THE FOURTY YEARS OF STATISTICAL SCIENCES IN JAPAN - MY RETROSPECT AND PROSPECT

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THE FOURTY YEARS OF STATISTICAL SCIENCES IN JAPAN—MY RETROSPECT AND PROSPECT*

By

Tosio KITAGAWA**

Abstract

The birth, the developments of statistical sciences in Japan and one of their remarkable tendencies of transitions to information science in Japan during the period of about the fourty years from 1940 to 1981 are described in terms of both national scale activities in the first three sections and the personal scientific experiences of the author in the latter two sections except Subsection 5.2 which is dedicated to the national achievements in information science. The paper gives also several graph representations showing the inter-relationship among various works of the author. The last Section 6 refers to a prospect regarding to the scientific responsibilities of statistical sciences in connection with information science.

1. The Current Thought of the Time

In talking about the topics enunciated in the title of the present paper, it seems to the author to be adequate and even necessary to refer to the current thought of the time ranging over about the fourty years since 1940 to 1981 in terms of the following five characteristic features (I)-(V).

(I) The progress of statistical methodologies has been remarkable in various areas of sciences including quantum mechanics, population genetics, econometrics, cybernetics and inference statistics.

(II) The change of the focus areas in the communities of sciences has happened during these fourty years, starting from physical sciences and social sciences and gradually shifting to biological sciences and linguistical sciences, as can be observed since 1975.

(III) A shift from the era of uniformization and planning to that of multitude and participation emphasizing creation and individualism has become gradually eminent.

(IV) A shift of industrial society to information oriented society has been broadly and intensively emphasized by various contemporary authors.

* The original form of the present paper was presented as an invited paper to the Special Lecture Meeting celebrating the Fifty Years of Japan Statistical Society which was held July 14, 1981 at Kansai University. Section 5 is supplemented with a more detailed description of the recent works of the author.

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(V) An explicit consciousness of global human society has become more and more realistic invoking the needs for the international efforts of solving conflicting problems such as (a) east and west and (b) north and south.

It is a matter of course that statistical sciences in Japan have been under the strong influences of these worldwide tendencies because of the contemporary international interactions.

2. Japanese Environments During the Period 1931-1970

In looking back the last fourty years, we have to remind the political and economical environments in Japan under which statistical sciences in Japan have been working to develop in order to fulfill their scientific responsibilities. The following six specific items may be worth while to be mentioned here.

(1°) The Manchuria disturbance since 1931, September 18, the Japan-China disturbance since 1937, July 7 and the second World War since 1941, December 8 to 1945, August 15.

(2°) The postwar economical rehabilitation under the occupation of the U.S. military powers.

(3°) The peace constitution since 1946, February and the security pact scheme between the U. S. and Japan since 1951, September 8.

(4°) The economical developments of Japan as small resource country.

(5°) Promotion of technology innovations in Japan as international trade oriented country.

(6°) Environmental problems in Japan caused by rapid industrial developments.

Many social scientists whose backgrounds had been in the area of economical statistics made great contributions in solving various difficult socio-economical problems occurriing in connection with (1°)~(4°). In particular we should mention here the names of economical satisticians I. Takano, H. Ouchi, H. Arisawa, I. Nakayama, M. Takahashi, T. Ninagawa, Y. Morita and R. Minobe in this connection. It is indeed quite a remarkable progress in the history of statistics in Japan to have established Statistics Commission in which H. Ouchi, Y. Morita and T. Minobe and others made great contributions in establishing the system of the designated statistics and in promoting national sample surveys in consumer prices, rice planted areas and so on under the severe circumstances of the economical rehabilitation. With regard to the technical problems being encountered in designing sample surveys and statistical quality controls in industries many mathematical statisticians coming from members of Research Association of Statistical Sciences, (See Section 3, the paragraph [1]) had made great contribution as we shall show in the following sections.

3. Establishment of Statistical Sciences in Japanese Academic Community

We have already explained very briefly the current thought of the time in the world and the specific Japanese political and economical environments. The last fourty years were remarkable in making the epoch-making progresses under such specific siturations.

[1] *Activities of Research Association of Statistical Sciences* The Research Association of Statistical Sciences was established in 1941, February by the membership of about one hundred persons with the two definite aims: (a) establishment and fostering mutual scientific cooperations among all sciences and (b) promotion of mathematical statistics. The Journal "Bulletin of Mathematical Statistics" has been published since then until 1981 with nineteen volumes. During the early period the two Japanese Journals "Tokei Suri Kenkyu" (Researches on Mathematical Statistics) since 1941 and 'Torkei Kagaku Kenkyu' (Researches on Statistical Sciences) since 1948 were also published for the ranges of two or three years. Two volumes called 'Statistical Tables' (in Japanese) were also published by the Committee of the Association in which the present author and M. Masuyama took the active roles. The Association has been due to the self-devoting efforts of many scientists in establishing its existence and promoting its activities in various application fields. Our thanks are particularly due to R. Sato, J. Yamanouchi, Y. Ichida, T. Kawata, M. Masuyama, S. Kawai, H. Yonezawa, S. Furuya, G. Maruyama and M. Ogawara who contributed in the early period of the Association.

