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RESEARCH IN NETWORK, LINEAR GRAPH, AND COMMUNICATION NET THEORIES IN JAPAN

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Abstract

This report introduces some research groups in Japan that are in the fields of network, linear graph and communication net theories. In the Hokkaido and the Tohoku Universities, the groups are researching the synthesis of networks consisting of n-wire lines. In the Yamagata University, analysis of electrical networks by linear graphs is studied. In the Tokyo Institute of Technology, network synthesis is very active. Communication nets are studied in the Electrical Communication Laboratory and the Electrotechnical Laboratory. The filter design group is active in the Nippon Electric Co. Network theory is a very popular research subject in the Osaka University and the Kyushu University.

Introduction

This report is to introduce research in the network, the communication net, and the linear graph theories in universities and laboratories in Japan which I visited last Fall. The research groups reported here are a few among the active groups in these fields in Japan. Some of the active groups which are not introduced here are Dr. S. Hayashi's group in Kyoto University, Mr. R. Matsuoka's group in the Oki Electric Co., Dr. H. Hirayama's in the Waseda University, Mr. Y. Okada's in Hitachi Ltd., Dr. G. Yazaki's in the Fuzi-Tsuu Co., and Dr. K. Kondo's in the University of Tokyo, etc.

This report excludes all research groups in the field of non-linear systems such as Dr. C. Hayashi's group in the Kyoto University.

Technical Group on Circuit Theory

The Institute of Electrical Communication Engineers (IECE) in Japan corresponds to the IEEE in the U.S.A. and the Technical Group on Circuit Theory (TGCT) in IECE is the PGCT in IEEE.

The Chairman and the two Secretaries of TGCT are:

Chairman: Prof. H Ozaki
Dept. of Electrical Engineering
Osaka University
Higashinoda, Miyakojima-ku
Osaka, Japan

Secretaries: Dr. H. Watanabe
Nippon Electric Co.
Shimonumabe, Kawasaki, Japan

Prof. T. Yanagisawa
Dept. of Electronic Engineering
Tokyo Institute of Technology
Meguro-ku, Tokyo, Japan

I have been informed that the Chairman and the Secretaries of TGCT are willing to give any assistance whenever needed. It is highly possible that you can obtain an English-translated paper which has been published only in Japanese by asking for it from either the Chairman or the Secretaries of TGCT.

Research in Northern Japan

A network theory group led by Dr. A. Matsumoto in the Department of Electrical Engineering, Hokkaido University is studying networks consisting of distributed elements such as coaxial lines and shielded n-wire lines.

When a network is synthesized with basic sections in cascade by the Darlington procedure, these basic sections can be classified according to the location of transmission zeros as follows: A section, that has a transmission zero $\lambda_0 = \sigma_0$ on the real positive axis of the λ-plane (where λ = tank $\gamma \ell$ with propagation constant γ and length ℓ), is called a type C section. A section which has a pair of transmission zeros $\lambda_0 = \sigma_0 \pm j\omega_0$ in the right half plane is called a type D section.

A. Matsumoto shows that a type C section can be realized by a hunk of two-wire line if the transmission zero σ_0 is greater than one. When σ_0 is less than one, he can show that an ideal transformer will be necessary. Furthermore, he shows that a Brune section itself cannot be made by the use of a two-wire line alone, but if it is accompanied by an ideal transformer, the section may be realized with a two-wire line with an ideal transformer connected at the far end. When a three-wire line is employed, he can synthesize a type C section as well as a Brune section by a single three-wire line.

The synthesis of multiport networks with multi-wire line, a type D section with two lengths of two-wire lines, and a bandpass filter with multi-wire lines are also studied by A. Matsumoto and his network theory group. The group is also interested in the synthesis of filters containing crystals.

There are two groups in the Tohoku University who are doing research in the network theory area. One is led by Dr. Z. Kiyasu and the other is under Dr. R. Sato. Kiyasu's group is analyzing a transmission line containing tunnel diodes. When tunnel diodes are properly distributed in a transmission line, whether a pulse can be transmitted by the line depends entirely on the height of the pulse. Several interesting theoretical and experimental results have been obtained which will be published soon.

