Ⅲ. 大学院学位論文

DISSERTATIONS

A. 大学院博士課程論文梗概

Doctor’s Dissertations

電気工学専攻

A1. マイクロマシンで作るブラウンモータ：ブラウン運動の整流によるナノ粒子の一方向駆動

Micromachined Brownian motors: Unidirectional actuation of nanoparticles by rectified Brownian motion

By Altintas Ersin

We report on energy efficient transportation system for nanoparticles, i.e. nanobeads, which exploits random thermal motion, Brownian motion, as the main actuation source, saving approximately 90% of energy compared to a pure electrostatic transport system.

The transportation system employs closed PDMS microfluidic channels to restrict Brownian motion of the nanobeads to only one dimension. A 3-phase dielectrophoretic ratchet rectifies this random motion into unidirectional transport by biasing spacial probability distribution. Applied force is strong enough to control Brownian motion of the nanobead on active electrode but it is not large enough to attract it from inactive electrode. Displacements between electrodes are achieved by Brownian motion and the direction of the transport is determined by 3-phase system.

A theoretical model of the system is developed and used to investigate its performance as a function of different design and actuation parameters, such as size of the nanobeads, driving voltage, electrode spacing and width, fluid viscosity, temperature and switching time. Theoretical calculations on the device have revealed that flows caused by electrohydrodynamic and thermal effects are negligible. A micromachined transport system is fabricated and employed to experimentally validate the model, showing a good agreement.

This study will improve our understanding of effective and efficient actuation (transportation or rotation) of nanoparticles in the artificial systems based on random thermal motion. Nanosystems similar to bio-molecular motors exploiting Brownian motion efficiently can be achieved.

A2. 分散されたセンサとオンボードセンサに基づく移動ロボットの制御スキームに関する研究

Mobile Robot Control Scheme Based on Distributed and Onboard Sensors

By Brsic Drazen

One of the desired advancement of mobile robots nowadays is their deployment in spaces that are populated by humans, like homes, offices, public spaces, etc. This will make possible new applications, such as robot servants or other service robots. However up to this date, there are almost no working implementations of robots in such environments. The reason for that lies in the fact that the robotic intelligence has still not matured to a level that would allow easy coexistence with humans.

The standard approach to the application of mobile robots is to provide the robot with sensors and computing power, and implement the necessary intelligence to do the required tasks, much in the same way like humans do. In this thesis we propose a different approach to the problem – to distribute the intelligence between the robot and the space it acts in, under the assumption that this kind of combination of outside and inside intelligence will lead to a considerable advantage when compared to the standard all-onboard approach.

We work on the control of the mobile robot inside environments that have distributed sensing and computing power – Intelligent Spaces. Although the research on such spaces is steadily growing, its application for better control of mobile robots has not yet been discussed. This is the objective of this thesis. The thesis is divided into several chapters, which present parts of the work done during the doctoral course.

Chapter 2 gives an overview of what Intelligent Spaces are, what are their characteristics and what can be done with them. An overview of similar researches is also given, describing the basic trends and similar research areas. After that a discussion on what mobile robots offer when implemented in Intelligent Spaces is given. Following that, we discuss the main merits the
introduction of Intelligent Space has for mobile robots.

The following chapter 3 is concerned with the motion control of the mobile robot. Considering the type of application we are aiming at in this work, here we consider several methods for robot control and compare their characteristics. The control is divided into two parts: global path planning and local path following and obstacle avoidance. Each of these parts is explained and the methods explained and compared in experiments. The basic two-step method is also expanded in order to achieve better behavior in the vicinity of dynamic objects, i.e. humans.

The methods described in chapter 3 rely heavily on the measurement and estimation of the relevant variables. Tracking and mapping tasks are dealt with in chapter 4, where sensing inside Intelligent Spaces is described. Here the accent is on the deployment of sensors that are distributed and fixed at different locations in the space. A description of mainly used sensors for this type of applications is given, and details of the implementation of tracking using sensors in our lab, such as laser range finders, are described.

We describe the developed method for tracking and mapping, which allows the sensors to be quickly installed and connected together to give a complete sensing system. Apart from the basic method for tracking we also discuss mapping, calibration and placement of the sensors, and the ability to distinguish between types of objects.

In chapter 5 sensing using the mobile robot’s onboard sensors in addition to the distributed sensors of the Intelligent Space is discussed. The inclusion of a mobile sensor into the network of static sensors from chapter 4 is not straightforward, as the two types of sensors have different characteristics. The main problem is that the mobile robot introduces correlations in the estimate, which in turn can result in an increase of the computational and communicational burden of the tracking system. In order to avoid this, we introduce the use of the Covariance Intersection method, in which case it is possible to combine the two types of sensors directly. We analyze several different types of information fusion architectures that can be used for such a combined sensor tracking system. Also, a different method based on the geometrical model of the robot and environment and the usage of particle filters is explained.

In chapter 6 the results from the previous chapters are combined in order to obtain a complete mobile robot control system based on the cooperative sensing using both onboard sensors and sensors distributed in the space. Here we discuss the proposed control scheme and analyze what are the advantages that can be realized when external sensors from Intelligent Space are added in order to enhance the overall sensing abilities needed by the mobile robot. This is followed by experimental results, where the merits of the proposed scheme are demonstrated in several different situations.

The thesis concludes with a list of contributions, plans for future work and a comment on the perspective of mobile robots in iSpace.

A3. 3 次元ピエゾ抵抗ヘリカルナノベルトカセン

Development and Application of 3-D Piezoresistive Helical Nanobelt Force Sensor
By Gilgueng Hwang

We present the fabrication and characterization of piezoresistive force sensors based on helical nanobelts. The three-dimensional helical nanobelts are self-formed from 27nm-thick n-type InGaAs/GaAs bilayers using rolled-up techniques, and assembled onto electrodes on a micropipette using nanorobotic manipulation. Patterned Au electrodes were fabricated using thermal evaporation or fountain-pen based gold nanoink deposition. Nanomanipulation inside a scanning electron microscope was conducted to locate small metal pads of helical nanobelts to be connected to the fabricated pipette type electrodes. Gold nanoink was deposited under optical micrograph using the fountain-pen method. Nanomanipulation inside a SEM using a calibrated atomic force microscope cantilever was conducted to calibrate the assembled force sensors and the values were compared with finite element method simulation results. With their strong piezoresistive response, low stiffness, large displacement capability, and good fatigue resistance they are well suited to function as sensing elements for high-resolution and large-range electromechanical sensors. I was motivated to develop ultra-high resolution helical nanobelt force sensing probe from the benefit of ultra-low stiffness of helical nanobelt. However, there was electromechanical properties of helical nanobelts were not known at that time. So, I made an effort to characterize the intrinsic piezoresponse characteriziation of helical nanobelts. Attaching two metal connectors in both sides of helical nanobelts brought me the better conductivity and assembly easiness. I measured repeatable piezoresistivity of helical nanobelts with high response. To be able to use these piezoresistive helical nanobelts for force sensor development, the more assembled devices prototypes were necessary for more property characterizations. As we used electron-beam induced deposition for the characterization, the problem was caused by the longer preparation. Therefore novel soldering method should be investigated. To assist the assembly, I applied an electrostatic and electromagnetic field to the helical nanobelts. As helical nanobelts are attached with Cr/Ni/Au metal connectors, it is straightforward to get benefit from the pull-in voltage (electrostatic) and electromagnetic field. By combining the assembly strategy, I could assemble the helical nanobelt force sensors and successfully calibrate the helical nanobelt force sensors with as-calibrated AFM cantilevers. In the mean time, I investigated gold nanoparticle ink deposition which was extremely useful for the helical nanobelt property characterizations such as optical property and etc. And I further extended the gold nanoparticle ink deposition method to the in-situ SEM applications. It inspired me to apply the method to chemical-free method. So, the resistance spot welding of helical nanobelt was investigated. The resistance spot welding could be the technology close to the future nanorobotic manufacturing by the benefit of easy
of the Flexible AC Transmission System (FACTS) devices.

A4. 送電線間潮流制御装置（IPFC）による電力系統最適潮流制御と安定度向上制御

Application of Interline Power Flow Controller (IPFC) to Optimal Power Flow Control and Stability Enhancement in Power Systems
By Jun Zhang

The recent request for better utilization of existing transmission networks and the constant demand of modern society for more flexible, controllable, and stable power systems have afforded great opportunities for the application of the Flexible AC Transmission System (FACTS) devices. With the availability of the fully controlled semiconductors such as the gate turn-off thyristor (GTO) and the insulated gate bipolar transistor (IGBT) etc getting more and more economical, the voltage-sourced converter (VSC)-based FACTS devices have become more realistic choices for the power industries than ever before. The VSC-based interline power flow controller (IPFC) was first proposed in 1998, as the latest component of FACTS device family. Its unique capability of simultaneously compensating multiple transmission lines at a given substation has since aroused great interest of researchers and power industries around the world. This dissertation presents a study on the application of IPFC to optimal power flow (OPF) control and stability enhancement in deregulated power systems.

Like Unified Power Flow Controller (UPFC), the IPFC is a kind of combined compensators, in which at least two Static Synchronous Series Compensators (SSSCs) are combined via a common DC voltage link. If there is no energy storage system installed in the apparatus, this DC voltage link is usually modeled as a DC capacitor. It is this link that provides the self-assembly of the helical nanobelt sensor and the batch process of Teflon inter layer helical nanobelt force sensor. It only requires single helical nanobelt for the force sensor development.

In order to study the effect of inclusion of the IPFC in power systems by numerical simulation, proper mathematical modeling of IPFC is necessary and very important. Based on the equivalent circuit of IPFC, various power injection models have been developed by the author, in which the voltage sources are removed and the impact of IPFC is represented by active and reactive power injections at the buses connecting to IPFC series transformers. These power injections can be expressed by system variables and IPFC variables. According to different purposes of IPFC application, different control strategies are adopted, and accordingly, the VSCs are represented by different sets of variables, such as controllable magnitudes and angles of injected voltages, and controllable injected voltage components perpendicular to each other, etc. In the dissertation, power injection models of IPFC in steady state analysis, transient stability analysis, and small-signal stability analysis are proposed respectively. Here the IPFC is assumed to generate or absorb no active power.

First, investigation of IPFC steady state operation and some comparison with the performance of UPFC in steady state is carried out. Three possible applications of IPFC to optimal OPF control have been explored, namely congestion management, power flow regulation, and available transfer capability (ATC) enhancement. By using the IPFC power injection model in steady state analysis, we can know that IPFC is a powerful tool for congestion management. It is shown that based on the multi-objective OPF control method, congestion can be resolved by the application of IPFC without generation redispersching, while the simultaneous optimization of both the total active power loss and IPFC capacity is achieved. It is also shown in numerical examples that both the UPFC and the IPFC are powerful tools for power flow regulation. Combined with generating bus voltage adjustment, the OPF incorporating either FACTS device can effectively minimize the overall generating cost without active power generation redispersching. Due to the necessity of a relatively large shunt VSC, the capacity of the UPFC is usually significantly larger than that of the IPFC to achieve a similar or the same effect of the same goal, even when the series VSCs and their corresponding constraints are exactly same. The IPFC also demonstrates its superiority over UPFC in efficiency in its application to ATC enhancement. All the OPF control problems in this dissertation are solved by the sequential quadratic programming (SQP) method.