[2] *Establishment of Institute of Statistical Mathematics in 1944* The proposal to establish an Institute of Statistical Science was presented by the present author in 1943 in the meeting of Gakujutsu Kenkyu Kaigi (Science Research Council), and after the disscussion in the Diet the final name Institute of Statistical Mathematics was adopted by the Ministry of Education, Science and Culture. The first Director of the Institute was S. Kakeya, the professor of mathematics, University of Tokyo, and T. Kawata, J. Ogawa, H. Sakamoto, K. Matsushita, C. Hayashi and T. Mizuno were the active members in its early stage. The present author had the responsibility of acting Director about one year in 1947～1948.

[3] *Establishment of substantial professorship of statistical mathematics in 1943* Strictly speaking it may be said that there had been the respective professorship of mathematical statistics in some of Japanese universities before 1943, but it was absolutely clear that no department of mathematics until 1942 had any mathematician who could claim mathematical statistics as his sole or main job. Under this situation it was a remarkable event that the Department of Mathematics, Faculty of Science, Kyushu University, consisting of Professors M. Hukuhara, H. Honbu and the present author, had a definite idea of devoting one chair to mathematical statistics. This idea was realized in 1943, November. The present author took the responsibility to establish the education and research in this area.

[4] *Branch Society of Statistical Mathematics in the Mathematical Scoiety of Japan* This was established since the establishment of the Mathematical Society of Japan which became separated from the Physico-Mathematical Society of Japan in 1946. The Branch Society has two regular meetings every year, once in each Annual Meeting in Spring and once in the Autumn Consolidated Branch Society Meeting, as in the case of the other nine Branch Societies such as (i) Foundation and History of Mathematics, (ii) Algebra, (iii) Geometry, (iv) Function Theory, (v) Functional Equations, (vi) Function of Real Variables, (vii) Functional Analysis, (ix) Applied Mathematics and (x) Topology. Our Branch Society (viii) Statistical Mathematics includes Theory of Probability and has

become one of the most active Branch Societies in terms of the numbers of the papers presented to the two Meetings.

[5] *Research Liason Committee of Statistics in Science Council of Japan* This was established in 1954, as an organization representing Japanese statisticians working in all areas of sciences under the general scheme of Science Council of Japan. Its establishment and its activities have shown the recognitiin of statistical sciences as one independent consolidated science division in Japan. Since 1955 when the Rio de Janeiro Session was held, the Research Liason Committee of Statistics has been working in choosing at least one representative statistician to be recommended from the Science Council of Japan who is designated to attend at the International Statistical Institute as a delegate.

[6] *Publication of statistical dictionaries and statistical tables* In order to have the common bases upon which statistical works can be established, it was quite useful to have statistical dictionaries and statistical tables for Japanese communities by which common terminologies and modern methodologies are adequately illustrated. Three statistical dictionaries [1], [2], [3] were published in which I. Nakayama, economist, were chief editor and many members of Research Association of Statistical Sciences joined as coeditors and/or as writers. Two statistical tables [4], [5] were published by our Research Association, with the active cooperation of the present author and M. Masuyama. The Tables of Poisson distribution [6] in 1950 and the tables for the design of the factoial experiments [7] in 1953 (with M. Mitome) were published by the present author.

[7] *Conference of doctor degrees in mathematical statistics* It was quite remarkable phenomena in the period of the sixties that many research workers were confered doctor degree in mathematical statistics, particularly, from Faculty of Science, Kyushu University where the present author had been working as the professor in charge of statistical mathematics. In fact the present author was responsible as the chief refree to the thesis of many represntative mathematical staticians who did not graduate from the Department of Mathematics, Kyushu University, such as S. Yamamoto, M. Ogawara, T. Okuno, H. Aoyama and so on, to say nothing about the graduate persons from the Department.

[8] *Systematic approaches in establishing educations in statistics* These were promoted and realized under the guidance and/or the aid of the Ministry of Education, Science and Culture throughout all stages of school educations, in elementary schools, middle schools, high schools, colleges and universities. There have been many authors who contributed in publishing text books in statistics. The present author also published several kinds of text books. (See Reference [8]~[11].)

[9] *Members of International Statistical Institute* The increased numbers of the ordinary members of ISI, shows the Japanese tremendous activities in the area of statistics during these fourty years.

4. Retrospect of the Tours in Research during the Period 1940-1965

In contrast with the three previous sections, the present and the following sections are concerned with the personal career of the present author which, however, aims hopefully firstly to show the reason why we make use of the notion of statistical sciences instead of statistics and secondly to explain one of the feasible courses along which statistical sciences had become to be concerned in natural way with information science.

[1] *The way to statistical inference process during the period of 1940～1960* For the present author there were three decisive features (1), (2) and (3) in his research works which lead him to the theory of statistical inference processes.

(1) *Recognition of statistics* The Japanese monograph [12] (1948) by the present author was concerned with historical developments of statistics during these three hundred years and aimed to make clear the social backgrounds and the methodological characteristics under which modern statistics had been developed until the present stage of the middle of the twentyth century. Besides works due to various classical works on statistics due to German Academic School and French School of Probability and those due to F. Galton, K. Pearson, the present author was fortunate to make advantage of the excellent Japanese translations of classical monographes due to W. Petty, J. Graunt, J. P. Süssmilch, L. A. Quetelet and so on originally written in German, French and English in statistics, thanks to the works of I. Takano, H. Ouchi, T. Morito and others, coming from economic and social statistics.

