Human and Artificial Intelligence Systems

From Control to Autonomy

The Proceedings of the Fourth International Symposium on

Human and Artificial Intelligence Systems

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Preface

This volume contains the collection of papers presented in the Fourth International Symposium of Human and Artificial Intelligence Systems (HART2004): From Control to Autonomy, held in Fukui, Japan, on the 5th and 6th of December in 2004. The contributions include eight articles and abstracts written by the distinguished guests invited for keynote speeches and special lectures, and eighty-one papers submitted for presentation. All the submitted papers, including the ones for organized sessions, were reviewed by at least two anonymous referees, and revised by the authors when required. In addition, an article by Professor Toshiyuki Asakura, Univ Fukui, is included since in this Symposium the intelligence in stochastic dynamical behavior were discussed specially to dedicate his achievements on the occasion of his retirement.

The Symposium was composed of Keynote Speeches, Special Lectures, Oral Sessions, and Demonstrations. We were very honored to have keynote speeches by Drs. Fumio Harashima, Inman Harvey, Toshio Fukuda and Lakhmi C. Jain, and special lectures by Drs. Kunishiko Fukushima, Koji Ito, Kosei Demura and Takashi Gomi. And also, we were very honored to receive nearly 100 submissions and to have more than 300 participants, the numbers that are remarkable as a Symposium organized by a department of a university, not by nation-wide academic societies.

This series of Symposia have been organized by the faculty members of the Department of Human and Artificial Intelligence Systems at University of Fukui every two years since 1998. The plenary lectures have been open for public and characteristic to this Symposium. The lectures are simultaneously translated in Japanese, so that engineers and executives from industries can understand well. Electronics and Machinery as well as Textile and the materials are major industries in Fukui area, and the symposia have obtained worm support from them.

The First and Second Symposia consisted of only plenary talks by leading researchers. In the First Symposium held in 1998, Drs. Rodney Brooks (AI Lab., MIT), Dario Floreano (EPFL, Switzerland), Takashi Gomi (AAI Inc, Canada), Inman Harvey (Univ. Sussex, UK), J-A Mayer (Paris, France), R Pfeifer (Univ. Zurich, Switzerland) gave superb public lectures on the New Artificial Intelligence. In the Second Symposium in 2000, Drs. Takanori Shibata (JAIST, Japan), D. Floreano, and T. Gomi talked on co-habituation with robots.

In the Third Symposium in 2002, Drs. Stefano Nolfi (ISTC, CNR, Italy), Henrik H. Lund (Univ. N. Denmark), Tetsuya Higuchi (JAIST), Robert E. Shaw (Univ. Connecticut), Toshio Fukuda (Nagoya Univ.), Yoshishiko Nakamura (Univ. Tokyo), Masato Sasaki (Univ. Tokyo), Ezequiel A. DiPaolo (Univ. Sussex), Sung-Bae Cho (Yonei Univ., Korea), Md. Monirul Islam (BUET, Bangladesh), Prahlad Vadakkepat (Natl Univ. Singapore), N. Chaiyaratan (King Mongkut Univ., Thailand), T. Gomi and D. Floreano were invited to give lectures on Dynamic Systems Approach for Embodiment and Sociality. In addition, a poster session consisted of submitted papers was organized and more than 50 papers were presented. The book of proceedings was published from the Advanced Knowledge International, Australia, with the great help by Professor Jain.

In this Fourth Symposium, the number of submissions increased dramatically, and subjects related to the Department of Human and Artificial Intelligence Systems are very well covered. We like to thank all the participants for their efforts to come to Fukui and for their contributions. Finally we like to acknowledge the cooperation by the Center for Cooperative Research in Science and Technology, and Faculty of Engineering in University of Fukui.

December 5, 2004

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Invited Authors

(In Alphabetical Order)

Kosei DEMURA

Dr. Kosei Demura is an Associate Professor of the Human Information Systems Laboratory and the Department of Robotics at Kanazawa Institute of Technology (KIT) from 2004. He also serves as the Advisor of the Yumekobo RoboCup Project at KIT since 1999. He obtained a Dr. Eng. Degree in Computer Science from Keio University in 1996. After he worked as a Research Fellow of the Japan Society for the Promotion of Science in 1995-1997, he became an Assistant Professor of Human Information Systems Laboratory and Department of Human Information Science at KIT in 1997, and then promoted to an Associate Professor in 2002. He was a Visiting Scholar at the Massachusetts Institute of Technology, USA, in 2003. He has obtained a number of awards in RoboCup Middle Size League including the Vice World Champion at Fukuoka/Busan in 2002, All Japan Champion at Japan Open Niigata in 2003, Vice World Champion at Padova in 2003, Vice All Japan Champion at Japan Open Osaka in 2004, and Vice World Champion at Lisbon in 2004. He is presently interested in Cognitive Neuroscience as well as RoboCup.

