the migrants at places of their destination.

3. *A Study on Educational Wastage (Stagnation and Drop-out) at Primary and Middle School Levels (in collaboration with Sociological Research Unit)* : This study is continued : (a) to estimate the expected student life, a problem of methodological interest ; (b) to find out educational wastage differentials by various demographic socio-economic and other related factors and (c) to identify and evaluate various factors as determinants of educational wastage.

The sample survey conducted for the study employed three schedules—one for schools, one for teachers and another for students' households. The field work for rural areas and verification of 10% schedules have been completed. Processing and analysis of collected data are in progress. The second phase of the field work, i.e. the urban area survey, has been taken up. Sampling and other preliminary jobs are completed and the three types of schedules are printed. About 60% of the school schedules have been filled up.

4. *Child Mortality and Environmental Differentials in a Newly Industrialised Indian City—Durgapur in West Bengal (A Collaborative Project with the School of Oriental and African Studies)* : The central purpose of this study was to investigate the degree of duality that emerged between the various social and environmental sectors of this industrialised new town.

The message obtained was that using child mortality as an index, the city was strongly divided in ways that affected the child survival apart from being divided in general welfare terms, for example, in access to basic amenities like sanitation.

5. *Estimating Future School Enrolment in Districts of West Bengal (1981-2011)* : The study undertaken during the current financial year (1988-89) has the following objectives : (i) to project the general population at state and district levels by rural-urban and age-sex categories ; (ii) to derive population exposed to risk of enrolment, and estimate functional ratios ; (iii) to estimate student population at primary, middle and secondary stages by districts and to investigate the rural urban and sex differentials in these estimates.

The general population is being projected under plausible fertility-mortality and migration regime. In calculating "exposed to risk", four single year age at entry corresponding to each class in a particular stage would be assigned. Based on empirical evidence, differential weighing scheme would be adopted for any set of ages. Using the enrolment statistics at the base year, "functional ratios" will be estimated under various sets of assumptions.

6. *Economic Changes in Rural India* : (a) *A Study of 200 villages in Bengal, 1850-1981* : Data on land and people were collected for more than 3,000 villages

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of the districts of 24-Parganas, Nadia, Murshidabad, Malda, Birbhum, Bankura, Purulia, West Dinajpur, Darjeeling, Coochbehar and Jalpaiguri for 1846-1850 on a ten percent sample basis. Among them 1980 villages have been identified on a current list from which a systematic sample of 200 villages have been drawn. The data on variables like population, area, house, occupation etc. of these 200 villages thrown up by the District Census Handbooks for 1951, 1961 and 1971 have been tabulated. Data for a selected village in the district of Nadia have also been collected for three points of time, viz., 1927, 1955 and 1979, from the records of right preserved in the Settlement and collectorate Record rooms to make an intensive study of the pattern of change of the nature of land utilisation and its fragmentation. Tabulation of these data is being done.

(b) *Trends of Socio-Economic Changes in 4 Districts of India—Burdwan, Broach, Gorakhpur and Bellary, 1801-1981* : Data collection has been completed. A number of documents on Revenue Surveys and settlement reports are being consulted at the National Library at the final stage to incorporate the information in the report.

7. *Micro-Regional Statistical Surveys in India upto 1875* : An evaluation was started in April 1988. A full index of the survey reports, conducted during the first half of the 19th century and preserved at the National Archives of India, has been prepared ; a large number of documents have been thoroughly consulted, and necessary data collected from them. The collected materials from the earlier surveys are being scrutinised to prepare the final reports.

8. *Differential Impact of Modern Rice Technology on Favourable and Unfavourable Production Environments (Sponsored by Rockefeller Foundation and Approved by the Government of India : ISI Project)* : The general objective is to examine and to estimate, in the context of the rice based farming system in West Bengal, how and to what extent technological change in rice production affects the well being of people under different production environments.

Phase I (extensive) of the study has been completed. Preparation is being made for phase II (intensive) study.

9. *Perspectives on the Population Ageing in India* : The study focuses on statistics concerned with the phenomenon of ageing in India, using data mainly from the United Nations and National census series. It examines the dynamics of changes in the population age composition over the period 1950-2025, and discusses population ageing as a socio-demographic topic with specific attention to its prospects for India.

Some of the issues addressed in the study are the basic concept and measurement of ageing, worldwide trend of the process, threshold of old age, patterns and trends of mortality for the elderly and health aspects of the sub-population.

10. *A study on the Demography of West Bengal* : The present study was undertaken at the initiative of the Government of West Bengal, which made available all facilities for the purpose. It involves the task of finding the trends of the various elements of population dynamics through a long period of time, resulting in possible changes in the growth and age structure of the population. As one of the components of growth, the issue of migration has been considered in detail in this study. The trend of migration will be examined in both aspects of "stock" and "flow".

11. *Contraceptive Prevalence Rates in India : A Multivariate Analysis of Factors Responsible for the Variation by States* : The objective of this study is to explore certain factors such as demographic, ecological, health and family planning inputs, maternal and child health outputs and development to study the variation of contraceptive prevalence rate in India by states. Cluster analysis was attempted to minimise the number of independent variables by selecting one among a few independent variables based on similarity (correlation) between variables. Only sixteen variables were selected out of thirty-six variables and further analysis was done on the basis of 'best' subsets regression in terms of adjusted R^2 and Mallows C_p . The best predictor subset (adjusted $R^2 = 74.8\%$ and $C_p = 1.76$) is associated with female literacy, percent of medical officer in position, percapita income and ratio of state to total area. There are needs to emphasize more for the improvement of female literacy, to have enough medical officer to fill up vacant positions within the states, improvement in economic status and finally improvement in management to run the family planning in larger states.

12. *Population Projections by Marital Status, India 1981-2001* : The object of the study is to prepare population projections by marital status for all India Females 1981-2001. Cohort component method has been used for the projections. Some consistency criteria as relevant to population projections by marital status for both sexes have also been discussed.

13. *Estimation of Adult Mortality from Widowhood Data Districtwise Analysis* : Baseline data have been collected from the Census of India, 1981. Analysis is in progress.

14. *Biological Maturity among Rural Females in Uttar Pradesh* : Biological maturity—i.e., the end of adolescent sterility, is a necessary condition for exception. Knowledge of the age at which biological maturity takes place is important for all type of social planners especially for family planning policy makers because of low age at marriage/consummation in India.

The primary focus is to estimate biological maturity among rural females in the district of Kanpur and Etawah from one point retrospective survey data on demographic and fertility history from eligible females between ages 15 and 45. The lowest median year from consummation to first implantation among various consummation cohorts provides the time necessary for a biologically mature female to conceive due to influence of various factors and the corresponding consummation age is known as the maximum age of attaining biological maturity. The maximum age at attaining biological maturity is also supported by estimating the expected interval between consummation and first implantation for various consummation cohorts through life table techniques and selecting the cohort corresponding to the lowest expected interval as the maximum age at attaining biological maturity. The lowest expected interval between consummation and first implantation is known as expected waiting time. The number of biologically mature females at each age is estimated by prorating the proportion of females who are pregnant within the expected waiting time for each age at consummation assuming all are mature at the maximum age of biological maturity. Then the restricted quadratic curve is used to smooth the estimated proportion of biologically mature females at each age until the attainment of the maximum age at reaching biological maturity.

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The maximum age at attaining biological maturity is 20 years and the waiting time is 1.38 years where as the expected waiting time is 1.63 years. Seven percent women are matured at age 10, 25 percents at age 12, 53 percents at age 15, 81 percents at age 18 and all at age 20. The mean age at attaining biological maturity is 15.7 years which means marriage/Gauna below age 16 has little effect on fertility due to the extent of adolescent sterility.