Based on the energy function analysis, the operation of IPFC should guarantee that the time derivative of the global energy of the system is not greater than zero in order to damp the electromechanical oscillations. Accordingly, control laws of IPFC are proposed for its application to the single-machine infinite-bus (SMIB) system and the multimachine systems, respectively. By using the IPFC power injection model in transient stability analysis, numerical simulations on the corresponding model power systems are presented to demonstrate their effectiveness in improving power system transient stability.

This dissertation also evaluates the damping effect of the PI controller, which is originally for constant power flow control, and modal analysis of the power system is carried out. Then the pole shifting technique is adopted to stabilize the oscillatory mode having insufficient damping ratio by use of a PSS-type supplementary damping controller. The design process of the supplementary damping controller and the selection of input signal according to the mode observability are presented. By using the IPFC power injection model in...
small-signal stability analysis, numerical simulations demonstrate that the IPFC with the above control system is an effective tool to damp power oscillations. In the comparison between IPFC and UPFC in this part, the IPFC demonstrates its superiority over UPFC in both efficiency and effectiveness in damping of power flow oscillation and rotor swing. Numerical results are in line with the respective characteristics of series and shunt VSCs.

Finally this dissertation develops a detailed dynamic model of IPFC suitable for power system electromechanical stability analysis. The dynamic equation of the DC capacitor is derived and the effect of a PI-type DC voltage regulator on small-signal stability enhancement is analyzed. Quantitative analysis demonstrates that with proper control of the DC capacitor voltage and a large enough DC capacitor, variation of the DC capacitor voltage is very small during power oscillations. Therefore active power exchange between IPFC and the rest of power systems is very little. Thus the proposed power injection models are verified. In this part, eigenvalue sensitivity based parameter optimization technique has been adopted for PI controller parameter tuning.

Thus, modeling, simulation and application of IPFC in power networks have been fully explored.

A5. 空間知能化のための観測基盤の構築に関する研究

Research on Observation Platform for Intelligent Space

By T Takeshi Sasaki

Intelligent Space (iSpace) is a space (room, public space) in which various sensors and actuators are distributed and networked. iSpace observes the space using distributed sensors, extracts useful information from the obtained data and provides both informative and physical services to users.

iSpace system should have flexibility and scalability so that we can easily change the configuration of embedded devices and switch applications depending on the situation. In order to implement such a system, a basic framework which realizes a close cooperation among distributed devices has to be considered. In this thesis, a layered structure which consists of four layers - the sensor node layer, the basic information sever layer, the application layer and the actuator layer are proposed.

The structure makes it possible to fuse information extracted by each sensor node effectively and provides flexibility and scalability to the system. In this configuration, the applications only need to know the basic information server’s address to get information, so they don’t need to connect directly to the sensor which observes the target object. In addition, with this structure it is possible to add, remove or replace the sensor devices or sensor nodes without any change in the application program.

The component based implementation of observation function of iSpace and mobile robot navigation function is also addressed in order to realize a more flexible and scalable system. First the component design of iSpace - the information acquisition function and the information integration function is discussed. The information acquisition part consists of sensor components and data processing components whereas the information integration part is composed of fusion components and database components. The essential functions needed for mobile robot navigation are then discussed and the design of the components is presented. Finally, the components for sensors including CCD cameras, laser range finders and a 3D ultrasonic positioning system, for position and map servers and for mobile robot navigation system are implemented using RT (Robot Technology) middleware. The observation system is developed based on these modules.

Moreover, one of the major problems in developing the multi-sensor system is calibration of the sensors. Although calibration is needed for proper calculation from the local (sensor’s) coordinate system to the world (iSpace’s) coordinate system, it takes a great deal of time and effort to calibrate many sensors. In order to realize automated calibration, mobile robots in the space are utilized. The mobility of mobile robots allows us to cover wide areas of the environment without placing many landmarks in the exact positions beforehand. The calibration is performed based on the positions of the mobile robots in world coordinate system and their corresponding points in local coordinate system. The experimental results show the validity of this approach. However, the problem in the proposed method is that the position information of mobile robots in world coordinate system needs to be known. This means that the accuracy of the position estimation of the robots affects the result of calibration despite the difficulty of absolute localization of mobile robots. Therefore, this approach is also extended to utilize general moving objects such as humans and not limited to mobile robots. The relative position and orientation of sensors are first calculated based on the tracking result of moving objects in overlapping observable areas of different sensors and then global poses of sensors are estimated. The proposed method does not need to use position information of moving object in world coordinates and multiple objects can move in the environment simultaneously. Therefore, calibration of many laser range finders distributed in large area can be performed efficiently by cooperation of multiple moving objects.

Finally, a mobile robot navigation system which can localize the mobile robot correctly and navigate based on observation of human walking in order to operate in a space populated by humans with minimal disturbance to them is investigated. The human walking paths are obtained from a distributed vision system. Important points are extracted from observation and, a topological map of nodes which are important points and of edges which are added based on the presence of paths between important points is built. In addition, the human walking paths between two important points are averaged to get frequently used paths. The averaged paths are utilized as paths of the mobile robots. The proposed method enables us to generate paths which are efficient, have no obstacles and contain the
web communities in many aspects such as comparison with a
extraction algorithm to the Thai web snapshots. We study Thai
sub-regions of the Web. We also apply a web community
method than conventional crawling strategies. We then
simulation-based evaluation shows higher performance of our
large Thai web snapshot. Based on derived hyperlink patterns,
hyperlink patterns that frequently lead to Thai web pages by
borderless Web space. Towards this goal, we first identify
collect web pages written in a specific language from the
web archive.

This dissertation studies the challenges and issues faced in
collecting language specific web pages and building of Thai
web archive.

The dissertation starts by studying how we can efficiently
collect web pages written in a specific language from the
borderless Web space. Towards this goal, we first identify
hyperlink patterns that frequently lead to Thai web pages by
analyzing statistical properties and graphical structure of a
large Thai web snapshot. Based on derived hyperlink patterns,
we design a method for crawling language-specific web pages.
The evaluation of our language specific crawling method is
done on a trace-driven crawl simulator. The simulation-based evaluation shows higher performance of our
method than conventional crawling strategies. We then
implement our method on a language specific crawler for Thai
web crawling.

Unlike previous works on web archiving whose primary
cconcerns are long-term access and preservation of the Web
information, this work focuses on deriving values from the
archives. The remaining parts of the dissertation deal with
analysis and mining of the Thai web snapshots, and discuss
how we can utilize the obtained statistical properties in
application such as future crawls, web archive managements,
and spam detection. We analyze and mine the Thai web
snapshots stored in the Thai web archive using both link-based
and content-based techniques.

In link-based analysis and mining, we study several
statistical properties of the Thai Web graph such as degree
distribution, connectivity, and large-scale structure. The study
can be divided into three levels of abstractions: page-level,
host-level, and community level link analysis. For each level
of abstraction, we try, as much as possible, to compare the
derived characteristics of the Thai Web graph with other
sub-regions of the Web. We also apply a web community
extraction algorithm to the Thai web snapshots. We study Thai
web communities in many aspects such as comparison with a
real-world Web directory, linguistic purity of web community,
and the evolution of some socially significant Thai web
communities.

In content-based analysis and mining, we study the
evolution of Thai web keywords and explore its relationship
with real-world social events. As the Web is now being
inundated by hyperlinked information issued by many
organizations around the globe. Current events and trends that
are happening in the real world may be detected from the Web.
We first study the statistical characteristics of socio-topical
web keywords from Thai web archive. The socio-topical web keyword is a keyword relating to some
topics of interest in a real-world society. We propose a method
for extracting these socio-topical keywords from a series of
Thai web snapshots. Our proposed method relies on
correlations between link-based and content-based
characteristics of meaningful topical web keywords. By
studying the evolution patterns of the extracted socio-topical
keywords, it is possible to detect an event and/or trend which
were/are happening in the real world.

A6. 言語特定クローリングとタイウェブアーカイブの構築に関する研究
Research on Language Specific Crawling and
Building of Thai Web Archive
By Somboonviwat Kulwadee

This dissertation studies the challenges and issues faced in
collecting language specific web pages and building of Thai
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studying the evolution patterns of the extracted socio-topical
keywords, it is possible to detect an event and/or trend which
were/are happening in the real world.

A7. 局所特徴を使用した交通監視のための車両認識
識とクラス分類
Local Feature based Recognition and Classification
of Vehicles for Traffic Surveillance
By Mohottala Yasanthi Shirimila Wickramachchi

With the rapid increase of motorization and population density,
traffic problems such as congestion, road crashes and
environmental pollution have become serious and inevitable in
and around urban areas nowadays.

Intelligent Transport Systems (ITS), which apply advanced
computing, information and communication technologies to
surface transport systems, are widely viewed as a major
solution to many of these problems. ITS offers improving
safety, efficiency in transport and a positive environmental
effect by reducing vehicle emissions and energy consumption.

In many ITS applications, sensing is a fundamental task,
where different kinds of sensors have been used to collect
various traffic parameters. Point oriented sensors, such as
ultrasonic sensors and magnetic loop detectors, had been in
practical use for decades to count the vehicles passing through.
Compared to loop detectors, vision based sensors provide
more flexible and detailed traffic parameters such as vehicle
speed, location, vehicle class, lane changes and even
descriptions of road conditions. Moreover, the easiness to
install and maintain is another attractive advantage of vision
based sensors. However, vision based vehicle sensing is very
challenging, because the appearance of a vehicle may vary
hugely due to complex outdoor environmental conditions,
cluttered backgrounds, shadows and occlusion. This thesis
focuses on vision based vehicle recognition, and proposes a
system that can overcome these issues.

In the first study, the system detects vehicles from the still
images acquired through a single stationary camera mounted over the road, facing straight down. To minimize the effects of outdoor illumination changes, we convert the images to binary edge images. The recognition algorithm is a modification of Eigen window method, which extracts local binary features from training images and compress them using vector quantization method.

Outdoor experiments show an accuracy of over 98%, promising the robustness of the system to most of the common issues such as shadows, occlusion, and illumination changes.

In the next step, we enhance the system to recognize the classes of vehicles. Vehicle classification is important for traffic surveillance in many military and public systems, especially for the traffic census to obtain the information on the vehicle types that use a particular street. Currently, human operators manually count the vehicles for these systems, where the output is high cost and low in accuracy.

Therefore, automated vehicle classification systems are widely researched.