Richards' theorem is known as a key theorem for network synthesis. Let

[Y(S)] be a positive real matrix for an n-terminal pair matrix. Dr. N. Saito in R. Sato's group extends Richards' theorem into an n-terminal pair network by which he develops an interesting method of synthesizing n-terminal pair networks.

N. Saito also studies coupled transmission line filters and obtains a design process for filters by extracting coupled lines from a prescribed admittance matrix. The insertion loss functions used in the design of these filters are similar to those used on the design of lumped constant filters.

An interesting result given by N. Saito and K. Saito is as follows: Necessary and sufficient conditions that a given admittance [G] is a wave admittance of a multi-line is that [G] is non-singular hyperdominant.

The papers "Node Analysis of a Three Conductor Transmission Line by Transforming the Characteristic Resistance Circuit" and "Design of UHF Filters" are the results of the continuous studies in multi-line networks by this group.

In the Yamagata University, Professor R. Onodera has taught application of linear graph theory for a long time. This course is for M.S. candidates and uses a monograph written by him as a textbook. This monograph is written as follows: In the first chapter, definitions and properties of cut sets, circuits, and trees of the non-oriented graphs are given. The properties of cut set and circuit matrices of non-oriented graphs are given in Chapter 2. Chapter 3 gives the definitions and properties of cut sets, circuits, trees, circuit matrices and cut set matrices of oriented graphs. In Chapter 4 he discusses a way of obtaining a circuit and a cut set matrix of a modified graph which is obtained by shortening and opening edges of a given linear graph, directly from a circuit and a cut set matrix of the given linear graph.

The remaining monograph shows how to analyze electrical networks by the use of linear graphs. He gives not only topological formulas for passive electrical networks without mutual couplings, but also a way of replacing part of an electrical network by an equivalent network topologically.

Dr. R. Onodera and his group are studying to improve methods of network analysis by linear graphs.

System Theory Research in Tokyo

In the Tokyo Institute of Technology, Professors in the Department of Electronics (where Dr. M. Kawakami is the head of the department) and in the Research Laboratory of Precision Engineering are very active in the research of system theory.

The elimination of ideal transformers in the Brune process has been studied by Dr. F. Miyata. The primary feature of Miyata's method of synthesis is the use of lattice sections instead of ideal transformers. The properties of networks whose configurations are symmetric (or antimetric) are being investigated by M. Kawakami. This research strongly bears on the problem of establishing a simple method of realizing symmetric transfer functions.

In the field of transmission-distortion caused by networks, numerous sets of curves for transient responses of conventional filters have been completed by Dr. G. Kishi. Performance of some variable networks has been investigated by Dr. M. Sagawa.

A design method for delay networks based on their time performance has been established by Dr. M. Onoda. Dr. H. Shibaya studies a tolerance problem of mechanical filters. Dr. G. Kishi studies tolerance problems from the reactive energy point of view.

Dr. T. Yanagisawa is interested in active network synthesis with negative impedance converters. He has found useful configurations for the practical realization of negative impedance converters. His current interest is theoretical considerations of the physical realizability of negative elements. A practical application of a negative capacity has been studied by Drs. M. Kawakami and M. Onoda. A simplification problem of logical functions, especially in terms of majority elements, has been studied by Drs. F. Miyata and Y. Tohma.

In the Electrotechnical Laboratory, Dr. Y. Komamiya and his group are interested in system theories. M. Takagi shows a method of changing a job assigning problem to a minimum distance problem of linear graphs as follows: Let M_j $(j = 1,2,...,n)$ be the available machines. In order to accomplish a job J_i, the machines $M_1(t_1)$, $M_2(t_2)$ and $M_p(t_p)$ must be used in the sequence where t_r in $M_r(t_r)$ represents the time required to use machine M_r. The problem is that for a given set of jobs J_i each of which is specified by a sequence $M_{p_1}(t_{p_1})$, $M_{p_2}(t_{p_2}),...,$ $M_p(t_p)$, how we can obtain a minimun required time in which all of these jobs are accomplished. M. Takagi's method is to change the set of jobs to an oriented graph with a proper weight on each edge so that the minimum distance between two fixed vertices is the minimum required time to accomplish these jobs.