Toshio FUKUDA

Dr. Toshio Fukuda graduated from Waseda University in 1971 and received the Master of Engineering degree and Dr. Eng. from the University of Tokyo in 1973 and 1977, respectively. Meanwhile, he studied at the graduate school of Yale University from 1973 to 1975. In 1977, he joined the National Mechanical Engineering Laboratory and became Visiting Research Fellow at the University of Stuttgart from 1979 to 1980. He joined the Science University of Tokyo in 1982, and then joined Nagoya University in 1989. Currently, he is a Professor of Department of Micro-Nano System Engineering and Department of Mechanical Science and Engineering, Nagoya University, Japan, mainly engaging in the research fields of intelligent robotic system, cellular robotic system, mechatronics and micro-nano robotics.

Dr. Kunihiko Fukushima is a full Professor at the School of Media Science, Tokyo University of Technology, Tokyo, Japan. He received a B.Eng. degree in electronics in 1958 and a PhD degree in electrical engineering in 1966 from Kyoto University, Japan. He was a professor at Osaka University from 1989 to 1999, and at the University of Electro-Communications from 1999 to 2001. Prior to his Professorship, he was a Senior Research Scientist at the NHK Science and Technical Research Laboratories.

He is one of the pioneers in the field of neural networks and has been engaged in modeling neural networks of the brain since 1965. His special interests lie in modeling neural networks of the higher brain functions, especially the mechanism of the visual system. He invented the "Neocognitron" for deformation invariant pattern recognition, and the "Selective Attention Model"; which can recognize and segment overlapping objects in the visual fields. One of his recent research interests is in modeling neural networks for active vision in the brain.

He received the Achievement Award and Excellent Paper Awards from IEICE, the Neural Networks Pioneer Award from IEEE, and so on. He was the founding President of JNNS (the Japanese Neural Network Society) and is a founding member on the Board of Governors of INNS (the International Neural Network Society). He serves as editors for many international journals.

Takashi Gomi was born in Tokyo in 1940. He obtained his M.Eng in 1964 from Waseda University in Electrical and Electronic Engineering and his D.Eng in 1997 from Hokkaido University in Complex System studies. After working at the University of Alberta, Bell Northern Research, and Atomic Energy of Canada, Dr. Gomi established Applied AI Systems, Inc. (AAI) in 1983 as a company dedicated to the research and development of intelligent system technology. The oldest specialty AI company in Canada and known widely in Japan, Europe, and USA, AAI conducts application research, intelligent system development including intelligent robotics, markets a wide range of AI and ALife products, and trains AI research engineers. Despite its small size of 18 people, the company is recognized as one of the top intelligent system R&D organizations in Canada. Since 1992 a series of projects has aimed at the transfer of behavior-based, or New, AI technology to government, business and industry. In October 1995 a Japanese branch was established. Dr. Gomi is a member of the IEEE's Service Robot Technical Committee.
Dr. Fumio Harashima was born in Tokyo in 1940. He has received B.S., and M.S. and Ph.D. degrees all in Electrical Engineering from University of Tokyo in 1962, 1964 and 1967, respectively. He was employed as Associate Professor at Institute of Industrial Science, University of Tokyo in 1967, and had been Professor from 1980 through 1998. He was Director of the Institute from 1992 to 1995. He was President of Tokyo Metropolitan Institute of Technology since April, 1998 through March 2002. He is currently Professor at Tokyo Denki University. He was also Visiting Professor at KAIST (Korea) for 2002-2003. Dr. Harashima was elected President of Tokyo Denki University with four-year term starting on June 15, 2004. Professor Harashima is Professor Emeritus of University of Tokyo since April, 2000.