The vehicle recognition system is improved to distinguish five vehicle classes, namely sedan, wagon, mini-van, hatchback and others. Three improvements, namely: Robust feature extraction, Background matching, and Template matching, are combined in a probabilistic manner, which enables the system to distinguish the small differences between these classes.

As this system is model-based, it requires good training images of all targeted vehicle classes. Collecting these images is generally a hard and time-consuming task. To overcome this issue, we propose using training images rendered using three dimensional computer graphics.

The evaluation experiments using real input images show an accuracy of 89%.

In third study, we propose a system to fuse data from two sensors, a laser range sensor and a video camera, mounted on a probe vehicle. The system enables us to extract objects by depth. Then we improve it to detect and classify on-street-parked vehicles. The sensors scan on-street-parked vehicles while the probe vehicle runs on the lane next to parked-vehicles.

First we extract the vehicles and eliminate the background from laser range data. Following a process for camera and laser sensor calibration, we fuse the laser range data and image data. The scanned lines can be drawn on the vehicle area of the images. On the base of this result, Graph-cut method is applied to the images to segment the vehicles from the background more accurately.

The vision based classification system is modified with a part based weighting process to avoid misclassifications due to reflection of the vehicle body. The experiments show good results in sensor and image data fusion, and high classification rate.

The contribution of this thesis is a vehicle recognition system which can detect and classify the vehicles robustly despite of shadows, occlusion, cluttered backgrounds and illumination changes. Moreover, by fusing with laser range data, the system becomes more capable for many ITS applications.

A8. 映像にもとづく人物行動のモデリングと認識

Modeling and Recognizing Human Activities
By Kitani, Kris Makoto

This thesis presents a complete computational framework for discovering human actions and modeling human activities from video, to enable intelligent computer systems to effectively recognize human activities. This work is motivated by a desire to create an intelligent computer system that can understand high-level activities of people, thus allowing computer systems to efficiently interact with people. A bottom-up computational framework for learning and modeling human activities is presented in three parts. First, a method for learning primitive actions units is presented. It is shown that by utilizing local motion features and visual context (the appearance of the actor, interactive objects and related background features), the proposed method can effectively discover action categories from a video database without supervision. Second, an algorithm for recovering the basic structure of human activities from a noisy video sequence of actions is presented. The basic structure of an activity is represented by a stochastic context-free grammar, which is obtained by finding the best set of relevant action units in a way that minimizes the description length of a video database of human activities. Experiments with synthetic data examine the validity of the algorithm, while experiments with real data reveals the robustness of the algorithm to action sequences corrupted with action noise. Third, a computational methodology for recognizing human activities from a video sequence of actions is presented. The method uses a Bayesian network, encoded by a stochastic context-free grammar, to parse an input video sequence and compute the posterior probability over all activities. It is shown how the use of deleted interpolation with the posterior probability of activities can be used to recognize overlapping activities. While the theoretical justification and experimental validation of each algorithm is given independently, this work taken as a whole lays the necessary groundwork for designing intelligent systems to automatically learn, model and recognize human activities from a video sequence of actions.

A9. 陰関数を用いた２D 曲線と 3D 曲面の多項式表現とその応用

2D Curve and 3D Surface Representation Using Implicit Polynomial and Its Applications
By Bo Zheng

2D curve and 3D surface models are widely used for a variety of purposes in computer vision and graphics. There exist efficient function based shape representation techniques such as Fourier, B-Splines, Non-Uniform Rational B-Splines.
(NURBS), Radial Basis Function (RBF), and Implicit Polynomial (IP). Among these techniques, representation in IPs focuses attention from researchers in the vision community who, in particular, are developing sophisticated techniques for the automatic recognition, registration and matching of 2D/3D objects. In contrast to other representations, IPs are superior especially in the areas of fast fitting, few parameters, algebraic/geometric invariants, robustness against noise and occlusion, etc.

IP representation mainly suffers from the following two issues that not only greatly limit its applicability, but also confuse the users who need to model their target objects with IPs:

1) Poor representation for complex shapes.

Objects obtained by vision modalities are often very precise and thus complex. Unfortunately, generating IP even with high degrees is nearly impossible to give fine shape representation for these objects due to numerical instability and high computational cost.

2) Difficulty in determining a moderate IP degree and achieving global/local stability.

Prior IP fitting methods require that the degree of IP must be determined before handling fitting and therefore they are difficult to determine a moderate degree for a complex object. Furthermore the prior methods suffer from computational instability that many redundant zero-level sets are generated around the desired one. This makes the fitting result nearly impossible to be interpreted in the desired region space.

In order to address the first issue, we propose a 3D segmentation method based on a cut-and-merge approach. Through this method, we can divide a complex surface into segments and each segment is encoded by a low-degree IP. The advantages are that it is capable of i) finding the appropriate segmentation for various desired accuracies, ii) achieving stable fitting since we avoid using high-degree IPs, and iii) decomposing heavy computation from one high-degree IP fitting into light computations from multiple low-degree IPs. This method maintains inherent algebraic/geometric invariants. Therefore the segmentation method opens up new vistas for 3D applications such as 3D matching, recognition and registration. This method can be applied to general 3D data formats such as polygonal mesh models.

Regarding the second issue, we propose a method which is capable of: i) adaptively determining the moderate degree for fitting that depends on the complexity of objects, in an incremental manner without greatly increasing the computational cost, ii) retaining global stability while also avoiding excessive loss of local accuracy. Once this method is properly applied into the above segmentation method, we obtain an extended version that the adaptive segmentation result is available.

Furthermore, based on the better IP representation obtained by our previous methods and for further extending the applicability of IP, we develop a fast 2D-3D / 3D-3D alignment technique making use of 3D implicit polynomials (IP) and it has been effectively applied into Ultrasound (US) image pose estimation for medical purposes. Three main advantages over the traditional registration method are i) a fast transformation method for IP coefficients is introduced; ii) the alignment is formulated as to minimize an energy functional derived from IP gradient flow and thus avoid the cost for calculating point-wise correspondences; iii) with the property of IPs having very few coefficients, it makes both IP gradients and its transformation calculation extremely light both on computational complexity and memory. Through applying our alignment techniques to a real-time US image pose estimation, we demonstrate the capabilities of overcoming the limitations of unconstrained freehand US data by robust and fast pose estimation.

In conclusion, the research provides insights into the theory and practice of polynomial representation, and the main contribution can be summarized by the three following points: Firstly, a 3D IP-segment representation method is developed even for robustly representing complex objects. Secondly, an efficient fitting method has been developed for adaptively estimating the IP of moderate degree for objects with various shapes. Thirdly, a fast and robust 2D-3D registration method using IP has been developed for medical image applications.

Light Field Compression and Conversion with Image-Based Rendering

By Yuichi Taguchi

Recent advances in camera, computer, and display technologies have led researchers to develop 3D TV systems, which provide a more natural and intuitive perception of real scenes than 2D TV systems. Such a system captures multi-view images of a scene by using an array of cameras or lenses, transmits them, and presents a free-viewpoint video on 2D displays or a 3D image on 3D displays by using image-based rendering techniques. A 4D function that represents the light rays included in the multi-view image set is called light field.

This dissertation focuses on handling light field data captured with relatively dense, planar multi-view imaging systems, which are used for reproducing an entire scene rather than only a set of objects, and addresses compression and conversion problems of the light field data. Efficient compression techniques are essential for transmission due to the vast amount of data, typically consisting of tens or hundreds of views. Conversion of light field data is also a core technology of 3D TV systems, because the light field data reproduced by displays is different from the data captured by imaging systems in most cases. Image-based rendering can be considered a basic light field conversion, generating a free-viewpoint image from multi-view images.

In both light field compression and conversion,
geometry information of the scene plays an important role, because it provides the correspondence of light rays in the light field; it helps compression methods to improve coding efficiency, while enabling conversion methods to enhance the quality of converted views. The first part of this dissertation therefore addresses dense two-frame stereo matching, a fundamental problem for estimating scene geometry from a set of images. We present an over-segmentation-based stereo method that jointly estimates segmentation and depth to overcome limitations of traditional segmentation-based stereo methods. For mixed pixels on segment boundaries, the method computes foreground opacity (alpha), as well as color and depth for the foreground and background, which gives a more complete understanding of the scene structure than estimating a single depth value.

The next part explores issues of light field compression. In particular, we focus on compression methods that are suitable for image-based rendering. We first present two compression methods that provide a novel scalability, which we call view-dependent scalability. The scalability enables us to render high-quality views around a significant viewpoint even at low bit rates and to improve the quality of views away from the viewpoint with increasing bit rate. One method performs image-based rendering before the encoding process to generate an image at the significant viewpoint, which is located at the head of the encoded bitstream and acts as a reference image for predicting the input multi-view images. The encoded bitstream can be used with three rendering methods depending on the bit rate. The other method uses region of interest (ROI) coding to provide more flexible control of the view-dependent scalability. It is designed for interactive streaming of free-viewpoint videos to compensate smooth movement of the viewpoint. We then explore how we can exploit inter-view correlation in image-based rendering systems while keeping the computational cost low and the system configuration simple. For this purpose, we use a distributed multi-view coding approach, in which the inter-view correlation is exploited only at the decoder, and propose an efficient method that jointly performs decoding and rendering processes in order to directly synthesize novel images without having to reconstruct all the input images.

The last part describes live 3D TV systems using real-time light field conversion. The system presented first in this part performs real-time video-based rendering using an array of 64 cameras and a single PC. The system estimates a view-dependent per-pixel depth map to render a high-quality novel view. The rendering method is fully implemented on the GPU, which allows the system to efficiently perform capturing and rendering processes as a pipeline by using the CPU and GPU independently. We then show a live end-to-end 3D TV system using the 64-camera array and an integral-photography-based 3D display with 60 viewing directions. We present a fast and flexible conversion method from the 64 multi-camera images to the integral photography format. The conversion method first renders 60 novel images corresponding to the viewing directions of the display by using the above rendering method, and then arranges the rendered pixels to produce an integral photography image. All the conversion processes are performed in real time on the GPU of a single PC. The conversion method also allows us to interactively control rendering parameters for reproducing the dynamic 3D scene with desirable viewing conditions.

AII. 検索順位の個人化及び関連語提示を用いたWeb検索の高度化に関する研究

Enhancing Web Search by Personalized Re-ranking and Related Keyword Suggestion

By Lin Li

Search engines are widely used on the Web and they are making more information easily accessible than ever before. In commercial search engines like Google and Yahoo!, keyword based query is a much more popular way to let Web users easily specify their information needs than SQL queries for Web information access. However, the difficulty in finding only those which satisfy an individual's information goal increases. The main limitation with keyword-based search is two folds. First, due to the ambiguity of user needs, some keywords have different meanings in different context, such as mouse trap, Jaguar, Java and so on. Present search engines generally handle search queries without considering user preferences or contexts in which users submit their queries. Furthermore, users often fail to choose proper terms that best express their information needs. Ambiguous keywords used in Web queries, the diverse needs of users, and the limited ability of users to precisely express what they want to search in a few keywords have been widely recognized as a challenging obstacle in improving search quality.