Teaching and Training Activities :

In addition to participating in ISI & ISEC's teaching and training programmes the following teaching and training programmes were also organised : (1) Training Programme in Demography for WIIO Fellow (18 April-29 April, 1988). (2) One Year Evening Course (Vital Statistics and Demography) (Nov.-Dec., '88). (3) Demography and Vital Statistics for participants of the ISEC Course (1988-89). (4) Dissertation for Students of MA Economics, Kalyani University (Specialisation : Population, April-July, 1988). (5) Teaching Demography to M.Stat. (M-Stream) Students (1988-89). (6) Providing guidance to two M.Stat. (Final Year) Students towards completion of their project work. (7) Teaching Demography to DIIS Students, All India Institute of Hygiene and Public Health (March-April, 1989). (8) Specialisation in Demography for ISEC Students (January-March, 1989). (9) As a part of the training programme, the Certificate Course Trainees of the International Institute for Population Sciences, Govandi Station Road, Deonar Bombay, Visited the Indian Statistical Institute, Calcutta on 22.2.89 and 23.2.89. The batch consisting of 21 students, including 19 foreign students (from different countries of ESCAP region) was accompanied by Dr. Kamla Gupta, Reader, IIPS, faculty in-charge of the study tour.

PSYCHOMETRY

Research work carried during this period :

1. Consequences of Social and Economical Deprivation on Academic Achievement :

The objective of the study is to investigate the effect of socio-economic deprivation upon the scholastic achievement of school going children. Several psychological and environmental factors which are expected to be related with scholastic achievement are also brought under the scope of the study.

Subjects are the students reading in Class-X in different schools of West Bengal. The intelligence level motivation and prolonged deprivation score of the subjects are being tested with the help of standardised tests. Data are being collected from different schools of West Bengal, half of which are situated in rural areas.

Such a study may throw some light upon the problem of school dropouts in our country and the results of the investigation may be utilised in planning the educational system that it suits our requirements specially in rural areas so that the whole system becomes more effective.

Data have been collected from 55 schools covering 1267 cases from 13 districts. A report was written analysing 641 cases covering 25 schools. Data from the remaining 3 districts will be collected during 1989-90, so that those who will be appearing in

Madhyamik Examination in 1990 are covered. It is further planned to have part scores of the Prolonged Deprivation Scale indicating different areas of deprivation and the analysis will be done to investigate their differential effects on academic achievement.

2. *Development of an intelligence test for hearing-impaired children* : The aim of the study is to develop an Intelligence test for hearing-impaired children when they come for admission to schools. The training of these handicapped children cannot be carried on along with the normal ones because their training procedure has to be different and the teachers should be specially trained to set up communication with them. In our country there are very few schools equipped with such training facility, whereas there are many children who require such training. Hence, it is desirable to identify those children from this group who are mentally normal and only such children should be admitted to these schools to ensure maximum utilization of training facility. It means that the intelligence level of the child has to be measured at the time of admission. But, it is difficult to design a test for these children when they come fresh from home having no prior training. The directions for the test should be simple and at the same time the questions should be so designed that it would be possible to identify the intelligent children from their responses to the questions.

Such a non-verbal intelligence test has been developed. It was revised on the basis of item analysis and was validated against Goodenough's Draw-a-man and Draw-a-woman test. Data have been collected from four different regions of India i.e., East, West, North and South, for preparing age norms. Analysis of the data and report writing are almost complete and the test is ready for publication.

3. *Predictive validity of the Forced-choice scale of Managerial skill* : The objective of the present study is to find out the predictive validity of the Forced-choice scale of managerial skill. The scale already developed, measures five types of managerial skill, namely, decision making, leadership, human relations, communication and conceptual skills. At that time concurrent validity of the scale has been developed. Now, the predictive validity of the scale has to be established. It has been decided that the scale will be validated against ratings made by peers and supervisors. Data from about 200 middle and lower level managers from different parts of India and their peer and supervisor's rating are being collected. Data collection have nearly been completed. Analysis and report writing is to be done.

4. *Intelligence and personality pattern in some social groups of West Bengal based on some Dermatoglyphic and Anthropometric variables* : The objective of the present investigation is to find out whether intelligence and personality pattern varies with the variation in the dermatoglyphic and anthropometric variables. Data from about 100 families belonging to different social groups (for example, groups formed on the basis of castes and tribes) residing in different parts of West Bengal have been collected.

5. *Assessment of minimum learning in primary education* : Evaluation of data collected during the year 1987-88 is on progress. Simultaneously, tests have been prepared for Class-I pupils to be administered during the year 1988-89.

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SOCIOLOGY

Research was carried out on the following projects :

1. *Potentialities and Constraints of Development : A Social-Ecological Approach* : The primary objective of this study is to explore the scopes and barriers to development of symbiotic relationship between societal groups and their natural resources in a specific ecological zones. The area under study is Simlipal forest range in the district of Mayurbhanj, Orissa.

The field survey has been completed. A draft report has been prepared.

2. *Social Ecology of Sundarban* : The objective of the study is to identify the possibilities and potentialities of development and survival through a network of relationship within and between the societal groups and their natural resources.

A preliminary report on some aspect of the study has been prepared.

3. *Ageing of population in India* : The objective of the project is to find out the nature and impact of ageing of population on society, and that of society on ageing of older and the conditions of life of older persons under varying social and economic circumstances. The studies undertaken were : (i) Health and medicare survey of the elderly persons ; (ii) Opinion about the elderly persons ; (iii) Human ageing in rural-urban Bihar (Senile Dementia) ; (iv) Country monograph on the demographic and socio-economic aspects of population ageing (a collaborative study sponsored by the CICRED, Paris).

Data under (i) and (ii) have been transferred to tape. Analysis is in progress. Preparation of a country monograph is also in progress.

4. *The peasant movements during the early phase of colonial rule in Bengal* : Collection of data from the State Archives and records preserved in the District Collectorate of West Bengal is in progress.

5. *Value system and Social Change* : Detail analysis of the entire data is in progress for preparing the final report.

6. *New Pattern of leadership and social action : An exploratory enquiry* : The objective of the enquiry is to study the process and background of the new generation of leaders emerging in the villages along with the recent socio-political changes in West Bengal. This study tries to answer questions like whether "new" generation of rural leaders appears to be qualitatively different from the traditional pattern of "local leadership" in the village which usually consisted of elite cliques with vested interests ; whether the pattern of distribution of power in rural society seems to be changing in West Bengal ; and so on. The full report based on the study is under preparation.

7. *Child labour : An exploratory enquiry in Giridih, Bihar* : Usually young workers below 14 years of age are known as child labour in India. Percentage of such workers (vide Census of India 1971) to total workers is nearly 6 % which covers nearly 8 % of total children population. In Bihar percentage of child workers to total workers and total children are 6 % and 4 % respectively.

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8. *A study of Educational Wastage (Stagnation and drop-out) at Primary and Middle School Levels (in collaboration with Population Studies Unit, ISI) :* The objective of the study is (a) attempt an estimation of expected 'life' of a student—a problem of methodological interest ; (b) find out educational wastage differential by various demographic, socio-economic and other related factors ; and (c) try to identify and evaluate various factors as determinants of educational wastage. The study is confined in the 24-Parganas district of West Bengal.

The field work has been completed for both the rural and urban phases. Scrutiny and tabulation work is in progress.

9. *Tribal Economics : Trends and Perspectives :* Tribal development programmes met with failures in the past as most of the measures were gambles in ignorance. In changed situation, when tribals are restive for their identity and development, it is necessary that there should be a thorough overhaul in the understanding and much need be learnt from the tribals themselves and orient our endeavours towards the need of people.

A review of literature was completed. Collection of data is in progress.