His research interests are in power electronics, mechatronics and robotics. He is a co-author of four books and has published over 1,000 technical papers in these areas. He has been active in various academic societies such as Institute of Electrical Engineers of Japan, Instrument and Control Engineers of Japan (SICE), Robotics Society of Japan and IEEE. He has served as President of IEEE Industrial Electronics Society in 1986-1987, and 1990 IEEE Secretary. He served as Founding Editor-in-Chief of IEEE/ASME Transactions on Mechatronics in 1995. He also served as Editor-in-Chief of the IEEE Transactions on Industrial Electronics from 2000 through 2003. He was President of IEE of Japan in the year 2001-2002.

Dr. Inman Harvey has a background in mathematics, philosophy, anthropology and oriental carpet-dealing. For the last 14 years he has been researching in the Evolutionary and Adaptive Systems group at the University of Sussex, which he helped to found whilst pursuing a doctorate in the development of artificial evolution for design problems. This has lead to a series of projects in evolutionary robotics, where the 'brain' and other aspects of the 'body' of a robot are designed through methods akin to Darwinian evolution. Other applications of interest include evolvable hardware, and directed evolution of pharmaceutical molecules. Current research interests are in Homeostasis, Gaia theory, Neutral Networks in fitness landscapes, the design of an Autonomous Glider, and developments in Passive Dynamic Walking.
Koji ITO

Dr. Koji ITO was born in 1944. He received the B.S degree from Nagoya Institute of Technology in 1967, and the M.S. degree in 1969 and the Dr. Eng. degree in 1976 from Nagoya University. From 1970 to 1979, he was a Research Assistant at Automatic Control Lab., Faculty of Engineering, Nagoya University. From 1979 to 1992, he was an Associate Professor in the department of Computer and System Engineering at Hiroshima University. From 1992 to 1996, he was a professor in the department on Information and Computer Sciences at Toyohashi University of Technology. From 1993 to 1996, he was also held an additional post of head, Lab. for Bio-Mimetic Control Systems at RIKEN; Bio-Mimetic Control Research Center. Since 1996, he has been a professor in the department on Computational Intelligence and Systems Science, Interdisciplinary Graduate School of Science and Engineering, at Tokyo Institute of Technology. His main research interests are in the computational brain sciences, in particular, model and theory of motor control, and the design and control of robotics and prostheses. Dr. Ito is a member of SICE, RSJ and IEEE.

Lakhmi C. JAIN

Dr. L.C. Jain is a Director/Founder of the Knowledge-Based Intelligent Engineering Systems (KES) Centre, located in the University of South Australia. He is a fellow of the Institution of Engineers Australia. He has initiated a postgraduate stream by research in the Knowledge-based Intelligent Engineering Systems area.

He has introduced innovative educational techniques such as computer-aided learning programs directly associated with laboratory hardware. The concept of software system that he has developed is adopted in the book entitled: Handbook of Measurement Science, Volume 3, Elements of Change, John Wiley and Sons, U.K., 1992 (Chapter 41, Author: N. Hancock, pp. 1784-1786), ISBN: 0 471 922196. His academic output (authored/co-authored/edited/co-edited) includes research papers, books, book chapters, edited conference proceedings and edited special issues of journals.

He was the Technical chair of the ETD2000 International Conference in 1995, and Publications Chair of the Australian and New Zealand Conference on Intelligent Information Systems in 1996. He also initiated the First International Conference on Knowledge-based Intelligent Electronic Systems in 1997. This is now an annual event. He served as the Vice President of the Electronics Association of South Australia in 1997. His interests focus on novel techniques such as knowledge-based systems, virtual systems, multi-agent intelligent systems, artificial neural networks, fuzzy systems and genetic algorithms and the application of these techniques in education, health sciences, business, engineering and science.
Professor Toshiyuki Asakura

Mamoru MINAMI, Dr. Eng.
The Chair of the Executive Committee of HART2004
Professor, Department of Human and Artificial Intelligence Systems
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The International Symposium on Human and Artificial Intelligence Systems has been organized by the Department of Human and Artificial Intelligence Systems at the University of Fukui at every two years since 1998. The Symposia have been to enhance the development of new technologies in artificial intelligence systems in various aspects including robotics, dynamical systems, human interfaces, and new materials for robotics. Topics ranging from theory to application, and from software to hardware, have been discussed in synergy. The Forth Symposium HART2004 was held on December 5-6, 2004. In this Symposium, the intelligence in stochastic dynamical behavior were discussed specially to dedicate the achievements of Professor Toshiyuki Asakura at University of Fukui on the occasion of his retirement at the end of this school year on March 31, 2005, who has made significant contributions to the field of intelligent control, to the University of Fukui, and to the Department of Human and Artificial Intelligence Systems. It is my great honor to present you a brief introduction of Professor Toshiyuki Asakura.