In the Nippon Electric Company, a network theory group under Dr. M. Koga is interested mainly in the filter design. Dr. H. Watanabe and others wrote a computer program to analyze and to synthesize filters; feeding the structure of filters which are to be analyzed into a computer is accomplished by defining symbols to indicate parallel and series connections and by using these symbols as operators. Thus, with parentheses, any series-parallel structure with respect to input (and output) terminals can be given to a computer very easily. Furthermore, because of this restriction on the structure of filters, the computer time for analyzing such filters is very fast.

Dr. H. Watanabe's papers "Approximation Theory of Filter Networks" and "On the Synthesis of Conductive n-port with n + 2 Nodes" show his wide interest in network theory.

In the Electrical Communication Laboratory (Nippon Telegraph and Telephone Public Corporation), Dr. M. Yokoi's group is studying linear graph theory and applications of linear graphs to communication nets. Y. Nakamura gives a method of synthesizing a communication net consisting only of circuit-elements, under a minimum cost contraint, so that there exists at least one path between any two vertices if any one edge in the net is removed. Because of the objective of the research in this Laboratory is to improve telephone and telegraph systems, this group's interest is toward multicommodity problems.

System Theory Research in Southern Japan

The group in the Osaka University led by Dr. H. Ozaki is very active in network synthesis, which can be seen by the publications "Synthesis of ± RLC Ladder Networks", "Necessary and Sufficient Conditions for RC Transfer Functions", "Theoretical Approach to Linear Passive Systems", "Approximation Problems in RC Network Synthesis", "Synthesis of Symmetric RC 3-terminal (Unbalanced 4-terminal) Network Without Ideal Transformers", "Synthesis of RC Transfer Functions", etc.

Drs. H. Ozaki and T. Kasami study variable linear networks, that is, they consider a network with two kinds of elements whose values are variable in the same sense as Levenstein's circuit elements. Then it is possible to give a concept of several-variable positive real functions which leads to the problem of variable-parameter networks.

Dr. T. Fujisawa, who introduced lossy communication nets, is also in the group and there are several graduate students who are interested in the theories of communication nets and linear graphs. One interesting problem which they are studying is to find a condition that a graph is a subgraph of an n-cube.

The paper "On Simultaneous Flow Requirements" gives a method of synthesizing a communication net which satisfies simultaneous flow requirements at minimum cost by the use of an equivalent electric network.

A network theory group in the Kyushu University under Dr. Y. Oono is active in network synthesis and the theory of communication nets.

A method of synthesizing a 2n-terminal network by means of scattering matrices is given by Y. Oono and K. Yasuura, in which all equivalent networks are classified and the minimum number of elements excluding ideal transformers are determined. According to Y. Oono, two positive real functions Z_{10} and Z_{1s} can respectively be realized as the open circuit and the short circuit driving point impedances of a passive two-port, if Z_{10} is an odd function.

T. Koga can show that any two-variable reactance matrix $W(\lambda,\mu)$ of order n can be decomposed into the sum of two-variable reactance matrices $W_i(\lambda,\mu)$ for $i = 1,2,\ldots,\rho \leq n$ each of which can be realized as an impedance matrix of a non-bilateral passive n-port. T. Koga has also studied to minimize ideal transformers when a multi-port network is synthesized. He found a method of removing ideal transformers whenever there is a possibility of removing them from a multi-port network.

Dr. S. Amari has been studying Kron's dinkoptics and Onodera's codiakoptics. He is also investigating properties of communication nets. One of his interesting results is as follows: A net consisting of continuous communication channels is treated under noises given to the edges of the net. The structure of a net of this kind which maximizes the output signal-to-noise (SN) ratio can be obtained. An interesting property is that the optimum SN ratio does not change when an edge is replaced by another edge having the same characteristics but different orientation.

In practical communication systems, it is clear that the characteristics of information transmission are largely affected by signal transformations such as encoding-decoding, statistical signal extraction, bandwidth compression, etc. Dr. S. Amari gives a theory concerning transmission of continuous signals in the presence of noise disturbances, with the aid of the geometrical consideration of information theory.

Acknowledgment

The author wishes to acknowledge the researchers appearing in this report, who spent a considerable amount of time explaining their research.

Because of the author's background, some research areas in some groups are explained more than the others. However, the author has no intention of emphasizing activities in one research group more than others.