10. *Agro-sociological exploratory study in south Bihar plateau :* This is a collaborative research undertaken by Sociological Research Unit and Agricultural Science Unit in three tribal villages near Giridih town. This study is in continuation of the recommendations regarding "Farm to Village to Farm communication" made by ISI Council's Committee on Giridih. The study is planned as an exercise in dealing with cropping systems in rainfed plateau region focussing upon farmers' perception, practices and their responses to risks and uncertainties of rainfed farming. The Soil Conservation Division of DVC is actively involved in this project.

A draft report has been prepared.

Externally Funded Project :

Evaluation of Rain-fed Farming in eastern India : The project has been sponsored by the Overseas Development Agency (ODA) of the Government of U.K. in collaboration with the Overseas Development Group (ODG) of the University of East Anglia, U.K. and is being implemented by the Hindustan Fertilizer Corporation Limited. The ISI is doing the work of impact evaluation and monitoring of the project.

Vast tracts of arable land in India still remain rain-fed and untouched by any marked agricultural improvement. Empirical studies to explore potentialities and appropriate measures for improvement in currently pursued agricultural practices in such rain-fed areas are therefore quite important. The objective of the project is to find out how to increase and stabilise agricultural production under rain-fed conditions. Efforts will be made to reach the poor farmers in rain-fed areas, specially the resource poor and inaccessible communities. The project in its current phase covers 45 villages in various treated and un-treated micro-watersheds in the states of Orissa, Bihar and West Bengal.

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In this connection requested by HFCL/ODA, ISI has agreed to do the following studies : (i) A base-line survey (HLS) before the HFCL begins its work in the villages and another survey *after* five years ; (ii) Annual monitoring and evaluation (AES) ; and (iii) In-depth studies (IDS) on specific issues as and when required.

For this purpose a multidisciplinary team consisting of scientists from social sciences, agricultural science and applied statistics division has been formed. Field work has just started.

Institutional collaboration : Dr. Suraj Bandyopadhyay worked collaboratively with a team of researchers on "Co-operative and Rural Development in India" covering eight states of India. This work was sponsored by the Department of Sociology, University of Delhi, the Department of Anthropology, McGill University, Montreal, Canada and International Development Research Centre (IDRC), Canada.

The final report has been prepared and submitted for publication.

Statistical Quality Control and Operations Research

1. *General* :

The SQC & OR Division is engaged in diverse types of activities in the field of Quality Control, Reliability and Operational Research. The regular activities of the Division include : (a) Rendering assistance and expert advise to manufacturing industries and service organisations in the field of Quality Control, Quality Management and Operations Research ; (b) Taking up project assignments in the areas of Quality, Productivity and Optimisation of resource allocation ; (c) Promotional work in propagating the concepts of quality, productivity and reliability and training of technologists and engineers in these methods for motivation and application of these techniques in live problems for quality and productivity improvements ; (d) Teaching in various academic courses of the Institute at all centres. The Division also participate in teaching in ISEC course and in the Evening courses of the Institute ; (e) Design and development of softwares for computer aided quality control and (f) Undertaking both theoretical and applied research in the field of Quality Control and Operations Research.

The Division during the period under review, initiated the proposal for M.Tech. in Quality, Reliability and Operational Research (Q, R & OR) in place of Diploma in SQC & OR at Calcutta. The M.Tech. (Q R & OR) programme is due to start from 1989-90 academic session. All the preliminary arrangements have been completed.

The Division is participating as one of the principal organisers of the Asia Congress on Quality and Reliability scheduled to be held during 30 October to 2 November, 1989 at New Delhi under the distinguished patronage of the Prime Minister of India and Organising the Congress with its Secretariate at ISI, New Delhi.

The Division is also taking a major role in organising Post Congress Conferences at Bangalore and Calcutta.

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The Division is actively engaged in the design and development of software for computer aided quality control. The Division is also engaged in developing "An Intelligent Computer Aided open learning system of Orthogonal Arrays" at Madras.

The Division has undertaken several new assignments during the period under review. Promotional activities continued in both the public and the private sector industries through inplant lecture programmes, seminars and by way of training technologists and engineers in SQC & OR methods.

A special programme on vendor development was carried out for top management covering 152 companies and for middle management covering 128 industries throughout the country sponsored by Bharat Heavy Electricals Ltd.

Besides the regular activities, the various units of the SQC & OR Division continued liaison with different academic, scientific and other institutions in India and abroad. The Division also collaborated with BIS, NPC, IIM, DGOA, Universities and professional organisations like OR Society, IAPQR, IAQR, NIQR, CEI, Quality Circle Forum of India etc..

2. Consultancy Service and Projects

During the period under review, 76 organisations were availing the services of the Division and 10 new organisations were taken up for service. 101 short term training programmes were organised. 59 organisations were visited to promote the applications of SQC & OR. 15 surveys/pilot projects were carried out and 17 proposals were sent.

Projects involving SQC & OR methods were taken up for various types of problems, some of the selected areas of work are : tea packaging, computer application in quality management, vibration in generators, process capability of radial drilling machine, rejection and rework of circuit-breakers, noise on compressors, gas leakage in water cooler, refrigeration system, SFC variation on Diesel Engine, drift variation on the relays, vendor quality rating, sampling and testing of incoming material.

3. Education and Training

Inplant training programmes for Executives and technologists at various factories continued. In addition to regular inplant programmes for executives at various levels, at BIHEL, a series of training programmes for senior executives continued on a regular basis. One year special programme for the BIHEL Executives at Madras at a fairly advanced level with practical orientation continued for the ninth batch.

During the period under review 2157 managers and technologists were given training in SQC methods, 117 trainees underwent professional training in SQC and OR at Calcutta, Bombay, Bangalore, Hyderabad and Madras, at the post Graduate/Post Masters degree level. The Division also trained 9 SDP Fellows during the period.

The Division shared a fairly heavy load in teaching in the academic courses of the Institute at all centres. The faculty members of the Division have taken all the courses prescribed for Diploma in SQC & OR at Calcutta, part time SQC & OR

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Diploma programmes at Bombay and Madras and in part time certificate courses at Bangalore and Hyderabad.

The Division also undertook teaching most of the courses prescribed in M.Stat. II (Specialisation in SQC & OR) at Calcutta and Delhi and participated in teaching in both M.Stat. I & II at Bangalore. The Division also participated in teaching ISEC courses at Calcutta and Bangalore and in one year Evening course at Calcutta.

4. *Research*

Applied and theoretical research were carried out in different areas. Some of the areas of work are, Bayesian three decision acceptance Sampling plan; continuous sampling plan; Optimum investment in drilling; strongly balanced uniform repeated measurement design, Fuzzy Goal programming in Acceptance Sampling plan; Life testing experiment and minute analysis; Parametric Design and Global Optimisation; Desirability function to evaluate erection quality; Ratio Statistic for weight variation in tablets; Design stability of table fans at low voltage, control of rotor-stator gap of ceiling fan; strongly degenerate complementary cones and solution rays; Linear complementary problem with No Matrix.

5. *Promotional Activities*

Introductory visits were paid to 59 factories; 15 surveys and/or pilot projects were carried out and 17 reports were sent. The industries covered in these surveys are of diverse type such as: Air conditioning; Agricultural machinery; Ceramics and Glass, Chemicals and Fertilizers; Electricals; Electronics; Electromagnet; Engineering (light as well as heavy) Motor Cars; Paper; Storage battery; Steel; TV; Tractors; Tobacco; Watches etc.

A Two tier special programme for Top and Middle management on "Vendor Development" was carried out under the sponsorship of Bharat Heavy Electricals Ltd. throughout the country. Participants from the Industries were trained in SQC techniques for improved productivity and quality. 152 industries represented in the Top Management programmes and 128 industries participated in the Middle Management programmes.

The specialists from the Division delivered 315 lectures and talks to various organisations/institutions on different aspects of Quality Control, Quality Management, Concepts of Productivity, Production, etc.