1 Biography

After graduating and starting his academic carrier as a research assistant at Kyoto Institute of Technology, Prof. Toshiyuki Asakura has been researching consistently theoretical studying on nonlinear stochastic dynamical systems with noisy disturbances and the control methods. The researches are distributed in an area being centered by chaotic behavior of nonlinear dynamics. As the result of these researches, he received doctor degree from Kyoto University, the title is “Studies on Behaviors of Nonlinear Dynamical Systems Subjected to Random Inputs”. He is also interested in applying the theoretical results into actual experimental systems with nonlinear time-delay and/or chaotic phenomena to evaluate and utilize the theories in the real world.

He moved to Fukui University as a lecturer in 1982, and an associate professor in 1985 in the department of mechanical engineering, and has been a full professor since 1991, where he started researches of robotics with visual feedback for the intelligent control of mobile manipulator, image recognition for traffic and agricultural products and fault diagnosis system in addition to the above mentioned researches. In 1999 a new department was established in Fukui University, whose name is “Department of Human and Artificial Intelligence Systems”, and he was invited as core professors to arouse the research activities toward the new evolution of intelligent systems especially concerning control engineering and robotics. His wide-spread interests and continuously active research manner for new trials were recorded as several streams and long trajectories through his academic history as a researcher by publications of transactions, journals and international conference papers.

During 1995-1996 and 1999-2000, he had been a member of committee of Robotics and Mechatronics Division of Japan Society of Mechanical Engineering (JSME). He arranged the 9-th Intelligent System Symposium (called FAN Symposium) with a leadership as a General Chair at 1999, which is an unprecedented symposium in the meaning that the subjects discussed in the symposium were spread around the middle area of mechanical engineering, computer science, information engineering and electrical engineer-
The symposium’s direction is completely along with the one of the above-mentioned newly established department in Fukui University at the same year of 1999. The coincidence of the year of FAN symposium at Fukui and establishment of the new department does not mean a casualty, but Prof. Asakura’s efforts to make a basement of intelligent systems in the Department of Faculty in Fukui University. In 2001, He was a vice executive chair of Annual Conference of JSME, which was held in Fukui University and Fukui University of Technology. He also managed a research group aiming at developing new robots with intelligence during 2000-2003, in which many researchers belonging to companies are participated. He was a chair of program committee of Society of Instrument and Control Engineers (SICE), which was held at Fukui University in 2003.

On the other hand, he has been a Fellow of Japanese Society of Mechanical Engineering and council member of JSME, SICE and the Institute of Systems, Control and Information Engineers. Further he was a chair of the third International Symposium on Human and Artificial Intelligence Systems at 2002 (HART 2002), whose name is the same with the one of the new department he is belonging, and this year he managed totally the HART 2004 as a general chair.

2 Research

It is impossible to describe everything of Prof. Asakura’s research activities, the followings are some milestones of his history as a researcher. He began his academic carrier by theoretical analyses of dynamics in Kyoto Institute of Technology, in which his main subject is “Stabilization of Non-linear Dynamical Systems by Noise” [1]. This research brought a possibility that the unstable system can be stabilized by random signals existing everywhere in natural environments, without inputting artificial feedback signals like as control systems. This result may be one of the reasons why the motions and behaviors of everything in the nature are stable. On the asymptotic behavior of nonlinear stochastic dynamical systems, the dynamical behaviors are highly depending on initial states, which is derived from non-linearity existing in ruling equations of all dynamical phenomena, and then the stability analyses are indispensable to realize a stable control restraining the unpredictable behavior of nonlinear dynamics. On this point of view, stochastic asymptotic stability of nonlinear systems suffering noises, which are modeled with parameters describing the randomness included in white Gaussian random process and finite state Markov chain process was studied and analyzed [2]. Then this analytical research results is followed by the analysis of “Chaotic Behavior of Nonlinear Dynamical System Driven by Cyclic External Forces” [3]. Recently he found that chaos could be generated by nonlinear servo control of induction motor from the influences of identifying error of the dynamical parameters, and the generation conditions are analyzed by using Lyapunov exponents, and chaos control method using neural network was proposed in order to remove the chaotic behavior that is thought to be dangerous for the rotation machine because of possibly generated irregular oscillation [4].