Currently, encoding human search experiences and personalizing the search result delivery through ranking optimization is a popular approach to enhancing the result quality of Web search and user experience with the Web today. A general process of search result re-ranking is to devise efficient mechanisms to re-order the search result ranking using the global importance by personalized ranking criteria. On the other hand, commercial search engines give keyword suggestions on the queries input by users, thus assisting them in rephrasing their query formulation to improve search quality. The difficulty of keyword suggestion is that since Web users typically submit very short queries to search engines, the very small term overlap between queries cannot accurately estimate their relatedness. Given this problem, the technique to find semantically related queries (though probably dissimilar in their terms) is becoming an increasingly important research
topic that attracts considerable attention.

In this thesis, we study how to enhance the retrieval quality of Web search by personalized re-ranking and related keyword suggestion.

In personalized re-ranking, our works focus on studying learning user profiles and utilizing the learned user profiles to re-rank search results. Because user preferences change over time, it becomes important to keep the user profile up-to-date. In addition, a user profile covers both short-term and long-term user preferences. Using one model to represent two differently featured parts of the user profile will be far from perfect. To address this problem, one of our works is that we design use profiles which contain a taxonomic hierarchy for the long-term model and a recently visited page-history buffer for the short-term model. We also propose updating strategy to capture the changes of user preferences. For re-ranking search results, we study score and rank aggregation methods by using ontology-based user preferences. The other work is that we discuss how metadata like ODP (Open Directory Project) can be further exploited to achieve high quality personalized Web search. We propose a query context window (QCW) based framework for learning and encoding users’ short-term and long-term search interests and re-ranking of search results through a careful combination of recent and previous search histories.

In finding related keywords as suggestion, we are interested in finding semantically related queries. We utilize query enrichment as an effective method to enrich the representation of a Web query by alternative feature spaces, instead of using terms in the query. We mainly study how to get suitable feature spaces in this thesis. One of our works is that we study two kinds of feature spaces from search results of a query, i.e., content-sensitive (e.g., nouns) and content-ignorant (e.g., URLs). It is crucial to improve the quality of the URL (content-ignorant) feature space since it is generally available in all types of Web pages. We are inspired to propose a novel content-ignorant feature space, i.e., Web community which is a collection of Web pages with different URLs, but sharing common interest on a specific topic. The other work is that we improve the performance of the URL feature space from another viewpoint. We generate query affinity graph based the similarity measure between pairs of queries using query-URL vector model. We propose to utilize the monotonicity of the merging distances of a hierarchical agglomerative clustering (HAC). By using HAC based algorithms we can globally capture the diffusive transition of similarity on each connected component extracted from query affinity graph to rank queries.

In thesis, we show that personalized search and keyword suggestion are effective strategies to enhance Web search.

By Hideo Saito

Over the past ten years, clusters have become the predominant architecture for performing parallel computation. By connecting multiple compute nodes by a Local Area Network (LAN), clusters make a large amount of processing power, memory and storage available for parallel computation. By connecting two or more of these clusters by a Wide Area Network (WAN), even more computational resources become available for parallel computation. Recently, the bandwidth of WANs has increased significantly, increasing the number of applications that can potentially take advantage of multi-cluster environments.

Unfortunately, multi-cluster environments are significantly more complex than single cluster environments. In particular, they introduce or magnify problems concerning connectivity, scalability, locality and adaptivity. As it is undesirable and unrealistic for each individual application to handle these problems separately demands for wide-area communication libraries that handle these problems have increased.

Concerning connectivity, wide-area communication libraries need to be aware that connections between clusters are commonly blocked by firewalls or NAT. A simplistic scheme that assumes that all processes can connect to each other will encounter problems when deployed in WANs. Only some connections will be allowed, and messages must be routed between every pair of processes using those connections.

As for scalability, wide-area communication libraries need to avoid simplistic schemes that establish a large number of connections. While all connections consume resources, wide-area connections especially consume a lot of resources, causing various resource allocation problems. In addition to resource allocation problems, using a large number of wide-area connections in an uncoordinated fashion can result in low communication performance due to congestion.

The two previous requirements basically say that a wide-area communication library will establish connections between a subset of all process pairs. Then in order to maintain high communication performance, the process pairs that do establish connections should be selected in a locality-aware manner. In general, connections between nearby processes should be favored over connections between faraway processes, and connections between processes that communicate frequently should be favored over those that communicate infrequently.

Moreover, wide-area communication libraries should automatically satisfy the three previous requirements by adapting to environments and to applications. They should not rely on manual configuration, because it is tedious, it does not scale, and it is the cause of various errors.

Much previous research has focused on each of these requirements separately, but more work is necessary in order for wide-area communication libraries to meet all of these requirements. For example, research centered around message passing offers good locality but poor scalability and adaptivity and research centered around P2P overlay networks
offers good scalability and adaptivity but poor locality.

This has motivated me to make two proposals concerning the design and implementation of scalable high-performance communication libraries for wide-area computing environments: a locality-aware connection management scheme and a locality-aware rank assignment scheme. Using the two proposed methods, I have implemented a wide-area MPI library called MC-MPI and a wide-area Sockets library called SSOCK.

My connection management scheme overcomes firewalls and NAT by constructing an overlay network, and achieves scalability by limiting the number of connections that each process establishes to $O(\log n)$ when the number of total processes is $n$. In order to achieve high performance with a limited number of connections, the processes that are established are selected in a locality-aware manner, based on latency and traffic information obtained from a short profiling run.

My rank assignment scheme for wide-area communication libraries. This scheme finds a low-overhead mapping between ranks (process IDs) and processes by formulating the rank assignment problem as a QAP. It uses latency and traffic information obtained from the profiling run as well as routing information obtained from the connection management scheme in order to adapt to environments and applications.

Using the proposed connection management and rank assignment schemes, I have implemented a wide-area MPI library called MC-MPI. I have evaluated its performance by running the NPB on 256 cores distributed equally across 4 real clusters. For the IS benchmark, MC-MPI performed up to 2.1 times better than when connections were established between all processes. For the other benchmarks, MC-MPI was able to limit the number of process pairs that established connections to just 10 percent without suffering a performance penalty. Moreover, MC-MPI was able to find rank assignments that performed up to 4.0 times better than locality-unaware assignments and up to 1.2 times better than host name-based assignments.

In order to support not just MPI applications but any parallel application, I have also used the proposed connection management scheme to implement a wide-area Sockets library called SSOCK. In one experiment, SSOCK was able to connect 1,262 processes with each other in a 13-cluster environment with firewalls and NAT, without any of the connectivity issues and resource allocation problems that were encountered when the Sockets library was used. In another experiment in which processes simultaneously tried to establish connections, SSOCK was able to establish connections between all pairs of processes, while the Sockets library suffered from a large number of packet losses and timed out after 189 seconds.

A13. Web からの社会ネットワークの抽出および応用

 Extraction and Application of Social Networks from the World Wide Web

By Yingzi Jin

Social networks explicitly exhibit relations (called ties in social sciences) among individuals and groups (called actors). They have been studied in social sciences since the 1930s to analyze social phenomena. Interaction patterns reveal relations among actors (such as persons, groups, companies), which can be merged to produce valuable information as a network structure. The power of social network analyses has become apparent through its use for orienting ideas and specific bodies of methods. Many applications are relevant to social networks: trust realization, ontology construction, community discovering, knowledge sharing, etc. While shaping our own knowledge, social networks are a strong influence shaping our lives.

Originally in social sciences, social networks are extracted through observations and interviews. The typical approach of questionnaire surveys is often used to obtain social networks, e.g., asking "please indicate which persons you would regard as your friend." Recent technologies have enabled us to obtain social network data from e-mail archives, electronic libraries, schedule data, and Web citation information. By virtue of the current trends of "Web 2.0", "Semantic Web", and "Web 3.0", a huge amount of information has become available on the Web. Current Web applications such as Wikis and blogs enable users to create and publicize their contents on the Web easily. Moreover, social networking services (SNSs) provide a foundation for users to communicate with their friends on the Web space. As an entrance to the Web corpus, a search engine is useful to access various information that is available on the Web. Extracting and analyzing social networks from the Web is expected to yield timely, comprehensive information of the real world on the Web.

Overall, in this thesis, we address two research topics for social networks on the Web:

1. How to extract various social networks from the Web, and
2. How to use and apply social networks mined from the Web.

Regarding the first topic, several methods exist to extract social networks including people (particularly researchers) from the Web using a search engine. In this thesis, we describe expansion of existing techniques to obtain social networks among various entities on the Web so that they become applicable to various domains. We propose two improvements that enable us to address complex and inhomogeneous communities. For the first improvement of relation identification for the complex communities, we extract social networks among companies as examples. Extraction of relations between a pair of companies is realized using a search engine and text processing. Because names of companies co-appear coincidentally on the Web, we propose an advanced algorithm, which is characterized by the addition of keywords (relation keywords) to a query. The
relation keywords are obtained from the Web using a Jaccard coefficient. This method is a first attempt to extract companies' social networks from the Web using a search engine. The approach is also applicable to other actors, such as famous persons, organizations or other multiple relational entities. For the second improvement of threshold tuning for inhomogeneous communities, we extract social networks among artists (contemporary), who participated in the International Triennale of Contemporary Art (Yokohama Triennale 2005) to facilitate the navigation of artists' information. The algorithm can identify even tenuous relations among the artists. We first describe the basic idea of extracting social networks from the Web; then indicate that objective rule-based methods do not function well when applied to inhomogeneous communities. We propose a subjective rule-based method that is inspired by network questionnaires in social science. Furthermore, we propose a more advanced algorithm, an objective and subjective rule-based method, which enables more exhaustive extraction than that available under the previous methods.

For the second topic, we provide an example of advanced utilization of social networks mined from the Web. We seek to learn a ranking model of entities from a social network that has been mined from the Web. We assume that the performance and power (i.e. ranking) of social actors are usually interpreted as relations and structural features embedded in the network. Therefore, the ranking of entities can be learned and predicted from the social network. For example, if we seek to rank companies by market value, we can extract the social network of the company from the Web, then discern and subsequently learn a ranking model based on the social network. Consequently, we can predict the ranking of a new company by mining its relations to other companies. We can learn from existing rankings to expect other rankings. Consequently, we can understand the kinds of relations that are important for what sorts of rankings; additionally, knowledge about the structural embeddedness (i.e. network features of entities) can improve the rankings. We can address various questions from the Web using our algorithm: Why are some companies successful and others are not? Why are some researchers more productive than others? Similarly to methods described in many existing studies of social network analysis, our algorithm is useful to uncover answers from a structural perspective rather than from an attributional perspective. The proposed model combines social network mining and ranking learning, which further uses multiple relations on the Web to explain arbitrary rankings in the real world. Moreover, we specifically examine a new approach to using Web information for advanced analysis by integrating multiple relations and network features of entities for interpreting rankings among them.