The specialists from various units attended 42 seminars on topics relevant to the fields of quality control, 14 seminars were organised by the Division during the period under review.

Library, Documentation and Information Sciences

CENTRAL LIBRARY

The Institute maintains a Central Library at Calcutta. With the addition of 1,184 books and 1,493 journals to the stock, the total collection of the Library rose to 1,89,699.

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Acquisition : The Central Library accessioned 1,184 books during the period under report, out of which 610 were purchased and 549 were received as gift. 16 titles were received on exchange basis. It also acquired 223 titles for the Circulating Library.

Periodicals : The Central Library received 1,493 periodicals out of which 330 were received as gift, 608 against subscription and 550 on exchange arrangement with national and international organisations. The Library also acquired 6 back volumes of journals and subscribed to 5 new journals. It accessioned 1,021 journals and completed the technical processing of 805 journals.

Circulation and Stock Maintenance : The Library issued 43,616 books and journals to the users on loan and reference. The total membership of the Library was 1,034 (after the introduction of New Library Rules from May 2, 1988) out of which 8 memberships were withdrawn. The total memberships includes ISI staff, research scholars, project assistants, B.Stat. and M.Stat., M. Tech. students, ISEC trainees etc., as well as outside students and institute members. 469 readers were given special permission to use the library for a short period. 48 books and journals were borrowed from other libraries and 8 books and journals were loaned to other libraries under the inter-library loan arrangement.

Reports & Records : The Library accessioned 674 titles and processed 704 titles. 2,203 titles were issued to borrowers during the period.

Documentation : The Library prepared a short bibliography on statistics, a list of articles on computer scientists abroad and their contributions in Indian periodicals and a short list of bibliography on rice.

Special Materials : The Library accessioned and transliterated 90 Russian books and translated 70 titles.

Technical Processing : The Library classified 543 and catalogued 918 new books.

Reprography & Photography : The Library provided 3,76,514 xerox prints for the users during the period under report.

414 frames of photographs of different natures, 6,000 prints of photographic enlargements, 412 frames of microfilming from drawing books, charts, journals etc., 255 frames of lecture slides and 2,07,340 off-set prints were made during the period under report.

Circulating Library : The Workers' Circulating Library acquired 223 new titles bringing the total collection to 33,779. It issued 25,194 books to the members.

BANGALORE CENTRE LIBRARY

1. Additions :

During the period, 404 books were added to the library by purchase. 12 books were received on gratis. 400 books were transferred to the library from the SQC Unit,

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Bangalore. During the year a total of 388 volumes of journals were bound. 15 back volumes of journals were purchased. Among the current titles received in 1988, 3 titles were cancelled and 9 new titles were subscribed.

2. *Stock Position :*

The total stock position as on 31 March, 1989 : books 10,578 ; books on gratis 608 ; bound volumes of periodicals 3,747 ; number of current periodical titles 237 ; number of current periodical titles (gratis) 28.

3. *Technical Work :*

About 782 books were classified and catalogued during the year. Nearly 3,200 cards were filed. The books received from the SQC Unit are yet to be processed.

4. *Circulation :*

A total of about 8,700 books and 2,400 periodicals (including loose issues) were circulated by the library. The in-house use of books and periodicals was around 16,500. About 150 inter-library loan transactions were registered.

5. *Services :*

During the year, ISI Bangalore Centre Library provided the following services : (i) Circulation service, (ii) Inter-library loan service, (iii) Reference service, (iv) Quarterly addition list of books, (v) Monthly list of current periodicals received, (vi) Bibliography compilation on demand, (vii) Reprographic service, (viii) Library cooperation in the form of exchange of about 25 current issues of periodicals with the TIFR centre in Bangalore.

DELHI CENTRE LIBRARY

During the period April 1, 1988 to March 31, 1989 the Delhi Centre Library was busy performing following activities :

1. *Acquisition :* 274 new books purchased and added to the stock during the period. Received 56 publications as gift from various sources and agencies. More than 360 sets of loose issues of periodicals after getting duly bound have been added to stock, thus raising the stock to 27,727.

Acquisition section also helped the students and researchers by way of procuring 165 publications for their personal use.

Besides more than 100 reprints/technical reports have been received in the library during the above period.

2. *Periodicals :* During the period April 1, 1988 to March 31, 1989, 274 current issues of the periodicals both foreign as well as Indian were received in the library. Out of these 256 were against subscription and 18 as complimentary. 360 sets of loose issues of the periodicals after getting duly bound have been added to the stock during the said period.

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3. *Membership and Circulation* : During the period 306 persons enjoyed the library membership with 150 as temporary members availing the reading room facilities only, whereas 130 as permanent members availed the lending facilities. 17 Visiting Professors were also given all the lending facilities. Approximately 9,516 publications were circulated during the period among the members.

Under the Inter-library Loan program, about 162 publications were lent out to the neighbouring Institutes and about 83 publications were borrowed from other libraries for use by ISI, Delhi Centre Library members.

4. *Reprographic Services* : Requests for providing photocopies of more than 56,933 pages were received during the period and complied with. Xeroxing facilities have also been provided to outside research scholars on nominal rates for taking photocopies of the articles available in library resources.

5. *Documentation Services* : An Annual issue of 'List of Additions' listing the new books added to the stock during the period January to December 1988 has been brought out.

6. *Other activities* : Like every year, this year too Library Trainees with remuneration were appointed. At the end of their training each trainee was given an experience certificate.

Automation of Circulation section has already been done. Efforts are on way to automate other routines in the library, for which packages have already been procured.

DOCUMENTATION RESEARCH AND TRAINING CENTRE (DRTC) BANGALORE

The activities of DRTC have been organised into : (1) Research programme (2) Advisory service programme; (3) Extension programme; (4) Publication programme; (5) Training programme; (6) Employment Information programme; (7) Continuing Education programme and (8) Faculty Development programme.

The following is the report of activities of the DRTC during the period April 1988 to March 1989 :

Training in Documentation and Information Science :

Course leading to ADIS Awards : Under its Training Programme, DRTC conducts a course of 24-month duration leading to the award "Associateship in Documentation and Information Science" (ADIS). This award is recognized by the Government of India as equivalent to a master's degree in "Information Science".

The students of 1987-89 session, appeared for their final examination in July 1988 after the completion of their course for the first year. There were 6 students in the 1987-89 batch. All the second year students are now engaged in their respective research projects. They are to submit their dissertations on or before 31 August 1989

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The session for 1988-90 commenced on 1st September 1988. In all, 8 candidates were selected for admission to the ADIS course (1988-90). All the candidates joined the course. However, one of them had to leave the course after a month because of some personal difficulty.

Short Term Course on Computerized Information Work and Service : Under the sponsorship of the National Information System for Science and Technology (NISSAT) forming part of the Department of Scientific and Industrial Research (DSIR), Government of India, New Delhi, DRTC has been conducting a 6-week course on "Computerised Information Work and Service" (CIWS) since 1986. Normally two such courses are conducted during each financial year. During the period April 1988 to March 1989, the 5th and 6th courses were conducted.

The 5th Course was conducted during the period from 4 July to 12 August 1988 with 14 candidates. All of them completed the course. The 6th Course was conducted during the period from 16 January to 24 February 1989 with 15 candidates. 13 candidates completed the course.

Study Tour by ADIS Students : According to DRTC policy, the students of each session are provided with the opportunity of visiting information centres including libraries, documentation centres, data centres, etc. for the purpose of carrying out observational study of the information work and services in action. The programme of Educational Tour for the students of 1988-90 and 1987-89 was fixed up for the period 15 to 28 December 1988. The Educational Tour was conducted by Dr. G. Bhattacharyya. The students were taken to Calcutta to participate in the 34th All-India Library Conference organized by the Indian Library Association and the 13th IASLIC National Seminar organised by the Indian Association of Special Libraries and Information Centres which were held during 19-23 December 1988 at the Yuha Bharati Krirangan at Salt Lake City in Calcutta. For the purpose of observational study the students visited : (1) National Library, Calcutta. (2) Indian Statistical Institute, Calcutta. The students attended the ILA Conference and the IASLIC Seminar during 19-23 December 1988. The students left Calcutta on 26 December 1988 and reached Bangalore on 28 December 1988.