After moving to Fukui University, the standing points of his researches are shifted a little to how to make use of his analytical experiences for overcoming actual problems in real control systems. For example, measurements being essential for precise control and analysis of dynamical phenomena are pursued in several applications, such as measurements of “Ventilation in Tunnels” [5], “Torque by Means of Magnetic Lattice” [6], and “Bearing-less Water Mill-type Liquid Flowmeter” [7], which are followed by “The Dynamics and Sensitivity Analysis of a Plunger-type Pressure Control Valve” [8] and the application of Kalman Filter [9]. The improvements of these sensing systems were connected to the refinements of characteristic of electro-pneumatic valve positioner and the proposals of robust control, where these researches include essential problems of hunting oscillation derived from non-linearity and time-delay character of valve positioner. Though the Smith’s method proposed before had already been known to be able to prevent hunting oscillation, the method had some difficulties for applications. Based on these problems and circumstances on this field, he proposed new compensator for the non-linear time-delay element in electro-pneumatic positioning system and examined its effectiveness [10]. As the results of continuous research of this theme, “Design of Robust Servo Control System for Pneumatic Manipulator” [11],[12] was published, whose controller was based on state feedback of H-infinite control theory and had superior advantages from the view points of robustness, comparing with the other techniques such as disturbance observer and adaptive control.

On the other hand, he started researches to apply the progresses of computational intelligence in sensing of environments for robotics, improving the nonlinear dynamics and fault diagnosis of machine by using Fuzzy, Neural Network and Genetic Algorithm. Concerning fault diagnosis, the proposed system by him
detects the fault by finding the dynamical behavior’s gap between the state of the real system and the identified normal one, and the fault part is specified by fault diagnosis neural network [13],[14]. The neural network is also applied to the identifications and intelligent control for fine regulation of the target dynamics, which are composed by both identifying N.N. [15] and controlling N.N. [16],[17]. The genetic algorithm was used for sensing the surrounding environments of robot by using new concept of how to use the GA for dynamic scene recognition, which was named as 1-step GA. The application researches of this GA-based real-time recognition are as follows, recognition of traffic signs [18], corridor recognition being robust with varieties of lighting conditions and other obstacles existing in the images as noises [19], recognition of agricultural products such as tomatoes and eggplant [20]. And this research brought a success of catching a fish by a net attached at the hand of robot manipulator using visual feedback of hand-eye camera, where the real-time recognition of the fish of 1-step GA was used for visual feedback. Through the catching experiments, it is understood that the tiny fish was much intelligent than the robot, which is simply controlled by visual servoing, that is, the fish could find several strategies to escape the tracking net [21]. This result posed a new standing point of research of intelligent systems to consider its computational intelligence, such as simple and understandable quantitative evaluation by comparing the intelligence of robots and living animals could be achieved. This real-time recognition method using GA is also applied for the navigation control of mobile manipulator, which is steered by using a visual feedback generated from the hand-eye camera [22].

3 Publications

He has been an author of 154 publications including Books, Journals, Transactions and Conference Papers. Some of his major publications are listed below.

Heart of Intelligent Control

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Abstract This paper develops with present situation and its future in Intelligent Control. First, the overview of control science is introduced from the past to the present, and the traditional process to the intelligent control is illustrated. Next, some main topics are discussed based on the fruits of my research; stochastic stabilization, system identification by neural networks, chaos phenomena in mechanical systems and its stabilization and health monitoring. As the tool of intelligent control, both the neural networks (NN) and genetic algorithms (GA) are utilized for the system identification, stabilization and searching of system optimization. Through simulation and experiment, the necessity and the importance of intelligent control are verified.

Keywords: Intelligent Control, Stochastic System, Chaos, Identification, Neural Networks, Fault diagnosis

1 Introduction

The scope of control science is shown in Fig.1. The control science is based on the foundations of feedback theory and linear system analysis, and it integrates the concepts of network theory and communication theory. Therefore, control science is not limited to any engineering discipline but is equally applicable to mechanical, robotics, chemical, civil, and electrical engineering. Furthermore, as the understanding of the dynamics of business, social, political and financial system increases, the ability to control these systems will increase also. Nowadays, the control science greatly contributes to human life, industry and circumstances. [1], [2]