(2) *Practical experiences in applied statistics* So far as the present author was conerned, there were the following three areas in which the current statistical theories could find their scientific validities and remarkable social effectiveness.

(2.1) Quality Control in manufacturing industries with cooperation of Y. Ishida, T. Kitahara, N. Yamakawa and T. Seguchi. (See Reference [13].)

(2.2) Argicultural field experiment and factorial design of experiments with cooperation of M. Mitome. (See Reference [7], [14].)

(2.3) Sampling surveys in coal mine, forest, and fishery catches with the respective cooperation of T. Fujita, K. Kinashi, M. Nishizawa, T. Yamamoto, M. Furuno and T. Shimura. (See Reference [15], [16], [17].)

(3) *Theoretical studies of inference theories* In comparison with the progress of modern mathematical statistics in the English speaking countries such as the U. K., the U. S., and India, we felt early in 1940 that Japan had the lag of thirty years behind. It was quite indispensable to catch up the lag through the establishment of Research Association of Statistical Sciences and by fostering cooperations among scientists all over Japan regarding theoretical studies and practical applications in statistical works, as we have already explained in the paragraph [1] of the Section 3. The item (3) covered naturally (3.1) exact sampling theories, (3.2) inference theories and (3.3) design of experiments.

(4) *Scientific exchange between foreign scholars in the period of 1953～1960* Since Japan had not any strong tradition in the area of mathematical statistics, it was indispensable to learn from abroad by visiting foreign scholars and institutions. So far

as his own experiences were concerned, the present author has been deeply due to the scientific exchange relationship among scholars such as (i) P. C. Mahalanobis, C. R. Rao in Calcutta; (ii) R. A. Fisher, F. Yates and M. S. Bartlett in England; (iii) T. A. Bancroft, O. Kempthorne, G. Tintner, and H. O. Hartley in Iowa; (iv) S. Wilks, J. Tukey, J. Amscombe, G. E. P. Box in Princeton; (v) N. Wiener in Boston; (vi) R. Bellman in Los Angeles; (vii) J. Neyman, E. Scott, D. Blackwell in Berkeley; (viii) C. Stein, C. Chernoff in Stanford; and (ix) P. Moran and J. Gani in Canberra; (x) V. Linnik in Leningrad. Some records are given in Reference [18].

(5) *Integration of the works during the period 1950~1960 by statistical inference and control processes* The foregoing items (1), (2), (3), and (4) lead the author to a clear consciousness of the needs for establishing the theory of statistical inference and control processes and hence to publication of a series of papers aiming to realize his ideas on this topics. (See Reference [19], [23].) It was in the occasion of 1960 ISI Session in Tokyo when his invited paper [21] was presented to show the logical foundation of sucessive processes of statistical inference and control. It was pointed out also in this paper that the interrelationship between his statistical ideas and cybernetics due to N. Wiener is crucial. In fact the present author referred in this paper [21] to cybernetical formulation of statistics. This referrence turned out to be substantially crucial as will be explained in Section 6 and so on. So far as the integration is concerned, the following Figure 1 shows the interrelation among these five research items:

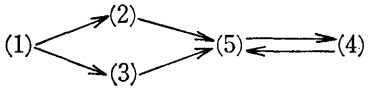

Fig. 1. Interrelation among the five research items leading to statistical inference and control processes

The present author owed very much to discussions and/or considerations, which were given during his visits, in preparing some of his papers quoted in Reference: [22] to P. C. Mahalanobis; [23] to R. A. Fisher; [24] to J. Neyman; [25] to G. E. P. Box; [26] to J. Neyman.

[2] *Refinements and further developments of theories of statistical inference process during the period 1960~1965* During this period; the following three works (6), (7) and (8) were important as the refinement and the further developments of theories of statistical inference process:

(6) *Data analysis in 1963* (See Reference [27].)

(7) *Automatically controlled sequence of statistical procedures in 1963* (See Reference [28].)

(8) *Relativistic logics of mutual specification in 1963* (See Reference [29].)

These three topics (6)~(8) implied an explicit introduction of the various key notions in the new phase of statistical sciences such as

(9) *learning by experiences,* (10) *automated statistician*

(11) *statistical programming* and (12) *accumulation of information*

as being explained in References [27], [28] and [29]. Their mutual interrelationship can be obrerved from the following illustration shown in Figure 2.

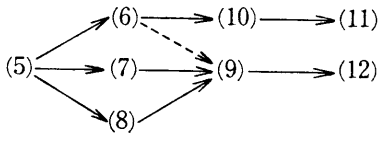

Fig. 2. Key notions (9)～(12) in the new phase of statistical science

[3] *Connections with science research planning and their scientific consequence during the period 1953～1956* The following seven items (13)～(19) show the backgrounds upon which science research plannings became the serious concerns of the present author since 1953.

(13) Planning works of the present author as a committee member of preparing *long range plan of science research* being sponsored by the Science Council of Japan. (See Reference [30].)

(14) Learing from P. C. Mahalanobis of *the second five year plan in India* being realized by the visits of the present author to India in 1953, 1957 and 1966. (See Reference [18].)

(15) Responsibility of the present author in charge of *new professorship in mathematical programming* in the Department of Mathematics, Faculty of Science, Kyushu University.

(16) An establishment of *methodology for science research planning* by means of explicity introducing four research areas such as (a) free research area, (b) planned research area, (c) liquid research area and (d) basic research area. The emphasis of (d) had a deep connection with the works in the items (17) and (18).