3. *Research Activities* : The main areas of research in which the different members of the DRTC Faculty were engaged during the period of the report are : (a) Preparation of a State-of-the-Art Report on the "Methodology of Constructing a Vocabulary Control Device" such as, schemes for classification, thesauri and classauri, (2) Preparation of a Manual for the construction of a Classaurus, (3) Designing a Classaurus for the depth-indexing of micro subjects going with the Base "Agriculture and Related Sciences and Technology", (4) Demonstration of the use of the above mentioned classaurus, (5) Application (use) of the Colon Classification, Edition 7 (a) for the purpose of arranging documents on shelves, and (b) for documentation work and service, (6) Design of multiaccess thesauri, (7) Study of the varieties of thesaurus-formats and their impact on information retrieval, (8) Design and development of Depth Classification Schedules, Thesauri and Classauri for depth indexing in different disciplines, (9) Planning and management of information systems and services, (10) Information Analysis and Consolidation, (11) Preparation of a State-of-the-Art Report on Performance Standards in the field of secondary information services, (12) Bibliometrics : Development of measures

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for evaluating use of library and information services, (13) Library automation : Guidelines for developing software for library housekeeping operations, (14) Development of a computerized tutorial for CDS/ISIS (Mini-Micro Version).

4. *Project Work :*

1. *Preparation of a manual for the construction of classauri :* (The fundamental basis of the classaurus would be the general theory of subject/information analysis. For the purpose of demonstration, the discipline "Agriculture and Related Sciences and Technologies" would be considered as the Base).

A select-bibliography was compiled with 200 entries. The bibliography was on the "Methodology of Constructing Vocabulary Control Devices". Such devices include : (1) Schemes for notational classification ; (2) Lists of enumerative subject headings/propositions ; (3) Thesauri and (4) Classauri. The next stage was devoted to the compilation of a state-of-the-art report on researches in the field of the "Methodology of Constructing Vocabulary Control Devices" on the basis of the bibliography. These steps are essential for the preparation of a manual for the construction of a classaurus. During the period July 1988 to March 1989, the activities completed are as follows : (1) Preparation of fully informative abstracts/extracts/digests of the original sources of information ; (2) Designing an organisational framework taking the shape of a systematic verbal scheme for classification ; (3) Indexing of the entries according to this reference framework ; (4) Arranging/sequencing the entries to generate sections and chapters and (5) Writing the sections and chapter according to the principles of consolidation. The first draft of the text portion of the state-of-the-art report was completed during the period.

2. *"Performance Standards for Library and Information Work and Services" :*

Compilation of an annotated bibliography on Performance Standards has been completed. It covers the literature from 1930-80 and consists of 172 entries.

Based on the bibliography, a state-of-the-art-report on "Standards for Libraries and Information Centres" is being prepared. A draft of the same has been prepared and needs to be finalised.

Critical evaluation of the activities of each section in a library or information centre to identify the intellectual (processing) content to be done manually and those which can be done using computer technology has been started. It has been found that the distinctive library functions like acquisition control, serial control, circulation control, reference service and some information services like SDI, Information Retrieval Services can be carried out by applying computer technology. On the other hand, information consolidation work and services have to be done manually. Computer technology has not as yet entered information consolidation area.

In regard to an automated acquisition control, a suitable flow chart has been derived. For the purpose of computer applications to Libraries and Information Centres, the CDS/ISIS software package and dBase III + are being used. The testing of CDS/ISIS PASCAL is in progress.

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3. SYMPOSIA, SEMINARS, LECTURES AND CONFERENCES

Among different conferences, symposia, seminars, workshops and lectures organised by the Institute mention may be made of the following :

3.1 *Symposia, Conferences, Workshops etc.*

A Summer School on Probability and Analysis was held in May-June 1988 at Bangalore Centre of the Institute by the Stat-Math Division. This was attended by twentyfive people from various Colleges/Universities from different parts of India.

The first series of P. Kesava Menon Memorial lecture on "Algebraic Coding Theory" was delivered by Professor D. K. Ray-Chaudhuri, Ohio State University, USA at Calcutta during the period 12-13 December 1988. This was attended by the participants from India and abroad.

The Institute organized two international conferences to honour the memory of Professor Raj Chandra Bose. The first, entitled Raj Chandra Bose Memorial Conference on 'Combinatorial Mathematics and Applications' was organized jointly with Calcutta Statistical Association and held in Calcutta during 14-16 December, 1988. The second, entitled Raj Chandra Bose Symposium on 'Probability, Statistics and Design of Experiments' was jointly organized with Delhi University and Indian Agricultural Statistics Research Institute and held in Delhi University during 27-30 December, 1988. Both the conferences were well attended by participants from India and abroad.

A INDO-U.S. Workshop on 'Bayesian Analysis in Statistics and Econometrics' (BASE) was organized in collaboration with the Department of Science and Technology. The National Science Foundation, USA, Ohio State University, USA, and the Indian Econometric Society in Bangalore during 19-23 December 1988. The theme of the workshop was Bayesian Statistics and Econometrics, an area of research on foundations and new tools which remains largely neglected in India. The workshop was attended by 30 experts from abroad including such eminent scientists as C. R. Rao, Arnold Zellner, Joseph Kadane and Bruce Hill, who presented invited papers. There were 50 Indian statisticians, and econometricians participating in the Workshop. Several contributed papers were discussed in the Poster Sessions.

The Institute was one of the co-sponsors of Nation building, development process and communication : A national seminar in search of India's Renaissance. This was held in Delhi from December 3-7, 1988. Many of the India's leading intellectuals participated.

DRTC Annual Seminar on Computerised Software and Information Work and Services was held during 6-8 March 1989 at ISI Bangalore Centre. Like all other years, the Seminar was based on research contributions made by Information Service Professionals all over India. There were 26 papers presented in the Seminar. The seminar was attended by Information Scientists from all over India. There were 102 participants.

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A National Workshop on Thesaurus for Information Retrieval was organised by DRTC in collaboration with IASLIC, NISSAT and Govt. Polytechnic for Women during 15-25 March 1988. The workshop was attended by 25 participants from all over India. The workshop covered the tools and techniques of information analysis including the different kinds of vocabulary control devices.

A 10-day all India Workshop on 'Information Management' was organised by the Central Library in Calcutta from 7 to 17 June 1988. The workshop was co-sponsored by IASLIC and the Department of Science & Industrial Research, New Delhi.

A seminar on "Application of Software in Quality Control and Inspection" was conducted by SQC Unit, Calcutta during 15-16 December, 1988.

A summer course on "Practical Optimization Techniques and Application" was organised by the SQC & OR Division at IIM, Bangalore during 30 May-11 June 1988. Dr. T. S. Arthanari was the Course Director. 25 Teachers and research scholars from different universities and colleges attended the course.

A Top Management seminar on 'Quality' was organised by SQC and OR Unit, Bangalore at Titan Watch Co., Bangalore on 25 August 1988. Ten senior executives including the Managing Director and three Vice Presidents attended the programme.

A Workshop on "Taguchi Techniques of Quality Engineering" was organised by SQC and OR Unit, Bangalore during 17-31 August 1988 at the Bangalore Centre Campus. 18 Executives of different industries throughout the country attended.