The development of control system is explained by using Fig.2. The conventional control theory has been based on the mathematical modeling, in which the deterministic system without noise and the stochastic system with noise have been treated. However, the real systems have nonlinear characteristics, the existence of uncertain parameters and no principle of dynamics such as a chemical plant. Due to the increasing complexity of the system under control, it is difficult to make a modeling. Recently, as the breakthrough of this problem, the intelligent technology can be instituted by applying the functions of learning, recognition and prediction. First, stochastic stabilization is discussed [3], and the possibility of intelligent system is shown. Second, when the system includes a nonlinearity and uncertainty, the system identification is often difficult. The new identification method is proposed by using neural networks [4]. Furthermore, Using this system identification, new intelligent control system can be constructed and it effectiveness can be shown through simulation [5]. Third, in nonlinear systems, chaos phenomena may occur. The detection and its stabilization of chaos are discussed [6] [7]. Finally, a health monitoring method by using neural networks is demonstrated through the detection problem of fault diagnosis [8].
2 Stochastic Stabilization

This chapter develops the noise stabilization of a class of second-order nonlinear dynamical systems. The block diagram is shown in Fig.3.

\[
\ddot{x} + \omega^2 x + \varepsilon G(x, \dot{x}) = -\delta h(x, \dot{x}) \dot{f}(t)
\]

In Eq.(1), \(G(\cdot, \cdot)\) and \(h(\cdot, \cdot)\) are nonlinear functions. Also, it is assumed that the nonlinear system without noise term is unstable or a limit cycle. The noise stabilization term added to the system is selected in the modified form of the white Gaussian noise process. The determination of stabilizing signal can be performed through the procedure that the singular point at where the diffusion disappears is obtained and sample path behaviors around the singular point are examined by Feller’s classification criteria. As an illustrative example, the possibility of realizing the noise stabilization on Duffing type nonlinear dynamical systems is shown in Fig.4.

\[
\begin{align*}
\alpha &= -1.0, \omega = 0.1, \rho = 1.0, \delta = 0.1, \varepsilon = 0.01, \alpha = 3.0, c = 0.1
\end{align*}
\]

For this noise stabilization, the problem is to find the modified noise term. As the theme to intelligent control, it is to construct the stabilizing noise term by the learning of neural networks.

3 System Identification by Neural Networks

This chapter develops the identification of chaotic dynamical system using neural networks and its application to vibration control. In conventional control theory, it is difficult to identify a mathematical
model of practical system because of system complexity and existence of nonlinearity. Instead of theoretical method, neural networks with different architecture have been applied to the identification and control for wide class of nonlinear systems. In this research, we propose a learning control scheme to realize the identification and control of chaotic vibratory system, using multi-layered neural networks, in which the control performance is satisfied for an unknown controlled object by repeated trials [8]. First, the effectiveness of neural networks is shown in the identification problem of Duffing’s chaotic time series data. Second, new technique is proposed which identifies the nonlinear system as a nonlinear mapping in forward direction and employs its inverse mapping as a controller. Third, this technique is applied to 2-link pneumatic manipulator and the effectiveness is verified [9].

As a nonlinear system, the Duffing vibrating system is considered, whose dynamics is described as follows.

\[ M\ddot{x}+c\dot{x}+kx+\alpha x^3 = Q\cos \omega t \]  

It is certified that the chaotic solution arises for \( M=c=1.0, \alpha=100, \omega=2.0 \) and \( Q=0.535 \). The result of identification is shown in Fig.5, in which the dotted line is a numerical solution and the solid line identified one. From Fig.5, the output of neural networks shows a good consistence with the one of chaotic solution, and the neural networks successes to the identification of chaotic solution. The identification results for both periodic and chaotic solutions are compared from the viewpoint of identified accuracy. The result is shown in Table 1.

<table>
<thead>
<tr>
<th>Qsin\omega</th>
<th>Behavior</th>
<th>With unified coefficients</th>
<th>( \text{rsm error} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.850</td>
<td>Periodic</td>
<td>By Periodic</td>
<td>0.0077</td>
</tr>
<tr>
<td>0.350</td>
<td>Periodic</td>
<td>By Chaos</td>
<td>0.0087</td>
</tr>
<tr>
<td>0.535</td>
<td>Chaos</td>
<td>0.0080</td>
<td>0.0045</td>
</tr>
<tr>
<td>0.650</td>
<td>Chaos</td>
<td>0.0100</td>
<td>0.0056</td>
</tr>
<tr>
<td>0.500</td>
<td>Periodic</td>
<td>0.0096</td>
<td>0.0042</td>
</tr>
<tr>
<td>0.680</td>
<td>Periodic</td>
<td>0.0098</td>
<td>0.0041</td>
</tr>
<tr>
<td>0.810</td>
<td>Periodic</td>
<td>0.0085</td>
<td>0.0052</td>
</tr>
</tbody>
</table>

Fig.5 Identification result by chaotic solution

In Fig.6, an adaptive control system is proposed with the identification mechanism by neural networks, in which the learning control circuit is constructed to control a nonlinear vibration model.