(17) *Modernization of university libraries* The present author had the responsibility of serving as the Director of University Library of Kyushu University during six years since 1961.

(18) Establishment of *seven computer centers for the common usages of academic circles in Japan* The proposal to establish the seven computer centers in Japan was prepared by our Committee and were accepted by the Japanese Government. (See Reference [31].)

(19) *The plan for establishing information science* in Japan was prepared by the Subcommittee associated with the Committee enunciated in (13). The present author was the chairman of the Subcommittee and was responsible to prepare a draft plan which was completed in 1965, August. (See Reference [31].) The seven items (13)～(19) just mentioned had mutually intimate connections among them. From the standpoint of the present paper these can be shown in the following Figure 3.

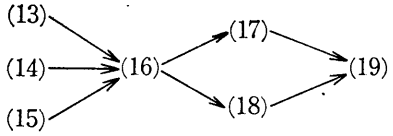

Fig. 3. The connections of the works leading to an introduction of the idea of information science

[4] *From statistical sciences to information science during the period 1963~1968*

(20) It was the first international opportunity for the present author to speak about our idea of *information science and its implications to statistics* when he published his paper on the occasion of the 1965 Berkeley Symposium on Mathematical Statistics and Probability. (See Reference [32].) Within Japan the present author found himself to be involved in an intensive promotion of researches on information science in Japanese academic circles and industrial communities. There had been certain circumstances which strongly supported the scientific voluntary adventure of the present author, which is now enunciated in what follows:

(21) *The way leading to information science* In early 1963 many scientists coming from various sciences in Kyushu University including T. Kurihara (Computer Science), H. Shimizu (Mechanical Engineering), M. Kuwabara (Biology), Y. Shibuya (Physics), M. Takada (Mechanical Engineering), and the present author initiated an informal committee meeting to discuss their common scientific interests and found that there is a new scientific research area which they might call "information science" (Joho Kagaku) in which their common interests can be concentrated. For the present author himself, it was the cybernetics due to N. Wiener which gave him a prototype of what we called information science. The situation looked like to be a mountain climbing in which many different routes leading us to the summit existed. The names of these different routes were (i) Control Science, (ii) Statistical Science, (iii) Biological Science, (iv) Computer Science, (v) Linguistics. and (vi) Management Science. Each group in each of these different routes had a set of mutually different terminologies. However, as they climbed up near the summit so as to find the existence of other groups and to be anxious to talk together with other groups, it became essential to identify what was the summit and what should be their common terminologies in order to justify their scientific area and to cooperate with each other in cultivating the area where they had

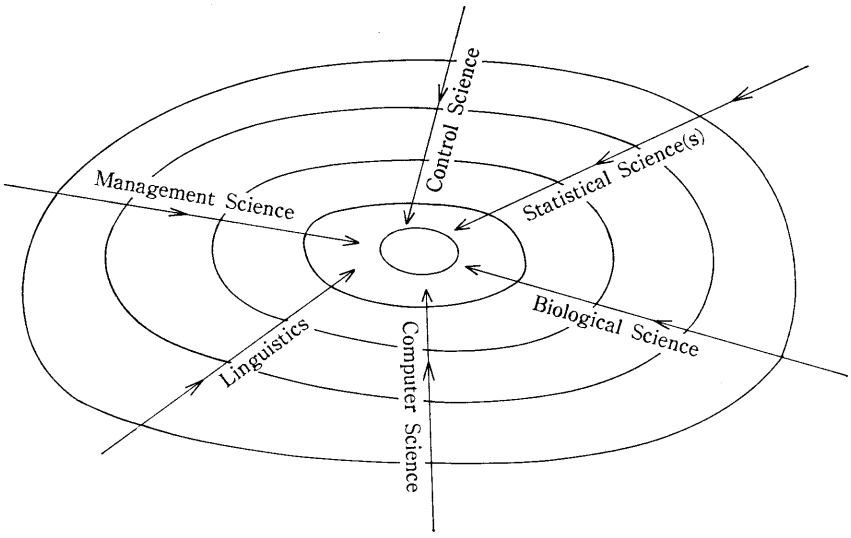

Fig. 4. Six different routes by which to attain the summit called 'information science'

reached. The situation of their understanding may be illustrated in the foregoing Figure 4. (See Reference [33].)

(22) *The location of information science* In our understanding, information science was broader than cybernetics in the sense of N. Wiener, and rather resembled with kibernetica in the USSR in the real converages of research areas. The location of information science can be illustrated in following Figure 5. (See Reference [33].)

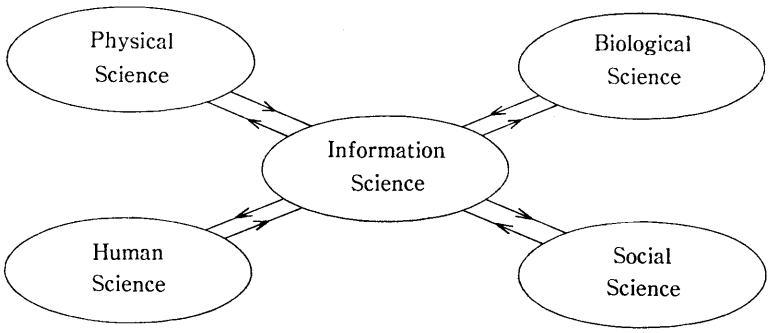

Fig. 5. Location and connection of information science among global classification of sciences

The interrelationship among the four items are shown in the following Figure 6.