A Seminar on "Orthogonal Array Experimentation" was organised by the SQC Unit, Bombay—for the Confederation of Engineering Industry, Western region, during December 1988 at Hotel Centaur, Bombay. It was attended by 20 participants.

3.2 Lectures and Seminars

The Stat-Math. Division at Calcutta conducts Monday colloquia, other seminars, invited talks by experts in the fields of research.

The following seminars/lectures were arranged during the period :

Stat-Math (Delhi)

Dr. T. Parthasarathy, ISI Delhi (19.4.88) : "Axiom of choice and determinacy".

Dr. K. R. Parthasarathy, ISI Delhi (26.4.88) : "A remarkable class of martingales".

Prof. Balwant Singh, TIFR, Bombay (4.5.88) : "Resolution of singularities of an algebraic variety".

Ms. Sambavi Madhavan, University of Texas at Dallas (20.5.88) : "Integer programming".

Dr. S. K. Mitra, ISI Delhi (12.7.88) : "A matrix programming problem".

Dr. Alladi Subramaniam, IIT, Bombay (13.7.88) : "On Asymptotic aspects of Sequential estimation".

Professor B. Ramachandran, ISI Delhi (26.9.88) : "On some functional equations of Probability Theory". Under the auspices of ISI-Delhi University Joint Seminar Programme held at Delhi University.

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Dr. R. L. Karandikar, ISI Delhi (28.9.88) : "Martingale methods and the Boltzman equation".

Professor D. J. Finney, FRS, University of Edinburg, U.K. (26.10.88) : (a) "A few memories of PCM", (b) "Some thoughts on Data and the Statistician".

Dr. L. Saulis, Inst. of Math, and Cybernetics, Lithuanian Acad. Sci., Vilnius USSR (2.12.88) : "On large deviations for random vectors".

Professor Adam Idzik, Warsaw, Poland (17.11.88) "Theorems on Closed Coverings of a simplex of the KKM-type".

Professor Czeslaw Olech, Warsaw, Poland (16.11.88 & 22.11.88) : (i) "Univalence and Differential Equations", (ii) "An introduction to Optimal Control Theory".

Dr. Rahul Roy, ISI Delhi (9.12.88) : "Critical densities for continuous percolation".

Professor J. J. Seidel, Eindhoven University of Technology (21.12.88) : "Designs and Measures".

Professor M. S. Nikulin, Leningrad, USSR (22.2.89) : " χ^2 -test, theory and practice".

Dr. P. Vellaisamy, IIT, Bombay (28.2.89) : "Estimation after selection : A study for some populations".

Professor G. A. Margulis, I.P.P.I., Moscow, USSR (30.3.89) : "Flows on Homogenous spaces and their applications in number theory".

Matrix-operator Seminar

Professor M. S. Raghunathan, TIFR, Bombay (12.7.88) : "Values of Quadratic forms at Lattice points".

Dr. R. B. Bapat, ISI Delhi (19.7.88) : "Order Statistics and Permanents".

Dr. R. Bhatia, ISI Delhi (2.8.88) : "Averaging and Dispersion".

Dr. J. M. Lindsay, (9.8.88) : "Quantum Chaos ?"

Dr. Bryan E. Cain, IOWA State University (16.8.88) : Conjugate Cones and Semi-definite Operators".

Dr. K. G. Ramamurthy, ISI Delhi (30.8.88) : "Certain classes of matrices in the linear complementarity theory".

Dr. Kalyan Mukherjee, ISI Delhi (6.9.88) : "Elliptic Operator and Topology".

Dr. R. Sridhar, ISI Delhi (27.9.88) : "On the simplex method and a class of linear complementarity problems".

Dr. R. L. Karandikar, ISI Delhi (13.9.88 & 29.11.88) : (i) "Multiplicative decomposition of non-singular matrix valued semimartingales", (ii) "On Feynman Integrals".

Professor Miroslav Fiedler, Czech. Academy of Sci. (25.10.88, 1.11.88 and 8.11.88) : (i) "Algebraic connectivity of graphs and its modifications", (ii) "Matrices and Euclidean Geometry", and (iii) "Hankel, Bezout and Loewner matrices (A survey)".

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Dr. Amit Roy, TIFR, Bombay (6.12.88) : "Epimorphisms of Polynomial Rings".

Mr. Rahul Roy, ISI Delhi (13.12.88) : "An introduction to Percolation Theory".

Dr. Karl Petersen, University of North Carolina (17.1.89) : "Nonhomogeneous ergodic theorems".

Dr. Joseph Horowitz, University of Massachusetts, Amherst (24.1.89) : "A glance at image-processing".

Dr. Ka-Sing Lau, University of Pittsburgh (31.1.89) : "Harmonic Analysis of Functions with Bounded Means".

Mr. D. V. Rajaram Bhat, ISI Delhi (7.2.89) : "The Berberian Extension of Hilbert Space Operators".

Mr. Anilesh Mohari (14.2.89) : "The equation $AX - XB = C$ in Banach Spaces".

Mr. K. R. Parthasarathy, ISI Delhi (21.2.89) : "Chaos of Markov Chains".

Mr. W. Von Waldenfels, University of Heidelberg (7.3.89) : "An example of Quantum Central Limit Theorem".

Dr. L. Elsner, University of Bielefeld (14.3.89 and 21.3.89) : (i) "On the spectral radius of entrywise functions of matrices", (ii) "Convergence of asynchronous paracontractions; application to tomographic reconstructions".

Game Theory and O. R. Seminar

Dr. T. Parthasarathy, ISI Delhi (1.9.88, 8.9.88, 22.9.88 and 29.9.88) : (i) "Introduction to repeated games", (ii), (iii) and (iv) "Repeated Games".

Dr. G. Raviindran, ISI Delhi (7.9.88, 6.10.88, 13.10.88, 27.10.88 and 3.11.88) : (i) " N -matrices", (ii), (iii), (iv) and (v) "Repeated Games".

Applied Statistics, Surveys and Computing

Dr. Bikas K. Sinha (8.4.88) : "A Statistical Analysis of Social Networks : problems and Perspectives."

Dr. A. K. Thakur (6.4.88) : "Statistical Modelling and Risk Estimation of Carcinogenic Dose-Response".

Dr. Bijan K. Chakraborty (4.5.88) : "Xerophthalmia in under-five children in Rural West Bengal".

Dr. David Abler (19.5.88) : "Distributional Implications of the Green Revolution in India".

Dr. Sildas Bandyopadhyay (2.8.88) : "Forgot the sampling design at estimation stage".

Dr. J. Roy (23.8.88 & 30.9.88) : (i) "Short Term Forecasting : An Empirical Approach", (ii) "Japan today".

Dr. Subir Ghosh (3.1.89) : "Measuring Dispersion Effects in Factorial Experiments".

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Dr. Anup Basu (23.2.89) : "Robot navigation".

Economic Research

Mr. P. Gajapati (28.12.88) : "Price Formation in the IO framework".

Dr. J. Y. Lin, Development Institute, Beijing (11.1.89) : "Agricultural Reforms in China".

Dr. Jouko Pannie, University of Helsinki (16.1.89). Instability and slow growth in Europe".

Dr. D. K. Bose, Vice-Chairman, West Bengal State Planning Board (2.3.89) : "Public Sector Pricing".

Economic Analysis (Bangalore)

Professor D. K. Bhattacharya, University of Leicester, UK (12.4.88) : "Estimation of Hidden Money with reference to the UK and USA".

Dr. S. N. Joshi, Stat-Math Unit, Indian Statistical Institute, Bangalore (17.5.88) : "Bayesian Analysis in Statistics and Econometrics".

Dr. A. K. Sengupta, Economic Research Unit, ISI, Calcutta (7.6.88) : "An alternative Measure of Factor Intensity in Production".

Professor Sanjit Bose, Economic Research Unit, ISI, Calcutta, (17.6.88) : "Service Form of Production".