Our study will expand social network mining from the Web so that is applicable to various domains. Furthermore, results of our study will provide a bridge between relation extraction and ranking learning for advanced knowledge acquisition for use in Web Intelligence.

A14. 自動獲得した世界知識に基づく日本語照応解析

Japanese Anaphora Resolution Based on Automatically Acquired World Knowledge

By Ryohei Sasano

In natural language text, several concepts have tight relations with each other. However, due to the linear constraints of text, most of them are not obvious in the normal form of text; thus automatic recognition of such relations is considered to be an essential step in natural language understanding (NLU). Anaphora resolution, including coreference resolution, zero anaphora resolution and bridging reference resolution, is one of the important subtasks for automatic recognition of such relations. In this thesis, we focus on Japanese texts. A typical NLU model for Japanese texts first segments input sentences into word sequences, assigns part-of-speech (POS) tags, recognizes named entities (NEs), and then recognizes syntactic structure and case structure. As a consequence of these analyses, relations that are expressed on the surface of text are recognized. In succession to these analyses, anaphora resolution, which resolves relations that are not expressed on the surface of text, are conducted. The state-of-the-art morpho-syntactic analyzer and NE recognizer are considered to have achieved reasonable performance. However, to recognize more complicated relations, such as coreference relations, more accurate systems are desirable. For example, NEs play an important role in coreference resolution; thus more accurate NE recognition system is considered to benefit the performance of coreference resolution. Therefore, we first aim to improve NE recognition. In Chapter 2, we propose an NE recognition system that uses non-local information. While conventional Japanese NE recognition system has been often performed immediately after morphological analysis and rely only on local context, our system performs after structural analyses and uses four types of non-local information: cache features, coreference relations, syntactic features and case frame features, which are obtained from structural analyses. We evaluated our approach on CRL NE data and obtained a higher F-measure than existing approaches that do not use non-local information. We also conducted experiments on IREX NE data and an NE-annotated web corpus, and confirmed that non-local information improves the performance of NE recognition.

Since there are few grammatical clues for resolving anaphoric relations, world knowledge concerning such relations is necessary to resolve them. For example, synonym knowledge is essential for recognizing coreference relations between paraphrased mentions; case frames, which describe what kinds of cases each predicate has and what kinds of nouns can fill these case slots, are essential for zero anaphora resolution. There have been some studies that have tried to elaborate these knowledge by hand, but the problem is their coverage. That is to say, it is very difficult to make wide-coverage knowledge manually, because language is
composed of an enormous number of content words. Moreover, there are technical terms or jargon for every domain, and new words are coined every day. In Chapter 3, we describe how to acquire world knowledge automatically. We first extract synonym knowledge, which is utilized for coreference resolution, from a large raw corpus and dictionary definition sentences. Secondly, we construct case frames from modifier-head examples in the resulting parses of large corpora. The problems for case frame construction are syntactic and semantic ambiguities. To cope with these problems, the case frames were gradually constructed from reliable modifier-head examples. Furthermore, in order to deal with data sparseness problem, we generalize the examples of case slots. Finally, we construct nominal case frames, which describes indispensable entities of nouns and utilized for bridging reference resolution. The point of the construction method is the integrated use of a dictionary and example phrases from large corpora. Chapter 4 presents a knowledge-rich approach to Japanese coreference resolution. In Japanese, proper noun coreference and common noun coreference occupy a central position in coreference relations. To improve coreference resolution for such language, wide-coverage synonym knowledge is utilized. Furthermore, to boost the performance of coreference resolution, we integrate primitive bridging reference resolution system into coreference resolver. The experimental results show that using the acquired synonyms and bridging reference resolution boosted the performance of coreference resolution and the effectiveness of our integrated method is confirmed.

Chapter 5 presents a probabilistic model for Japanese zero anaphora resolution. First, this model conducts coreference resolution, recognizes discourse entities and links all mentions to them. Zero pronouns are then detected by case structure analysis based on automatically constructed case frames. Their appropriate antecedents are selected from the entities with high salience scores, based on the case frames and several preferences on the relation between a zero pronoun and an antecedent. Case structure and zero anaphora relation are simultaneously determined based on probabilistic evaluation metrics.

Chapter 6 reports the effect of corpus size on case frame acquisition for discourse analysis. For this study, case frames were constructed from corpora of six different sizes ranging from 1.6 million to 1.6 billion sentences. These case frames were then applied to syntactic and case structure analysis, and zero anaphora resolution. Better results were obtained by using case frames constructed from larger corpora; the performance was not saturated even with a corpus size of 1.6 billion sentences.

Chapter 7 provides concluding remarks, summaries the thesis, and outlines the areas for future work.

A15. 無線マルチホッピネットワークにおける位置依存情報分散共有手法

角田 忠信

Location-aware Data Sharing in Wireless Multi-hop Networks

By Tadanobu Tsunoda

The development of network technology is going to bring us a ubiquitous environment where we can get various data in the world using small wireless terminals anywhere at any time. In addition, the research topics on wireless multi-hop networks have emerged as new techniques for exchanging any data between any local users. Using the P2P nature of wireless multi-hop networks, we can exchange real-time local data: store information, traffic information and environmental information in some cities or tourist attractions. In this context, there are many fundamental and applied researches on mobile ad hoc networks and wireless sensor networks, which could lead us to the ubiquitous environment.

Moreover, we can also retrieve spatial information about any people or objects by the development of location-aware technologies such as car navigation systems, cellular phones with GPS devices and map services like Google Maps. Integrating wireless multi-hop networks with location-aware technologies, we may create novel LBS (Location-Based Service), which can provide us with any spatial information anywhere at any time without any broadband backbone networks or powerful central servers.

Spatial data such as KML and GML play important roles to establish LBS systems. These data describe values or attributes about some points or areas of users' interest: coordinates, names, addresses of stores or buildings, etc. Using spatial data, we can get information around the locations of our interests. In some cases, these data are frequently updated and we have to retrieve the latest ones: some examples of these contexts are applications for news broadcasting, environment monitoring, business logistics, life-logs, and urban-computing. These applications make good use of real-time information rather than static data in conventional map services. Therefore it is very important to consider how we distribute and discover variable spatial data in networks.

To share variable spatial data in wireless multi-hop networks, we have to adopt distributed methods that are suitable for the wireless networks, whose natures are quite different from wired P2P ones. If the data are exchanged locally through wireless multi-hop networks and the creators of the data have to upload the data to distant central servers whenever they are updated. In addition, uploading them may also generate heavy traffic load in the wireless multi-hop networks because many intermediate nodes along the path toward the servers have to forward the updated data. Moreover, it is difficult to keep consistency of the data between creators and users because the links of wireless multi-hop networks are unstable and the creators or the users cannot always connect to the servers when the data are updated.

Several conventional studies have proposed distributed techniques, which are location-aware techniques for wireless multi-hop networks. To meet our purpose, we could use these methods to share spatial data in the networks; these methods
apply unstructured P2P networks and it is easy to implement them in wireless multi-hop networks. However, conventional works cannot always discover distributed data efficiently from the viewpoint of traffic load, memory consumption or consistency of data.

In this paper, we propose a novel distributed method to share variable spatial data in wireless multi-hop networks. Our method arranges the data in the terminals that exist only around the near areas to their source nodes so that we can reduce the uploading cost and keep the consistency of the data.

In addition, to achieve higher discovery ratio, we arrange routing tables in the terminals that exist in distant areas from the data sources. In this case, the routing tables are not for network layer of protocol stack but for application layer; in our method, the routing protocol that corresponds to the network layer is GPSR, which is one of location-aware protocols for wireless multi-hop networks.

Every entry in a routing table contains subset of query pattern. It is associated with the next target where users’ queries are forwarded. Our method implements the subset of query pattern by hash values of spatial data or class information of the data structure. This subset is used for query matching. If a query is matched with the subset of the pattern in an entry, the query is forwarded to the next target by GPSR. Using the routing tables, the queries are properly forwarded to the terminals that have the data about users’ interests.

Our method uses an aggregative propagation for the routing tables. We create an R-Tree hierarchy by the location information of spatial data. We let the terminals in higher regions of the R-Tree have abstracted entries in the routing tables. The data size of abstracted entries is small. Therefore they have only to distribute and exchange a small amount of data for exchanging information about the routing tables.

We have evaluated the performance of our method using a network simulator. The results of our simulation show that our method, keeping the consistency of the data, can find them with high discovery ratio, low traffic load, and small memory consumption.

A16. 4次元光線再生方式ディスプレイに関する理論的検討とその応用
小池 崇文

Theory, Design, and Application of 4-D Light
By Takafumi Koike

In recent progress, high-performance image displays are available with the progress in image media technologies. Evolution of displays, which begins in high-resolution, is achieving wide color space, high dynamic range, and high frame rate, thus contents can't keep up with the evolution of displays. This fact was caused by the digitization in many of display technologies, and we think this situation will continue for a while. Meanwhile, if we think image displays as devices to reproduce light ray, we can easily understand there are five parameters to describe any light ray. Three parameters show positions and other two parameters show directions. Thus, if we can reproduce light ray with 5-D, we can display correct light fields into real space, and it will be an ultimate display. For example, IP (Integral Photography) is well known as autostereoscopic display, and it also one of light field display, which can reproduce 4-D light fields. In recent years, several light field displays have been developed toward ultimate displays. Autostereoscopic images with reality are counted on in the near future.

In this paper, we focus attention on 4-D light field displays to realize 5-D light filed displays in the future. The objective of this paper is quantification of light field displays. The goal of this paper is to propose comprehensive framework to describe whole 4-D light field displays, and theoretically analyze 4-D light field displays. Another goal of this paper is to propose design and implementation methods for light field displays based on above analysis. Indeed, we propose a novel display, which is richly expressive beyond conventional displays as novel applications. To achieve these goals, we treat 3-D display technologies as optics and computer graphics and signal processing. One of the main contributions of this paper is a study of theoretical analysis of light field displays. I propose comprehensive framework of light field displays using image-based rendering in computer graphics and point-spread function in optics. In real space, it's not sufficient to consider light ray have simple line without width, so this paper introduces point-spread function to the theory for describing correct light ray with width. By using the theory, we can apply many of image-based rendering techniques to analyze light field displays. Next, this paper analyzes light field displays in a ray space and its frequency domain and a ray density space, and we show relations in real parameter of light displays.

There are many kinds of light field display methods, so it is very difficult to compare each method. By the proposed theory and its analysis, we can compare these light field displays.

Another important contributions of this paper are design and application based on the theory. Generally, samplings by a discrete pixel layout and a lens array cause moire. We can analyze moire of light field displays in ray space, and we have implemented an IP display with moire reductions and increased number of rays. Indeed, I propose and implement a BRDF (Bi-directional Reflectance Distribution Function) display as an application of 4-D light field display. BRDF representation needs 4-D light fields same as several 3-D displays need; we can design the 4-D light field display specialized for BRDF representation when we don’t represent depth of images. Thus, the BRDF display can display realistic image with unreality; the BRDF display is one of the ultra-realistic displays beyond realistic displays.