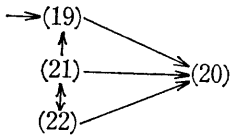

Fig. 6. The impulse to movement of information science in 1963

In fact the item (21) was a crucial step to the birth of information science in Japan.

5. Establishment of Information Science in Japan

This section consists of five Subsections 5.1~5.5. In Subsection 5.1 the efforts of the present author to construct theoretical foundations for information science and its kernel informatics will be explained. Subsecttion 5.2 is devoted to describe what have been realized in Japanese academic communities in building up a citzenship for information science. Subsection 5.3 gives three basic research strategies for promoting informatics. Subsection 5.4 is concerned with the specific research areas with which the present author has directly concerned in order to implement his ideas of basic research strategies enunciated in Subsection 5.3. Subsection 5.5 shows the interrelationship among the achievements explained in these four Subsections 5.1~5.4. In Subsection 5.5 the specific connections between statistical sciences and information science at the present time are explained.

5.1 Theoretical foundation for information science

(23) *Logics of information science* It was indeed a matter of our serious concern to make clear some logical foundation for our newly established science called information science. The present author presented an approach for this purpose in a monograph in Japanese [34] as well as in his paper [35]. His idea in these publications was based upon three coordinate system for information science, which consists of (I) structure subspace, (II) function subspace, and (III) feasibility of existence subspace. Each of the two subspaces (I) and (II) consists of their respective three coordinate axes such as (I_i) $(i=1, 2, 3)$ and (II_j) $(j=1, 2, 3)$ respectively:

(I) Structure subspace has three coordinate axes called (I_1) subjectivity, (I_2) objectivity, and (I_3) practices.

(II) Function subspace has three coordinate axes called (II_1) cognition (II_2) direction and (II_3) evaluation.

On the other hand we set (III) as follows:

(III) Feasibility of existence subspace is divided into three subspaces called (III_1) control, (III_2) eizon (new Japanese word), and (III_3) creation.

It is to be noted that for the present author, who had come to information science from statistical sciences, the three coordinate system in information science has an intimate connection with the logical principles upon which he had formulated statistical inference and control processes in his paper [21] already mentioned in the paragraph (5) of Section 4.

(24) *Informatics as the kernel of information science* In European communities there had been prevailing the terminology 'informatics' which was more frequently adopted there than 'information science'. The present author had in 1978 an opportunity to present his paper [36] in which his understanding about the difference between informatics and information science was shown by pointing out three aspects:

(i) Informatics aims to be a kernel area in information science in the sense that it should be a minimal, sufficient self-conservative assemblage of knowledge in the latter which is more or less an assemblage of interdisciplinary areas as explained in [33].

(ii) Informatics aims to be autonomous knowledge system in information science by establishing an intelligible field of knowledge based upon a set of fundamental principles.

(iii) Informatics aims to be an integration of various approaches in information science. (See Reference [33].) In his paper [36] the present author gave a theoretical foundation of informatics in which its scientific roles in connection with computer science can be adequately reflected. The paper [36] proposed three basic research strategies for promoting the developments of informatics, and then gave a retrospective review of the own works due to the present author in the area of theoretical informatics with reference to surrounding sciences being shown in the following Figure 7.

5.2. Building up the academic positions of information science during the period 1966~1980

The following nine items show how far and in what manner the foundation of information science was built up in Japanese academic circles during the period of her

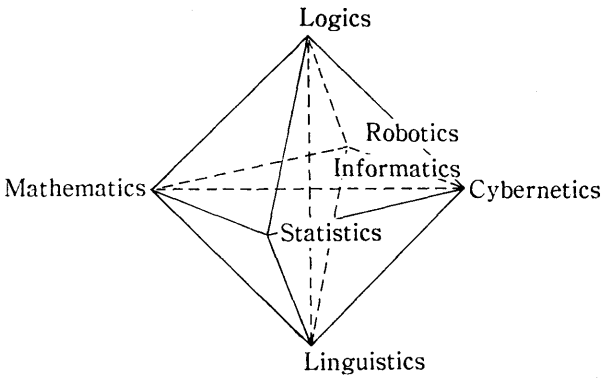

Fig. 7. Basic sciences surrounding informatics in its nearest neighbourhood

econmic development 1966～1980.

(1°) The Information Processing Society of Japan (IPSJ) was established in 1960, and had a membership of 15,786 as of July, 1981.

(2°) Three research institutes of information science were built up in Kyushu University (1967), Tohoku University (1967) and University of Tokyo (1969), among which the last one has been convered to Information Science Department and the other two have continued their activities as such.

(3°) Large scale computer centers for national academic use in universities were established between 1965 and 1971, in Tokyo (1965), Kyoto, Sendai and Osaka (1969), Fukuoka, Sapporo (1970) and Nagoya (1971).

(4°) The establishment of computer departments or information science departments in various universities amounted in 1981 to (i) 33 Bachelor degree granting departments, (ii) 167 professorship, (iii) three large division systems and 25 Master/Doctoral degree granting departments. The undergraduate program grants more than 1,900 degrees per year.