Dr. P. A. V. B. Swamy, US Federal Reserve Board, Washington, USA (22.8.88) : "Foundations of Bayesian Analysis in Statistics and Econometrics".

Professor Ranganath Bharadwaj, Director, Bombay School of Economics, University of Bombay (15.7.88) : "Pedagogics in India".

Professor P. R. Brahmananda, ICSSR, National Fellow (25.8.88) : "Comments on Dr. Sukhmoy Chakravarty's Recent Reflections on Development Processes".

Dr. M. H. Suryanarayana, Economic Analysis Unit, ISI, Bangalore (9.0.88) : "Poverty and its Determinants".

Dr. Somdeb Lahari, Indian Institute of Management, Ahmedabad (14.9.88) : "A General Saddlepoint Property for Two-Person Variable Threat Games".

Dr. M. R. Narayana, CSIR Pool Officer, Economic Analysis Unit, ISI, Bangalore (20.9.88) : "Federal Transfers and Inter-regional Resource Allocation : The case of India".

Ms. Suchitra Chakravarthy, Economic Analysis Unit, Indian Statistical Institute, Bangalore (30.9.88) : "The Role of Institutional Agencies in Karnataka's Agricultural Finance".

Professor Prem K. Goel, Ohio State University, USA and Professor N. S. Iyenger, Indian Statistical Institute, Bangalore (19-23 Dec. 1988) : "Indo-US Workshop on Bayesian Analysis in Statistics and Econometrics", Bangalore.

Population Studies

Population ageing in India with special reference to its Demographic and Socio-economic aspects, on 5 May, 1988.

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Interface between Family Planning Workers and Clients in Bangladesh, on 6 May, 1988.

Use of Micro Computer Software for Demographic analysis and Projection, on 21 July, 1988.

On Follow-up time Interval in Estimating and Comparing two Rates in Demographic Studies. Presented at a seminar at the Department of Demography, Kerala University, On August 16, 1988.

Explaining high Contraceptive Prevalence in Matlab, Bangladesh : A focus group Methodology, on 13 October, 1988.

Life Table Techniques, on 29 December, 1988.

Ischaemic Heart Disease in Indian Population : Past, Present and Future, on 20 January, 1989.

Population-related Problems of Bangladesh on 23 February 1989.

Some Demographic Problems of Bangladesh, on 20 March, 19 9.

Statistical Quality Control and Operation Research

Shri S. C. Bhattacharyya (4.4.88) : "Production Scheduling of Compounded Nylon Chips".

Shri P. K. Swain (5.5.88) : "Control of Rejection at neck sealing, neck flanging and pipe cutting".

Shri A. Sarkar (11.4.88) : "Useable waste study in spinning mills".

Shri G. Ravindran, ISI Delhi (June, 88) : "Game Theory".

Dr. T. P. Tripathi, ISI Calcutta (21.7.88) : "Estimation of some parameters based on ancillary information".

Dr. B. K. Sinha, ISI Calcutta (21.7.88) : "Non-adaptive hypergeometric group testing designs for almost two defectives".

Dr. S. K. Majumdar (22.7.88) : "Mechanistic modelling for statistical applications".

Shri R. Anantha Rao (25.7.88) : "Beta-correction methods".

Shri Rajiv Goel (31.10.88) : "A group sampling attribute plan to attain a given strength proposed by T. K. Chakraborty".

Prof. T. E. S. Raghavan, (23.12.88 and 24.12.88) : "Nash Bargaining in Two Person Games and application of Stochastic Games".

Shri A. Bandyopadhyay (Jan-Mar. 1988) : "Software Designing and File Management through Turbo Pascal".

DRTC (Bangalore)

A Seminar on Construction and Maintenance of Thesisrus by using CDS/ISIS (along with a demonstration) was held on 27th April 1988. The seminar was offered

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by Prof. A. Neelamegham, Honorary Professor, DRTC, Bangalore. About 30 participants attended the Seminar.

A seminar on "Marketing of Scientific and Technical Information" was held on 6 June, 1988. The seminar was offered by Shri N. K. Gopalakrishnan, Chief, Centre for Documentation, Institute of Public Enterprises, Hyderabad-7. About 40 participants attended the Seminar.

A Seminar on 'Information Support for Technology Management' was held on 8-9 June, 1988. The seminar was offered by Prof. A. Neelamegham, Honorary Professor, DRTC, Bangalore. About 40 participants attended the seminar.

'Seminar on Trends in Information Technology' was held on 10 June, 1988. The Seminar was offered by Shri N. V. Satyanarayana, Director, Informatics (India) Ltd., Bangalore. About 20 participants attended the Seminar.

A Seminar on Trends in Information Products Development was held on 15 June 1988. The seminar was offered by Shri N. V. Satyanarayana, Director, Informatics (India) Ltd., Bangalore. About 40 participants attended the seminar.

A Seminar on Bibliometrics was held on 4, 6, 8 and 11 July 1988. The seminars were offered by Dr. Quentin Burrell, Lecturer, Statistical Laboratory, Department of Mathematics, University of Manchester, UK. About 40 participants attended the seminars on each date.

Seminars on (1) Information and Communication ; (2) Information Transfer Chain ; (3) Information Systems ; (4) User Needs ; (5) Searching and Retrieval of Information and (6) Information Dissemination Techniques was held on 26-30 September, 1988. The seminars were offered by Dr. (Mrs.) B. Vijaya Lakshmi, Reader, Andhra University, Waltair. About 20 participants attended the seminars on each day.

A Seminar on 'Impact of New Information Technologies on Library/Information Work and Service was held on 27 September 1988. It was a special seminar organised by DRTC attended by general public of Bangalore. The seminar was offered by Ms. B. Vijayalakshmi as part of the Five Laws Lecture Series.

The DRTC Refresher Seminar—47 (1988) was held during 26 and 28 October 1988. The theme of the seminar was Colon Classification Edn. 7. The working document for this seminar was prepared by Prof. M. A. Gopinath. In the presentations Prof. M. A. Gopinath, Prof. A. Neelamegham and Prof. S. Parthasarathy took part. About 55 participants attended the Seminar.

A Seminar on 'Selection and Marketing of Library materials' was held on 23 January 1989. It was a special seminar organised by DRTC and attended by general public in Bangalore. Dr. K. S. Umashathy, Specialist, Northwest Regional Library, Philadelphia, USA.

A Seminar on 'Impact of Information Technology on Professional Training Programmes' was held on 31 January, 1989. It was a special seminar organised by

DRTC and attended by the general public of Bangalore. The seminar was offered by Prof. S. Parthasarathy, Director, Institute of Information Studies, Madras-5.

4. PUBLICATIONS

The following publications were brought out during April 1988-March 1989 :

(i) *Sankhyā* : The Indian Journal of Statistics, the official organ of the Indian Statistical Institute.

Series A : Vol. 50, Parts 2 & 3

Series A : Vol. 51, Part 1

Series B : Vol. 50, Parts 1, 2 & 3

(ii) Twentyfour technical reports from the Statistics-Mathematics Group have been issued during the period.

(iii) *Advances in Information Sciences and Technology, Vol. II : Information Storage, Retrieval and Processing*, Edited by J. Roy, 1st Edition, 1989.