The methods proposed in this paper realize technologies, which treat light ray in real space as information theory, and will be more refined and applied for comprehensive framework for light field displays and autostereoscopic displays. The theoretical studies in this paper try to approach to the problem of displaying visual information into real space with reality from the three technical fields, computer graphics, optics, and signal processing, beyond their boundaries. This
approach will be expected for what will happen when we can control light ray with perfect freedom. I hope this approach indicates the way to a new research field of displays, in which researches in related areas would be compared, related and integrated with each other.

A17. 品質計測・分析に基づいた選択的ルーティングアーキテクチャに関する研究

Proposal of Quality aware Routing Architecture based on Analysis of Wide-scale Internet Quality Measurement

By Kaoru Yoshida

More than ten years has passed since the Internet was widely deployed to residences, offices and campuses. For most of Internet users, a high-bandwidth Internet connectivity is now available with reasonable cost. In such the environment, users can easily exchange high volumes of data through peer-to-peer applications and can access to streaming services, such as video on demand streaming every day. In addition, the volume of such traffic has been increasing exponentially. Network operators in Internet Service Provider (ISP), enterprise or campus networks, have struggled to provide stable and high-bandwidth services for Internet access, however, no practical approach to provide such services to their users been confirmed yet. Therefore, even though users are able to access to the Internet anytime they want, the service quality is not constant. Moreover, there is no guideline which network connectivity service users should use to meet their communication quality requirements.

There exist various factors that make it hard for network operators to provide the information of their network condition to their customers, we, however, believe the following three factors are critical. 1) Traffic that goes through the Internet varies from hour to hour, therefore, available bandwidth and loads of network equipments such as routers or switches also differ depending on situations. 2) The Internet is a global scale distributed network, therefore, each network is managed and operated by various kinds of individual organizations; 3) The Internet has a hierarchically layered structure, therefore, each hierarchy is operated by a different organization generally. Especially due to the last two reasons, each network organization has a difficulty to figure out how its network impacts upon its user communications, therefore, it makes users hard to clarify where their communications have problems.

The contributions of this paper are as follows.

First, we propose the following two new methodologies for the purpose of exploring communication characteristics between end users: 1) A methodology to explore topological network characteristics through end-to-end measurement. Even though there is a research field called network tomography, previous works only figure out short-term characteristics of ISP, enterprise and campus networks requiring highly accurate time synchronized measurements. Since our methodology mainly focuses on figuring out long-term trends of ISP, enterprise and campus network so that users could realize which network they should connect to, our methodology is different from previous works. 2) A methodology to figure out what kinds of factors make their communications instable and where they occur. To figure out them, we introduce a new technique to split up user communication path into segments through multi-source and destination end-to-end measurements. To validate our methodologies, we have measured communication delay and packet losses between residential users of five nationwide ISPs in Japan for more than one year and investigated characteristics of the Japanese Internet with our methodologies.

We, then, propose a new routing architecture that provides multiple routing paths to a single destination. This architecture aims to give both core and edge (user) networks a chance to select a routing path dynamically so that one of routing paths satisfies users’ communication quality requirements. Our architecture has two components: 1) Edge network routing component called SOPRANO (Service Oriented Policy based Routing for Advanced NetwOrk). This component aims to provide a dynamic path selection scheme to on-going communications without any impacts to them. A main idea of the SOPRANO is to separate a communication identification from a routing identification, which they are now same. Separating these identifications, user communications are established without being influenced by their routing path or identification changes. 2) Core network routing component called IRIDES (Invitation Routi ng Information aDvertisement for path Engineering System). Providing multiple routing paths to a single destination, this component aims to stabilize their network condition. Since data traffic goes through the Internet changes from hour to hour as we described above, it potentially occurs that bursted data traffic possesses network resources even though core networks are carefully designed to avoid such a situation. The IRIDES uses the Anycast to provide a flexible routing path selection scheme in core networks. We deploy the IRIDES on Zebra, which is a routing daemon running on PCs, and validate availabilities of the IRIDES. The result shows that the IRIDES is able to a control routing path that destined for a specific destination without making intrinsic changes to other destinations.

In this paper, we present new methodologies to analyze network communication characteristics and a new routing architecture to provide a dynamic routing path selection scheme for both core and edge networks. Through proposing them, we show issues of the current Internet and the future Internet.

A18. モバイルセンサネットワークのローカライゼーション手法に関する研究

A Study on Localization Systems for Mobile Sensor Networks

By Marcelo Henrique Teixeira Martins

Marcelo Henrique Teixeira Martins

By Marcelo Henrique Teixeira Martins
A fundamental problem in designing sensor networks, and wireless ad hoc networks in general, is localization -- determining the location of sensor nodes. Location information is used to detect and record events, or to route packets using geographic-aware routing. Manual configuration of locations is not feasible for large-scale networks or networks where sensors may move. Providing each sensor node with localization hardware (e.g., GPS receivers) is expensive in terms of cost and energy consumption. A more reasonable solution to the localization problem is to allow some nodes (called anchors) to have their location information at all times, and allow nodes to infer their locations by exchanging information with anchors.

Localization in mobile sensor networks is more challenging than in static sensor networks because mobility increases the uncertainty of nodes' positions. Most existing localization algorithms in mobile sensor networks use Sequential Monte Carlo (SMC) methods due to their simplicity in implementation.

In this thesis, we propose a localization algorithm which outperforms the existing state of the art in terms of computation cost, communication overhead and location accuracy. Our proposal is a range-free positioning system based on heading data provided by a variety of orientation-tracking sensors of different precisions, applied to the Monte Carlo sampling technique.

The main idea of our technique is to represent the posterior distribution of a common node's position using a set of weighted samples. In each time unit, a common node predicts its new samples based on the samples obtained in the last time unit and movement orientation data extracted from navigation sensors. Later, invalid samples are filtered out by using the locations of the newly observed anchor nodes. The procedure repeats and the node can continuously update its position estimation.

Simulation results show that our proposal, called OTMCL, is able to achieve better accuracy than similar approaches with a fraction of communication overhead. In addition, we reduce the computational requirements to achieve such figures without affecting the algorithm performance. In the best-case scenario, our algorithm can estimate the location of a node with an error of approximately $\delta\delta m$ without the need of GPS.

A19. Sensing Human Actions for Mental State
By Shiro Kumano

Sensing Human Actions for Mental State

To realize comfortable human-machine interactions, it is not enough for human-machine interaction systems to just wait for user’s instructions. It is also significantly important to autonomously understand their mental states such as emotions and intentions, and then to offer services appropriate for the situation. Unfortunately, the mental states are internal states which cannot be directly observed. So, the systems are forced to estimate the mental states of users from their daily actions that can be directly observed. In this paper, recognition of facial expressions and visual attentive actions is studied, because they contain a lot of information about mental states. The stochastic relationship between the human actions and the observations is modeled with Dynamic Bayesian Networks.

First, we propose a method for pose-invariant facial expression recognition from monocular video sequences. The advantage of our method is that, unlike existing methods, our method uses a simple model, called the variable-intensity template, for describing different facial expressions. This makes it possible to prepare a model for each person with very little time and effort. Variable-intensity templates describe how the intensities of multiple points, defined in the vicinity of facial parts, vary with different facial expressions. By using this model in a combined framework of a particle filter and a gradient method, newly proposed in this paper, our method is capable of robustly and effectively estimating facial poses and expressions in real-time. Experiments demonstrate the effectiveness of our method. A recognition rate of over 90% is achieved for all facial orientations, i.e. horizontal, vertical, and in-plane from the frontal view.

Next, for the advanced driving safety supports, distinguishing driver intentions under visual distractions by utilizing contextual information is studied. The visual distractions, which are one of the main causes of severe traffic accidents, are two holds: driving-related visual distractions, i.e. checking the side blind spot, and non-driving-related visual distractions, i.e. gazing at a non-driving-related object in the lateral direction. Drivers perform the former for increasing the safety, while do the latter with awareness of the danger. However, with regard to detection of driver’s visual distractions, most of existing works do not pay attention to the underlying intentions. The main contribution of this work is focus on the significant difference between these visual distractions, and to newly propose a method that can discriminate three types of visual attention states: no visual distraction, i.e. looking ahead, and two types of visual distractions with different intentions. To this end, contextual information, i.e. artifact operations and driving situation is utilized as well as driver’s physical actions. Our experiment with a realistic driving simulator shows that the proposed method is effective for recognizing these driver states.

The two types of human action sensing methods proposed in this paper, that is, recognizing multiple kinds of actions from observation data where a variety of information is coupled and discriminating contextual-dependent actions, are expected to be important components for estimating human mental states from multimodal information.
Room-temperature growth of Wz-GaN using photochemical vapor deposition

By Shunsuke Yamazaki

GaN has attracted much attention because of its excellent optical and electrical properties for wide-gap optical device and high-power and high-frequency electronic device applications. For these applications, GaN is grown on AlN or GaN buffer layers on sapphire substrates using metallocorganic chemical vapor deposition (MOCVD) or molecular beam epitaxy (MBE). These processes require high growth-temperatures to obtain high-quality crystallinity in GaN. GaN, however, requires low temperatures during growth to reduce the thermal damage in substrates, as well as after growth during the cooling process to prevent cracking and thermal residual strain in the GaN film. Therefore, many different techniques have been proposed. However, the detailed optical properties of GaN grown at room-temperature (RT) by these techniques remain unclear. Photochemical vapor deposition (PCVD) is a promising method that can lower the growth temperature by forming the reactive radicals gallium and nitrogen via precursor photolysis. In this thesis, we report the RT growth of Wz-GaN using PCVD.

We used trimethylgallium (TMG) and semiconductor grade (99.999%) NH3 as the III and V sources, respectively. H2 was used as the carrier gas for the TMG. Since gas-phase TMG and NH3 have strong photoabsorption at \( \lambda < 270 \text{ nm} \) and \( \lambda < 220 \text{ nm} \) respectively, we used a frequency-quintupled Q-switched Nd:YAG laser \( (\lambda = 213 \text{ nm}) \) as the light source for the photodissociation of the precursors. The PL spectra of the samples were examined after removing a surface layer of the sample.

We investigated the dependence of photoluminescence (PL) spectra on the V/III ratio of nanocrystalline GaN films deposited at room temperature using PCVD. A sapphire substrate was used to prevent the deposition of GaN onto the optical window. During the deposition process, the light source illuminated the sapphire substrate from back, the light was absorbed by the GaN. Consequently, the amount of decomposed precursors decreased, and led to the formation of polycrystalline GaN having cubic and hexagonal crystal-structures. To avoid a decrease in the amount of decomposed precursors, we examined GaN growth when the illumination was directed from above the substrate. To accomplish this task, the light source was introduced through the optical window. H2 gas was introduced around the window to prevent GaN deposition onto the window. The substrate was set at the center of the reaction chamber. The V/III ratio was 8000:1.