(5°) Three Special Research Projects called (a) 'Foundation of Information Processing', during the period 1970～1972, (b) 'Advanced Information Processing of Large Amounts of Data Over a Broad Area', during the period 1973～1976, and (c) 'Formation of Information System and Organization of Scientific Information', during the period 1976～1980, were sponsored by the Ministry of Education, Science, and Culture under the scheme of the Science Research Grant System. Many professors and research workers in departments of computer science or information science as well as scientists working in various fields such as mathematics, statistics, physics, chemistry, geology, biology, medicine, engineering, social science and humanities in universities joined in these Special Research Projects. (See Reference [37]～[42].)

(6°) The University called Joho Toshokan Daigaku was established in 1978 for promotion and fostering research and education in the area of information and library science.

(7°) The Lecture Series "Joho Kagaku" (Information Science) was initiated in 1966 with the intension of publishing sixty two volumes which has still in continuation,

while the other Lecture Series Joho Shakai Kagaku " (Social Information Science) started in 1968 and was completed in 1979 with eighteen volumes in total.

(8°) IPSJ has published a series of Information Processing Handbooks in Japanese whose new edition (1980) amounted to 1,166 pages. The present author served as the Chairman of Editorial Committee nominated by ISPJ.

(9°) The last but not the least important progresses had been realized during these fifteen years in the systems of information processing education at various levels of primary, secondary, high shool and university levels.

It is noted that the items (2°), (3°), (4°) (5°) and (9°) can be realized as realization of the proposals presented in the Planning for Information Science by the Subcommittee of Information Science 1965, which was associated with the Long Range Research Planning Committee in the Science Council of Japan.

5.3. Three basic research strategies in promoting informatics and their implementations

(25) The present author proposed *three basic research strategies (BRS) in promoting informatics*, which read as shown in his paper [36]:

Basic Research Strategy (1), *BRS* (1) Five research axes B-(Ⅰ), B-(Ⅱ), B-(Ⅲ), B-(Ⅳ) and B-(Ⅴ) are set up by which to form consolidated research vlew spaces where any problem in informatlcs can be and should be formulated:

B-(Ⅰ) Information processing process (P)

B-(Ⅱ) Space of informative loglcs (S)

B-(Ⅲ) Expression forms of information and language systems (E)

B-(Ⅳ) Levels of intelligence (L)

B-(Ⅴ) Equilibration and genesis in information phenomena (G)

Basic Research Strategy (2), *BRS* (2) The emphasises are placed on the following three interrelationship:

(i) Interconnections among sciences in global classificatlon (See Figure 5.)

(ii) Theoretical informatics and its surrouncing sciences (See Figure 7.)

(lii) Fostering cooperations ln connection routes shown in the following Figure (See Figure 8.)

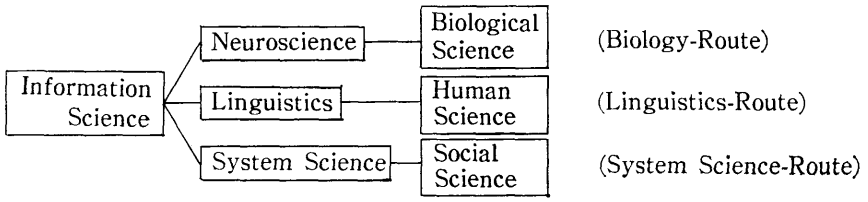

Fig. 8. Fostering cooperations in the three connection routes called B-R, L-R and S-R.

Basic Research Strategy (3), *BRS* (3) We should employ a systematic investigation of research trends in informatics by appealing to i) coordination of individual researches and ii) objective understanding of research trends, and then we should endevour to appeal to abductive procedures of creative science to find out future directions of

researches in information science.

5.4 Implementation of basic research strategies for informatics

The following two Subsections 5.4.1 and 5.4.2 are devoted to explanation how far and in what way two basic research stratigies BRS (2) and BRS (3) have been implemented in the researches of the present author respectively, while the basic research strategy (1) (BRS (1)) has been realized throughout all of them.

5.4.1 Basic research strategy (2), (BRS (2))

(a) The connection route between information science and biological science (abbreviated by B-R) is vital, since information and life are so initimately connected that no life can exist without information and no information can exist without life. Early in the seventies the present author began to work in the following three areas belonging to the route:

(26) *Cell space approach in biomathematics* (See References [43], [44].)

(27) *Neural dynamics approach* (See References [45]~[49].)

(28) *Ethological considerations* leading to the *formulation of local spaces in biological existences* (See References [50], [51].)

It is noted that these works are concerned with the formulations of mutually interrelated existences through the exchange of information.

(b) The connection route between information science and system science (abbreviated by S-R) is also essential since there exist various vital problems to be investigated deeply. The topics which the present author treated were as follows:

(29) *Control processes in large systems* (See Reference [52].)

(30) *Fuzziness in informative logics* (See Reference [53].)

(31) *System science approach to the methodology of futurology* (See Reference [54].)

(32) *Formation of information system and organization of scientific information* (See References [40], [41], [42].)

The topics (32) had lead the present author to various key notions which seem to be crucial to develop theoretical informatics.

(33) *Brainware of the types* (1) *and* (2) (BRW (1) *and* BRW (2)) (See References [55]~[58].)

(34) *Knowledge information processing system (KIPS) and its nine component representation.* (See Reference [59].)

(35) *Datalogy* in close connection with statistical inference processes. (See Reference [60].)