5. SCIENTIFIC PAPERS AND PUBLICATIONS

SCIENTIFIC PAPERS PUBLISHED

Theoretical Statistics and Mathematics

Calcutta

1. Bngchi, Bhnskar (with Sastry, N. S. N.) (1988) : Codes associated with generalized polygons. *Geom. Dedicata*, 27, 1-8.
2. ——— (1988) : No extendable biplane of order nine. *Jour. Comb. Theory (A)*, 49, 1-12.
3. ——— (1989) : Intersection pattern of classical ovoids in symplect space of even order. *Jour. Algebra*.
4. Ghosh, J. K. (with Bhattacharya, R. N.) (1988) : On moment conditions for valid formal Edgeworth Expansions. *Jour. Multi. Anal.*, 27(1), 68-79.
5. Mazumder, B. S. (with Mukherjee, A.) (1988) : Dispersion of contaminant in oscillatory flows. *Acta Mechanica*, 74, 107-122.
6. Mukherjee, R. (with Sen, M.) (1988) : Kronecker factorial designs for multiway elimination of heterogeneity. *Ann. Inst. Stat. Math.*, 40, 195-210.
7. ———(with Sen, M.) (1988) : Non-equireplicate Kronecker factorial designs. *J. Stat. Plann. Inf.*, 19, 261-267.
8. ——— (Kageyama, S.) (1988) : Classification of semi-regular group divisible designs with $\lambda_4 = \lambda_1 + 1$. *Ars Combinatoria*, 25, 51-57.

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9. ——— (with Kageyama, S. and Saha, G. M.) (1988) : D^{-1} -partially efficiency-balanced designs. *Commun. Stat.—Theory and Methods*, 17, 1669-1683.
10. ——— (with Gupta, S.) (1988) : Universal optimality of main effect deletion designs. *Statistics and Probability Lett.*, 7, 89-91.
11. ——— (with Hudn, S.) (1988) : Optimal weighing designs : approximate theory. *Statistics* (formerly a series of *Math. Operations forschung und Statistik*), 19.
12. ——— (with Bose, M.) (1988) : Estimability-consistency and its equivalence with regularity in factorial designs. *Utilitas Mathematica*, 33, 211-216.
13. Ramakrishnan, C. S. (1988) : An improvement of Goyal's modified VAM for the unbalanced transportation problems. *Jour. O. R. Soc.* (U. K.), 39, 609-610.
14. Rao, B. V. (with Maitra, A. and Srivatsa, V. V.) (1988) : Some applications of selection theorems to parametrization problems. *Proc. Amer. Math. Soc.*, 104 (1), 96-100.
15. Rao, T. J. (1988) : Transformation on the auxiliary variate for Midzuno-Sen sampling scheme. *J. Ind. Soc. Agri. Stat.*, 40, 173-177.
16. ——— (1989) : Efficiency of a new estimator in PPS sampling for multiple characteristics. *J. Statist. Plan. Inf.*, 21, 75-84.
17. Sinha, B. K. (with Shah, K. R.) (1988) : Optimality aspects of 3-concurrence most balanced designs. *J. Statist. Plan. Inf.*, 20, 229-236.
18. ——— (with Mukhopadhyay, N. and Sen, P. K.) (1988) : Stopping rules, permutation invariance and sufficiency principle. *Ann. Inst. Stat. Math.*, 41, 121-138.
19. ——— (with Mukhopadhyay, N. and Sen, P. K.) (1988) : Bounded risk estimation of a finite population mean : optimal strategies. *Sequential Analysis*, 7, 91-109.
20. Tripathi, T. P. (1988) : Estimation for domains in sampling on two occasions. *Sankhyā* (B), 50, 103-110.
21. ——— (with Singh, H. P. and Upadhyay, L. N.) (1988) : A generalised method of estimation in double sampling. *J. Ind. Stat. Assoc.*, 26, 91-101.

Delhi

1. Bapat, R. B. (1989) : Infinite divisibility of multivariate gamma distributions and M -matrices. *Sankhyā, Ser. A*, 51, 1, 73-78.
2. ——— (with Beg, M. I.) (1989) : Order statistics for non-identically distributed variables and permanents. *Sankhyā, Ser. A*, 51, 1, 79-93.
3. ——— (with Raghavan, T. E. S.) (1989) : An extension of a theorem of Darroch and Rateliff in loglinear models and its application to scaling multi-dimensional matrices. *Linear Algebra Applic.*, 114/115, 705-715.
4. Dhatia, R. (1988) : Perturbation inequalities for the absolute value map in norm ideals of operators, *J. Operator Theory*, 19, 129-136.

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5. ——— (with Holbrook, J. A.) (1988) : On the Clarkson—McCarthy Inequalities, *Mathematische Annalen*, 281, 7-12.
6. ——— (with Kittaneh, F.) (1988) : On some perturbation inequalities for operators. *Linear Algebra Appl.*, 106, 271-279.
7. ——— (with Davis, C. and Koosis, P.) (1989) : An extremal problem in Fourier analysis with applications to operator theory. *J. Funct. Analysis*, 82, 138-150.
8. ——— (with Sinha, K. B.) (1988) : A unitary analogue of Kato's Theorem on variation of discrete spectra. *Lett. Math. Phys.*, 15, 201-204.
9. ——— (with Holbrook, J. A. R.) (1989) : A softer, stronger, Lidskii Theorem. *Proc. (Mathl. Sciences) Ind. Acad. Sci.*, 99, 75-83.
10. Bhattacharya, C. G. (1988) : On the Cohen Sackrowitz estimator of a common mean, *Statist.*, 19, 4, 493-501.
11. Mitra, S. K. (1988) : Infimum of a pair of matrices, *Linear Algebra Appl.*, 105, 163-182.
12. Mitra, S. K. (1988) : On the method of overlapping maps in survey sampling, *Sankhyā*, 50, 9-38.
13. Parthasarathy, K. R. (1988) : The passage from random walk to diffusion in quantum probability. Appld. Prob. Celebration (Ed. J. Gani) Applied Probability Trust.
14. ——— (with Lindsay, J. M.) (1988) : The passage from random walk to diffusion in quantum probability II. *Sankhyā. Ser. A*, 50, 151-170.
15. ——— (1988) : A unified approach to classical, bosonic and fermionic Brownian motions. *Asterisque*, 157-158, 303-320.
16. ——— (1988) : Andrei Nikolaevich Kolmogorov, Obituary. *J. Appl. Prob.*, 445-450.
17. Parthasarathy, T. P. (with Ravindran, G.) : Completely mixed games and global univalence in convex region, *Optimization, Design of Experiments and Graph Theory*. Edited by M. N. Gopalan, G. A. Patwardhan, IIT, Bombay, 417-423.
18. Prakasn Rao, B. L. S. (1988) : Laws of iterated logarithm for fluctuation of posterior distributions for a class of diffusion processes and a sequential test of power one. *Teor. Veroyat. iee primenen*, 33, 289-294.
19. ——— (1988) : Statistical inference from sampled data for stochastic processes, *Statistical Inference from Stochastic Processes*. (Ed. N. U. Prabhu) *Contemporary Math.*, *Amer. Math. Soc.*, Providence, Rhode Island, 80, 249-284.
20. Ramachandran, B. (with Lau, K. S. and Gu, H. M.) (1988) : On characteristic functions satisfying a functional equation and related classes of simultaneous integral equations. *Sankhyā, Ser. A*, 51, 2, 190-198.
21. Sinha, K. B. (with Bhatia, R.) (1988) : A unitary analogue of Kato's theorem on variation of discrete spectra. *Lett. Math. Phys.*, 15.

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22. Sinha, K. B. (with Muthuramalingam, P. L.) (1986) : Existence and completeness of wave operators for the Dirac operators etc. *J. Ind. Math. Soc.*, 50 : 1-4.
23. ——— (1986) : Quantum stochastic integral and martingales, *J. Orissa Math. Soc.*, 5, 1.
24. ——— (with Parthasarathy, K. R.) : Representation of a class of Quantum Martingales II. *Springer Lecture Notes*, 1303, *Quantum Prob. Appl.* III.

Bangalore

1. Rao, K. P. S. Bhaskara (with Heuvers K. and Cummings L.) (1988) : A characterisation of the permanent function by the Binet-Cauchy theorem. *Linear Algebra Appl.* 101.
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