This approach is applied to 2-link manipulator with pneumatic actuators in each joint, as shown in Fig.7. First, it is shown that the occurrence of chaos phenomena is verified based on time series data through the calculation of Lyapunov exponent. Next, the important problem is to suppress chaos in 2-link manipulator with a dead time. A method of chaos stabilization is proposed by using a neural network. Figs. 8 and 9 show the results of chaos stabilization under parameter conditions for the learning. The neural network controller starts after 20 seconds. The dotted line is the desired input and the real line output response. In Figs.8 and 9, the chaotic behavior generates until 20[sec]. However, after NN controller works...
at 20[sec], chaotic behavior is suppressed and agreed with the desired input.

![Fig.7 Construction of 2-link manipulator](image)

**Fig.7 Construction of 2-link manipulator**

![Fig.8 Chaos stabilization for Arm 1](image)

**Fig.8 Chaos stabilization for Arm 1**

![Fig.9 Chaos stabilization for Arm 2](image)

**Fig.9 Chaos stabilization for Arm 2**

### 4 Chaos and its Stabilization

This chapter is concerned with the occurrence of chaotic motion and its chaos control in velocity control system of induction motor, as shown in Fig.10. Though the control of induction motor is very difficult, it is currently used by realization of so-called vector control method. The reason is that the induction motor is superior to a dc motor in maintenance. But, the stability of the velocity control system is not established, neither is robustness. The dynamics of the induction motor is represented by nonlinear equations with three-inputs and three outputs. Though precise parameters are necessary for the vector control method, we cannot obtain the precise values. Therefore, there are often identified errors in parameters and then the effect of the

\[ M/Tr \]

*is an important fact

for vector control.

As \( M/Tr \) changes under the influence of heat, an identified error occurs.

**Identified value**

\[ Ke = \frac{\text{Identified value}}{\text{True value}} \]

- \( \omega_r \): rotor angular velocity [rad/s]
- \( L \): coil inductance [H]
- \( R \): Resistance [Ω]
- \( J \): moment of inertia [kg · m²]
- \( D \): viscosity constant [N · m · s]
- \( G(s) \): PI Controller
- \( M \): mutual inductance [H]
- \( T_i = L/R \): rotor time constant [s]
- \( Ke \): Rate of identified error
nonlinear terms remains. Therefore, it is known that chaotic motions may occur in the system. In this chapter, the existence of chaotic motion in the velocity control system can be verified [9], and the generating conditions of chaotic motion are found. In order to prevent the chaos occurrence, a chaos control method is proposed, by using the neural network controller, as shown in Fig.11.

Fig.11 Block diagram with neural network controller

Fig.12 Chaos control by neural network controller

Fig.12 shows the result of chaos control by using neural network controller. The chaos behavior in using PD controller until $t=2.2$[s] is shown, but can not remove chaotic behavior. However, the neuro controller is added at $2.2$[s], and at result, it can be controlled after $3.0$[s] to the target periodic orbit.

5 Health Monitoring

This chapter develops a method of fault diagnosis based on machine fault diagnosis system using neural networks and spectral analysis. Generally, because of the complexity of machine system, the uncertainty of operating condition and the effect of many nonlinear factors, it is in most cases very difficult to diagnose the machine's fault by the conventional method. In this research, the sound signal of operating machine can be used as fault diagnosis signal. First, normal and fault spectral data of sound, which are obtained from operating machine, are learned by the diagnosis neural network. Through the learning, the diagnosis neural network can memorize the normal state and abnormal state of the object machine. Therefore, when a fault occurs in the object machine, the fault is detected using this fault diagnosis system. As an application, this method is applied to the wood slicing machine and then the effectiveness of fault diagnosis method is verified.