The morphology of the GaN sample was investigated with a scanning electron microscope (SEM). Two typical areas, labeled area A and area B, were observed. In area A, nanocrystallines could be seen, and the grain size ranged from 50 to 200 nm. In contrast, in area B dendrite-like structures with 100 nm widths were observed.

To examine the crystallinity, we determined the optical properties of the deposited film. In area A, a high and sharp peak at 3.47 eV (I2) was observed. The PL peak at 3.47 eV derived from the bound exciton in Wz-GaN.

The residual stress of the a-axis direction in GaN sample was 1.19 GPa. The value of the residual stress in our sample was as low as that of a GaN film on a sapphire substrate that had a GaN buffer layer grown by MOCVD. These results confirmed that the growth of GaN film using PCVD at RT effectively relieved the thermal strain in GaN/sapphire due to the RT growth.

We obtained PL spectra from area B of dendrite-like GaN. In addition to the presence of I2 at 3.47 eV, a blueshifted, sharp PL peak at 3.55 eV was observed at 5 K, indicating the quantum size effect in dendrite-like GaN. The formation of the dendrite-like GaN nanostructure was attributable to its growth at RT using PCVD, when the low kinetic energy of the precursors for migration aided the growth.

In conclusion, we have demonstrated the RT growth of ultraviolet-emitting Wz-GaN by PCVD.

A21. 二段階温度成長法による酸化亜鉛ナノロッドの成長と金微粒子析出への応用

By Kokoro Kitamura

Growth of ZnO nanorods using a two-temperature method and its application to the precipitation of gold nanoparticles

Duplicating the physical randomness of artifacts will play an important role in supporting a secure life. For this purpose, a nanophotonic replica using a near-field optical interaction was proposed in order to duplicate physical randomness. This thesis demonstrates the formation of gold nanoparticles using the near-field optical interaction for nanophotonic replica. ZnO nanorods were used as a mold, and spin-on-glass material containing HAuCl4 was used as the replica.

ZnO nanorods were grown on a sapphire (0001) substrate using catalyst-free metal organic vapor phase epitaxy.
optical near-field. A mask aligner and Hg lamp were used for (UV) light. First, a photomask was used as the source of the HAuCl₄ decomposes into Au on irradiation with ultraviolet coated onto the substrate, and dried in a vacuum desiccator.

width at half maximum of 95 meV, which is comparable to that room temperature. The spectra at room temperature had a full emission from ZnO over the range from –268°.

revealed that the ZnO nanorods consisted of single crystals and flexibility even after nanorod growth. TEM measurements the nanorods grew along the c-axis. PL spectra indicated optical properties of the ZnO nanorods. The spectra indicated emission from the free exciton, even at low temperatures, optical near-fields of each nanorod.

To satisfy these requirements, a novel two-temperature growth method is proposed. This method consists of lower-temperature growth of vertically aligned thick ZnO nanorods and subsequent higher-temperature growth to fabricate vertically aligned ultrathin nanorods. In the first step, vertically aligned thick ZnO nanorods are grown at 450° C; these determine the growth direction in the next step. After the substrate temperature has increased to 750° C without DEZn gas flow, the second step grows ultrathin nanorods at the tips of the thick nanorods. The direction of the ultrathin ZnO nanorods is maintained vertical to the substrate. Experimentally, the mean diameter of the ultrathin ZnO nanorods measured from scanning electron microscopy (SEM) images was 17.7 nm. Transmission electron microscopy (TEM) measurement revealed that the ZnO nanorods consisted of single crystals and the nanorods grew along the c-axis. Photoluminescence (PL) spectra were measured to evaluate the optical properties of the ZnO nanorods. The spectra indicated emission from the free exciton, even at low temperatures, which supports the high crystal quality of the nanorods. The diameter of the ultrathin nanorods varied with the growth temperature. Growth required a minimum of 650° C and had a V-shaped dependence on temperature. The density of the ultrathin nanorods was decided by the difference in the diameters of the nanorods made in the first and second steps, because the nanorods produced in the first step were densely arranged. In this case, the interval between adjacent nanorods was about 100 nm, which was sufficient to distinguish the optical near-field of each nanorod.

To improve the contact between the ZnO nanorods and the spin-on-glass material, ZnO nanorods were grown on a polyimide film at 450° C. The polyimide film maintained its flexibility even after nanorod growth. TEM measurements revealed that the ZnO nanorods consisted of single crystals and the nanorods grew along the c-axis. PL spectra indicated emission from ZnO over the range from &8211;268° C to room temperature. The spectra at room temperature had a full width at half maximum of 95 meV, which is comparable to that of ZnO grown on a sapphire substrate (86 meV).

A spin-on-glass material containing HAuCl₄ was spin coated onto the substrate, and dried in a vacuum desiccator. HAuCl₄ decomposes into Au on irradiation with ultraviolet (UV) light. First, a photomask was used as the source of the optical near-field. A mask aligner and Hg lamp were used for exposure. Gold nanoparticles with an average diameter of 39 nm were precipitated and aligned linearly following the pattern of the photomask, indicating that the optical near-field generated at the edge of the photomask played an important role in precipitation. The optical near-field at the edge of the photomask enhanced the precipitation, and nucleation occurred in this area faster than in other areas, which resulted in the alignment of gold nanoparticles. Next, ZnO nanorods grown using the two-temperature growth method were pressed against the spin-on-glass material containing HAuCl₄ and irradiated with a HeCd laser. Gold nanoparticles precipitated around the holes that were the vestiges of the nanorods. The average diameter of the gold nanoparticles was 23.5 nm. A few particles were located around each nanorod. Although a finite-difference time domain (FDTD) simulation predicted that the gold nanoparticles would appear in opposing corners of nanorods in parallel to the laser light polarization, the directions of the particles were random in the experiment. This discrepancy arose because the emission from the ZnO nanorods was not considered in the FDTD calculations. Since these emissions affected the polarization, the direction of the gold nanoparticles did not follow the polarization of the incident laser light.

These experiments confirmed the successful precipitation of gold nanoparticles due to the optical near-field of ZnO nanorods.

A22. ナノスケール強磁性 MnAs 微粒子を含む III-V 半導体ヘテロ構造におけるスピン依存伝導現象

ファム ナム ハイ

Spin dependent transport phenomena in III-V semiconductor heterostructures with ferromagnetic MnAs nano-scale particles

By Pham Nam Hai

Ferromagnetic nanoparticles embedded in a semiconductor are being considered as prospective materials for semiconductor spintronics. They possess both good compatibility with semiconductors and high Curie temperature, which cannot be obtained by either ferromagnetic semiconductors or ferromagnetic metals alone. Understanding of their spin-dependent transport characteristics is indispensable for any future applications.

GaAs:MnAs in which hexagonal (or zinc-blende) ferromagnetic MnAs nanoparticles embedded in a GaAs matrix is a well-known prototype of this kind of material. The GaAs:MnAs granular material is formed by phase decomposition and phase separation in meta-stable GaMnAs alloy semiconductor annealed at 500-700° C. When annealed at around 500° C, zinc-blende (ZB) MnAs nanoparticles, which correspond to nano-scale areas with very high Mn concentration, are formed due to phase decomposition of GaMnAs. When annealed at higher temperature (> 550° C), the more stable hexagonal NiAs phase precipitates. If spin dependent transport of hexagonal or zinc-blende MnAs
nanoparticles is realized, they can be used as spin injecting and spin detecting sources in FM / SM multi layers. Furthermore, because the size of MnAs nanoparticles is as small as 2-10 nm, the Coulomb Blockade (CB) effect is supposed to appear, thus MnAs nanoparticles can be used in single-electron devices. Finally, MnAs nanoparticles can also be used in many important parts of quantum computers using quantum dot systems, such as sources of local magnetic field, spin injectors, and spin detectors of the dot spins. Detailed investigations on the spin dependent transport as well as the charge effect in semiconductor nanostructures containing MnAs nanoparticles will be very important for understanding basic phenomena that can help us to develop new kinds of nano-scale spintronic devices.

This thesis presents studies of spin dependent transport phenomena in semiconductor heterostructures consisting of MnAs thin film / III-V semiconductor / GaAs: MnAs granular layer, magnetic behaviors of MnAs nanoparticles, and applications of ferromagnetic nanoparticles in active devices.

First, high quality single crystal magnetic tunnel junctions (MTJs) consisting of MnAs thin film / GaAs / AlAs / GaAs: hexagonal MnAs nanoparticles were grown by molecular beam epitaxy. Tunneling magnetoresistance (TMR) of those MTJs was clearly observed for the first time. We show that by using hexagonal MnAs nanoparticles as ferromagnetic electrodes, semiconductor based MTJs with high TMR ratio (18% at 7 K), high Vhalf (1200 mV at 7 K) and high operating temperature (~ 300 K), can be obtained. The observed TMR ratio is the highest among MnAs-based MTJs. The TMR ratios were found to oscillate against the tunnel barrier thickness while the tunneling resistances follow the WKB approximation, revealing that there are some kinds of quantum effects in our single crystal MTJs. This result shows that hexagonal MnAs nanoparticles can be used as spin injecting and spin detecting sources in semiconductor based spintronics devices.

Next, magnetic properties of hexagonal MnAs nanoparticles were studied by spin dependent transport measurements and Monte Carlo simulations. By utilizing the TMR effect, we observed rich magnetic phenomena of the hexagonal MnAs nanoparticles system, such as their static and dynamic M-H characteristics, relaxation of magnetization, and high blocking temperature. By fitting the Monte Carlo simulations to the M-H data at 7 K, we estimated the anisotropy constant of hexagonal MnAs nanoparticles to be about 2.1*10^5 ~ 2.5*10^5 ergs/cc. Furthermore, hexagonal MnAs nanoparticles are found to have long relaxation times as well as high blocking temperature. Those magnetic behaviors cannot be explained by Neel model for non-interacting particles. We suggested that the dipolar interaction is the origin of such long relaxation time and high blocking temperature.

Then, we studied the CB effect of double barrier MTJs consisting of hexagonal MnAs nanoparticles. The charging energy and the capacitance of hexagonal MnAs nanoparticle with size of 5 nm in diameter are estimated by measuring the temperature dependence of conductance of GaAs:MnAs granular layers. The TMR oscillation of hexagonal MnAs based double barrier MTJs due to CB was observed for the first time both in vertical and lateral structures. The TMR oscillation curve observed in the lateral structure reveals that spin-relaxation time of MnAs nanoparticles is as long as 10 microseconds.

We then propose a new type of spin device called single-electron spin transistor (SEST) that utilizes the TMR and CB effects. We show that by using SEST, many reconfigurable circuits can be realized without using any floating gates. The proposed logic gates can provide nonvolatile and scalable reconfigurable hardware for future electronics.