(36) *Generalized artificial grammar* in deaiing with scientific information system. (See Reference [61].)

(37) *Generalized relational ecosphere based upon paired multiple morphisms.* (See References [62]~[64].)

(38) *Generalized relational ecosphere of (distributed) knowledge information processing systems* (GRESKIPS). (See References [64], [65].)

(c) The route between information science and linguistics (abbreviated by L-R) has been realized to be crucial in computer science. From the standpoint of the present author who has been proposing the four levels of intelligence, (H) human, (B) biological, (M) mechanical and (S) social, the interrelationship can be duly undeerstood by intro-

ducing various generalized artificial grammars to which programming languages in computer technologies can be located as examples. It is quite natural to the present author to enter into semiolgy which will hopefully serve to formulate generalized artificial grammars in a unified approach, as was indicated in the following

(39) *Datalogy* in establishing knowledge-information processing systems. (See Reference [60].)

(40) *Semiology* in establishing knowledge information processing systems. (See Reference [60].)

5.4.2 Basic research strategy (3), (BRS (3))

There was the Division in the scheme of the Special Research Project (c) mentioned whose aim was to develop a systematic methodology by which to find out research trends in specific research areas. Several methods have been developed by several research workers belonging to the Division, as can be observed in Tanaka, H. and Nikkuni, M [66]. The present author contributed a method for this purpose:

(41) *Generalized relational ecosphere applied to analyze the research trends* in the areas of statistical inference and control processes. (See Reference [67].)

5.5 The interrelationship among the achievments (20)~(40) explained in the four preceeding Subsection 5.1~5.4.

This is given in the following Figure 9 in which the sources are the important items (20), (25) and the destinations are (38)~(41), while the item (37) is crucial as an intermediate situation. These facts imply, so far as the research routes of the present author are concerned, (i) that the logic of informatics (20) and the three basic research strategies BRS (i) (i=1, 2, 3) involved in (25) are essential, (ii) that generalized relational ecosphere with paired multiple morphisms plays a unified role in synthesizing various approaches, and (iii) that (39) datalogy, (40) semiology, (41) research trend analysis, and

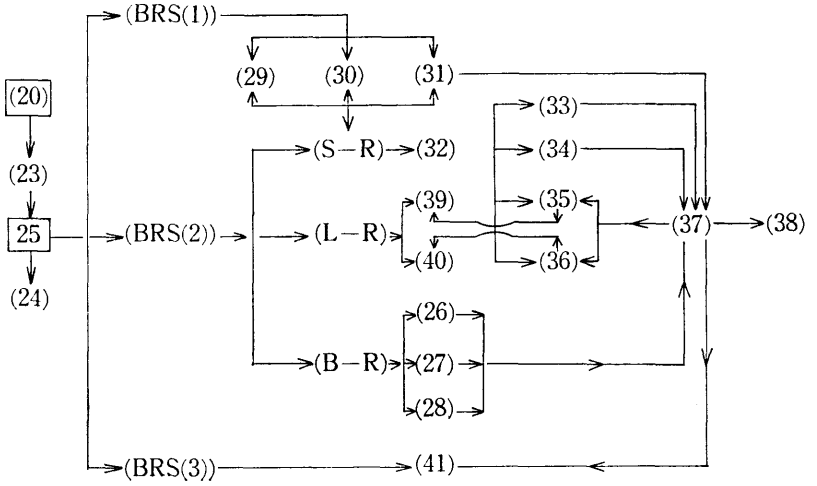

Fig. 9. Directed graph representation of the interrelationship among the achievements (20)~(41) explained in the Subsections 5.1~5.4.
BRS=Basic Research Strategy; S-R=System Science Route: L-R=Linguistics Route; B-R=Biology Route.

(38) generalized relational ecosphere of knowledge information processing systems are shown to be important items for further investigation.

5.5 Connections between statistical science and information science

After having experienced the developments of information science in the last fifteen years, we are now in a position to review the new features regarding connections between statistical sciences and information science. On one hand statistical sciences can and should introduce some of newly established concepts in information science such as we have referred in the last four Subsections 5.1～5.4, simply because statistical information is one of the special informations which belong to the general framework of information being treated in information science. On the other hand some of the urgent problems in information science can and should be discussed with the aid of methodologies and techniques having been developed in statistical sciences. Here we want to point out the two specific examples to illustrate them.

(42) *Computational statistics* being developed by Ch. Asano, K. Wakimoto, T. Shohoji, M. Goto, K. Jojima and others in the form of the NISAN (New Interative Statistical Analysis) system. (See References [68]～[71].)

(43) The implications of statistical inference process approach to *knowledge engineering* which is instrumental in implementation of generalized relational ecosphere of knowledge information processing systems. (See References [61]～[65], [67], [72].)

The direct interrelationship between statistical sciences and information science can be observed by the following Figure 10.

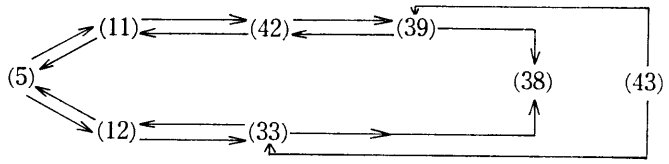

Fig. 10. Connections between statistical science and information sciences viewed from statistical inference process and knowledge engineering via datalogy

6. Problems, Missions and Methods—Prospect of the Idea of Generalized Relational Ecosphere

We shall summarize the present paper by giving our prospects regarding problems, missions and methods of statistical sciences in the last twenty years as well as in the coming twenty first century.