The structure of fault diagnosis system is shown in Fig.13. This system is composed with FFT analyzer and
the diagnosis neural network. FFT analyzer performs spectral analysis for sounds obtained from the object machine. The calculated power spectrum is introduced to diagnosis neural network, as shown in Fig.14. The diagnosis neural network learns both the normal and abnormal states of the object machine. Therefore, the output from diagnosis neural network is nearly 0, if the object machine is normal state.

![Diagram](image)

**Fig.13 Structure of fault diagnosis system**

![Diagram](image)

**Fig.14 Fault diagnosis neural network**

This fault diagnosis system is applied to wood slicing machine. The learning normal and abnormal data is shown in Fig.15. The fault diagnosis experiment is performed for 20 unlearning data obtained from operating wood slicing machine.

![Diagram](image)

**Fig.15 Learning normal and abnormal data**

This fault diagnosis system is applied to wood slicing machine. The learning normal and abnormal data is shown in Fig.15. The fault diagnosis experiment is performed for 20 unlearning data obtained from operating wood slicing machine.

<table>
<thead>
<tr>
<th>Signal No.</th>
<th>Operating condition</th>
<th>Output value from NN</th>
<th>Diagnosis result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>0.1563</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>0.1236</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>0.0955</td>
<td>Normal</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>0.3012</td>
<td>Normal</td>
</tr>
<tr>
<td>5</td>
<td>Normal</td>
<td>0.4124</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>Normal</td>
<td>0.0845</td>
<td>Normal</td>
</tr>
<tr>
<td>7</td>
<td>Normal</td>
<td>0.1322</td>
<td>Normal</td>
</tr>
<tr>
<td>8</td>
<td>Normal</td>
<td>0.3526</td>
<td>Normal</td>
</tr>
<tr>
<td>9</td>
<td>Normal</td>
<td>0.6854</td>
<td>Uncertain</td>
</tr>
<tr>
<td>10</td>
<td>Normal</td>
<td>0.1014</td>
<td>Normal</td>
</tr>
<tr>
<td>11</td>
<td>Normal</td>
<td>0.0745</td>
<td>Normal</td>
</tr>
<tr>
<td>12</td>
<td>Normal</td>
<td>0.0945</td>
<td>Normal</td>
</tr>
<tr>
<td>13</td>
<td>Normal</td>
<td>0.0125</td>
<td>Normal</td>
</tr>
<tr>
<td>14</td>
<td>Normal</td>
<td>0.3827</td>
<td>Normal</td>
</tr>
<tr>
<td>15</td>
<td>Abnormal</td>
<td>0.7006</td>
<td>Abnormal</td>
</tr>
<tr>
<td>16</td>
<td>Abnormal</td>
<td>0.7451</td>
<td>Abnormal</td>
</tr>
<tr>
<td>17</td>
<td>Abnormal</td>
<td>0.8564</td>
<td>Abnormal</td>
</tr>
<tr>
<td>18</td>
<td>Abnormal</td>
<td>0.9189</td>
<td>Abnormal</td>
</tr>
<tr>
<td>19</td>
<td>Abnormal</td>
<td>0.8547</td>
<td>Abnormal</td>
</tr>
</tbody>
</table>

**Table 2 Fault diagnosis result**

The fault diagnosis result is shown in Table 2. From Table 2, it can be seen that fault diagnosis is performed almost exactly. The precision of fault diagnosis is about 90%. Accordingly, the effectiveness of proposed fault diagnosis method is verified, which diagnoses the fault by the neural network based on spectrum data obtained from operating machine's sound.

6 Concluding Remarks

In this research, some topics using intelligent technology were discussed, concerning with control problems. Though the intelligent technology has been yet immature, this control science continues to be a field rich in...
opportunities. To realize these opportunities, it is important that the next generation of control researchers receive the support to develop new tools and techniques such as intelligent processing and image recognition, and explore new application area such as robotics and biosystem. The view of intelligent control is as follows:

(1) Search of environmental biology attractor; what like action or behavior is appropriate in the environment.

(2) Collaboration principle with sensor and motor; every intelligent action (reconstruction and the calculation of the Lyapunov exponent were proposed by considering a dead time learning and recognition) must be understood as sensor and motor collaboration system.

(3) Cheap design principle; the design is economized, and furthermore, the interaction with the environment and biological characteristics must be utilized properly.

The scope in future for control technology is shown in Fig.16.

**Fig.16 Scope in future for control technology**

**Acknowledgement**

I would like to thank Prof. K.Murase and the members in the department of human and artificial intelligence system for recommendation of writing my survey report.

**References**