[1] *Problems* We have to be clearly conscious of the global problems in front of us which are concerned at least with the following three items.

(1°) There is a crucial requirement for human societies in globe to be conscious of the serious problems of population growth, foods, material resources and environments. These problems can not be solved without establishing a realistic implementation of the idea of human society in globe including space colony, which every nation should join in cooperating to solve the common problems in our globe.

(2°) The developments of information oriented society should be expected which

will carry with it various revolutions to our existing societies.

(3°) The political and economical conflicts, one between the east and the west and the other between the north and the south, will become more and more serious and require adequate and systematic solutions in which integration and even amalgamation of various cultures in the world should become one of basic effective strategies to be realized in the coming era.

Some of these problems have been already presented by various contemporary authors, such as G. Myrdal [73], C. H. Waddington [74], H. Kahn [75], A. Toffler [76], J. J. Servan-Schreiber [77] for example, since the last decade. It seems to the present author that recent social issues have been concentrating to a few crucial aspects such as mentioned just now.

[2] *Missions* Statistical science has some responsibility to contribute to solving the problems enunciated in the preceeding paragraph [1], as every other science does have, more or less, directly or indirectly, their own responsibility in this respect. Looking back the three origins of statistics, the German Academic School, the British School of Political Arithmetics, and the French School of Theory of Probability in the seventeenth and the eighteenth century, statistics since its establishment has had the self-consciousness of its responsibility, and it has continued to fulfill its responsibility during the whole history ranging more than three and half centuries until the present time. In this connection we remind of two sentences which has impressed the present author by their direct communication to him. "Statistics must have a purpose" (P. C. Mahalanobis, February 1956). (See Reference [78].) "The essential role of statistics lies in its function of fact finding" (R. A. Fisher, January, 1958). (See Reference [12], p. 48 ~49). These two phases are not simple to be amalgamated in one sentence. In surface these two phases do seem to be even contradictory. Nevertheless statistician ought to find his specific roles and his methodologies in synthesizing these two phases. In this sense, in view of recent development of statistical sciences and information science, we are required to endevour an exploration of methodologies in fulfilling our responsibilities just enunciated in this paragraph.

[3] *Exploration of methodologies* There are several characteristic features which should be emphasized in statistical sciences in the coming era in connections with influences from and to information science. We shall briefly summarize these in the following five points.

(1°) Statistics, information and knowledge should be connected with each other by firm and penetrating understanding based on a modernized deep epistemology which is certainly required for the coming information oriented or knowledge society.

(2°) In the cooperation with information science, statistical sciences should be and can be reinforced by developing datalogy and semiology which will be developed in the authentic realm or at least in the vicinity of information science.

(3°) One of the most powerful contributions from information science and technology to solve various problems enunciated in the paragraph [1] and hence to fulfil the sicentific and technological responsibility is a systematic construction of various information processing systems in human activities. In the present time there have been already some proposals to build up distributed knowledge information processing

systems which require a consolidation of various advancements in knowledge information processing technologies covering artificial intelligence and knowledge engineering and also those in network system of computer, control and communication. Any realization of such proposals will lead us to the needs for combination of two sciences, information science and statistical sciences in a deeper and more intimate cooperation than it has been until now.

(4°) As we have mentoned in the logics of information science, we have to be concerned not only with control, but also with eizon and creation as well. Statistical sciences had been so much closely connected with various planning works until the sixties of this century. Thus the various methods of economic planning being based upon econometric approaches resembels a form of mathematical programming in operations research in which statistics could and should provide a set of parameters being required in model describing of the reality. In quality control the role of statistical sciences can be observed by statistical control processes. Nevertheless there has been already pointed out by many authors including the present author the other aspects of our attitude for keeping our feasibility of existence besides control. These are nothing but eizon and creation in the terminology of the present author [34], [35]. From the standpoint of informatics, it seems quite understandable to have these three aspects of our attitude for keeping our feasibility of existence: control, eizon and creation. Now looking back our statistical sciences, the emphasis of their role in fact finding is rather concerned with eizon, while from the standpoint of emphasizing their role in pursuiting our purpose, we have to refer to control and creation as in our publications [34], [35].

(5°) The most essential features of informotion-oriented society leading to knowledge society will be realized in a shift of our attitude from the present confrontation between freedom and planning to a synthesis in the sense of realization of creation and participation. We may anticipate a new classification and a new creations of sciences in terms of knowledge information processing systems which, at the same time, will give us suggestion where and how statistical science and information science should work in the coming era in order to cope with the developments of other sciences and to fulfill their own responsibilities in solving the problems in the coming era. It is noted that the present author has been developing a theory of generalized relational ecosphere in a series of his papers [50], [51], [61]~[65] with a clear consciousness of the responsibilities just enunciated. Social implications are discussed in References [79]~[81]. It is also noted that the bibliographic descriptions of the present authors are given in Reference [18], [81]. The two recent monographes [82] and [83] describe the viewpoints of the present author in dealing with the topics being discussed in this section. In view of the technological innovation now being in progress in Japan, a more detailed discussion can be found in the articles of the present author being presented in Reference [72], [84].

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