Finally, electromotive force, Coulomb blockade, and huge magnetoresistance in MTJ with zinc-blende MnAs nanoparticles are described. By detailed theoretical and experimental investigations, we show that the observed emf results from the conversion of the magnetic energy of ZB MnAs nano-magnets into electrical energy when these nano-magnets undergo magnetic quantum tunneling. Our results strongly suggest that Faraday’s Law of induction must be generalized in order to account for purely spin effects in such magnetic nanostructures.

A23. MOSFET のしきい値電圧ばらつきの要因解

Cause Analysis of Threshold Voltage Variability in MOSFETs by Device Simulation

By Arifin Tamsir Putra

The fluctuating parameters which are considered to be the origins of threshold voltage (Vth) variation in metal-oxide-semiconductor field-effect-transistors (MOSFETs) are developed and introduced into three-dimensional device simulator. Using device simulation with new developed fluctuating parameters, it makes possible to evaluate the Vth variation in real devices. Each fluctuating parameter is assumed independently to see the impact on Vth variation more clearly.

In the past couple of years MOSFETs have reached decanometre (between 10 nm and 100 nm) dimensions with 40-50 nm physical gate length devices available now in the 45 nm technology node, 32 nm transistors ready for mass production in next couple years. The gate length of the most advanced MOSFETs has already fallen below 30 nm. However, various problems that obstruct more miniaturization of MOSFETs have become prominent as the device size is aggressively scaled down. The electrical characteristic variation, such as Vth variation is one of the big issues in scaling MOSFETs. To reduce the issue of Vth variation, its origin should be clarified first. This issue becomes prominent in short channel because the fluctuating parameters are not averaged out in small size MOSFETs.
The objective of this study is to analyze the origins of Vth variation of both NMOS and PMOS in current VLSI technology. Since, it is very complicated to determine the real origin of Vth variation in short channel due to the short channel effect (SCE) and drain induced barrier lowering (DIBL), this work is focused on not-so-aggressively scaled down gate length at low drain voltage. In cause analysis of the Vth variation, Takeuchi coefficient BVT is utilized, which is derived from uniformly random dopant fluctuation with low drain voltage. For estimating dopant profile effect on Vth variation, a new methodology is proposed. Using a newly proposed method, dopant profile effect on Vth variation is enhanced, so that profile impact can be observed clearly.

A very rapid method of estimating the effect of gate edge fluctuation on Vth variability in MOSFETs is proposed. An empirical model is developed, in which correlation width (Wc) from gate line width roughness (LWR) is a key parameter of the model. The validity of the model is confirmed using the measured data and an autoregressive model. Wc is extracted from the gate line edge shape depicted in a scanning electron microscope (SEM) image. This method is very useful for the intuitive understanding of the gate edge fluctuation effect on Vth variability.

Two well known dopant models for the Coulomb effect, which are atomistic model and long-range model, have been compared using device parameters in the 45nm technology node and beyond. It is found that the atomistic model has unacceptable dependences of average threshold voltage on mesh spacing and substrate dopant concentration, while the long-range model has minimum dependences. Consequently, the atomistic model severely overestimates the Takeuchi coefficient BVT, which is one of the most important parameters for random threshold voltage variation. It is concluded that the long-range model is more suitable for the prediction of random variation in future aggressively scaled metal-oxide-semiconductor field-effect-transistors (MOSFETs). Vth variations induced by oxide thickness fluctuation (OTF) and local gate depletion (LGD) in MOSFETs are studied using classical three-dimensional (3D) drift-diffusion (DD) simulations. The models for both OTF and LGD are based on transmission electron microscope (TEM) observations. OTF is generated using random roughness steps at SiO2/Si interface and LGD is generated using random size and position of grains in poly-Si gate. The impact of both models on Vth variation is analyzed by the Takeuchi coefficient, BVT. It is found that both OTF and LGD are not the main origin of Vth variation demonstrated by BVT analyses.

Randomness of discrete fixed charges at SiO2/Si interface of NMOS, which is thought to be one of the possible origins of threshold voltage (Vth) variation, is investigated using 3D device simulation. Three cases of fixed charge types are assumed; (i) both negative and positive sheet charges exist with zero net charge (mix charges), (ii) only negative sheet charges exist, and (iii) only positive sheet charges exist. BVT is used as a Vth variation indicator. It is found that, even if high concentration of fixed charge (1012 cm-2) is assumed, the difference of Vth variation between measured NMOS and random dopant fluctuation model by 3D TCAD still can not be explained, which reveals that other fluctuated parameters exists.

Finally, a new methodology for evaluating dopant profile effect on Vth variability is proposed. Body bias coefficient is a key to the model used in this method. Using this method, pure random dopant fluctuation and its profile effect can be clearly observed.

A24. 光ファイバ通信における波長・偏波モード分散の能動的補償のための適応制御方式
谷澤 健
Adaptive Control Methods for Active Compensation of Chromatic and Polarization Mode Dispersion in Optical Fiber Communications
By Ken Tanizawa

In optical fiber communications, adaptive impairment compensation is required for the next generation high-speed and reconfigurable networks. The impairments of optical fiber, e.g., chromatic dispersion (CD) and polarization mode dispersion (PMD), should be compensated for adaptively by the feedback control of each tunable compensator with signal monitoring. Many excellent researches have been done concerning the tunable compensators and the real-time signal monitoring techniques for effective adaptive compensation. However, the control method has not been studied fully in spite of the fact that the optimization algorithm influences the accuracy and the speed of compensation to a great degree when we construct a subsystem for adaptive compensation.

In the dissertation, we focus on the active compensation of CD and PMD, and report the improvements of the control methods of a tunable compensator. CD is the most influential impairment in optical communications, and the adaptive compensation is required for the compensation of large CD variation induced by the change of transmission distance in reconfigurable networks. PMD is an unstable impairment varying stochastically in time, and adaptive compensation is essentially required for the compensation of PMD variation caused by environmental changes as well as transmission path changes. We propose and demonstrate new control methods employing adaptive control algorithms for respective compensation of CD and PMD, and succeed in more effective compensation compared with the conventional control methods. The proposals and achievements of our research are summarized below.

In the adaptive CD compensation, the most important requirement for the control method is fast optimization of the tunable compensator. We therefore propose a control method
based on the steepest descent method (SDM) which is a high-speed local search algorithm to minimize (or maximize) an objective function. In our proposal, the objective function defined as the difference between the actual and ideal received waveforms is minimized by the SDM with the real-time approximation of partial derivatives without actual measurements. High-speed compensation is expected since the step size of the local search changes adaptively according to the approximated partial derivatives. Experimental demonstrations and a performance analysis are performed in nonreturn-to-zero (NRZ) on-off-keying (OOK) transmission, and the proposed control methods operate effectively for the compensation of CD variation caused by transmission path change of a few hundreds km in 10 Gb/s. The compensation range is from -6000 to 6000 ps/nm at 10 Gb/s, and from -450 to 450 ps/nm at 40 Gb/s, respectively. The compensation time is 1 to 2 s for CD variation within ±1000 ps/nm. These results show that the proposed SDM-based control method provides better performance in adaptive CD compensation.

In the adaptive PMD compensation, the most important requirement for the control method is depending on the network, the high-quality optimization for the compensation of large PMD variation in reconfigurable networks and the high-speed optimization for the compensation of PMD fluctuation in high-speed transmission over 100 Gb/s. Since the optimization is complex in PMD compensation because of a large number of control parameters, the compensation quality is an important factor for the compensation of large PMD variation. Also, as the PMD fluctuation is reported to be faster than 10 ms, a high-speed control is required for high transmission quality in high-speed transmission. First, we propose a new search control algorithm with random search step size for the adaptive PMD compensation in reconfigurable networks. In this proposal, degree of polarization (DOP) is maximized by the local search whose search step size changes randomly depending on the Gaussian probability density function. The randomness of the step size is effective to avoid falling into local maxima without increasing the compensation time. Transmission simulations are conducted for the comparison between the compensation performances of the proposed and conventional control methods. It is confirmed that the proposed algorithm operates effectively for the improvement of the compensation quality in various network situations, and achieves 40 % reduction of the possibility to be trapped at local maxima in 160 Gb/s NRZ-OOK transmission.

Next, we propose a SDM-based control method for fast DOP maximization in high-speed transmission with PMD fluctuation. In this proposal, the partial derivatives of the DOP are obtained in approximation by Mueller matrices modeling of the tunable compensator with the state of polarization (SOP) monitored at the input of the compensator. The fast tracking compensation is expected because the control parameters are updated simultaneously in the correct direction with an appropriate step size by the use of the approximated partial derivatives. The transmission simulations are conducted when the fiber SOP is changing in milliseconds. The simulation results show that the adaptive compensation with the proposed algorithm achieves higher transmission quality in 160 Gb/s transmission. The required optical signal-to-noise ratio for bit-error ratio=10^-3 is improved by 1-2 dB compared with the conventional algorithm based on the hill-climbing method when the speed of SOP variation is 0.13 rad per 1-4 ms. These two control methods contribute greatly to the PMD mitigation in the future optical fiber networks.

A25. 多波長長子もれ配光ファイバネットワークアーキテクチャおよびデバイスに関する研究

Research on Architectures and Devices for Multi-Wavelength Quantum Entanglement Distribution Optical Fiber Network

By Han Chuen Lim

The recent merger of quantum physics and information theory into a new field called quantum information has provided new motivations for both theoretical and experimental research. Emerging concepts such as quantum computing and quantum cryptography that harness the coherence properties of multi-partite quantum systems for processing information have not only triggered theoretical curiosities but have also shown potential for practical applications as well. The more ambitious experimentalists and engineers today face two experimental challenges. The first being how to store and process quantum information, while the second being how to reliably transfer quantum information. This thesis is specifically concerned with the latter.

After more than twenty years of intense development, conventional fiber-optic communication technology has reached maturity. It is therefore natural and timely to inquire into the possibility of transmitting quantum information via the conventional optical fiber network. However, as quantum information cannot be amplified nor measured without affecting the information content, direct transmission of quantum information over long lengths of optical fiber is not feasible. On the other hand, it has been discovered that quantum information can be reliably transferred by quantum teleportation. In this protocol, shared entanglement must be consumed as a resource. An interesting and non-classical feature of shared entanglement is that it cannot be created nor increased by local operations and classical communications, and therefore entanglement must be physically distributed to application users for sharing. The role of an optical fiber network in quantum information transfer is thus to facilitate the distribution of entanglement.

So far, entanglement distribution has attracted limited attention from the engineering community. Although enabling device and subsystem technologies such as quantum memories and entanglement purification are still beyond reach, a study on quantum entanglement distribution network architectures and devices from an engineering perspective based on current level of understanding and technology would help to clarify...
system and device requirements, and shape their future development. This thesis aims to provide an overarching framework, as well as to demonstrate the very first steps towards realizing a bandwidth-efficient, multi-wavelength local-area quantum entanglement distribution optical fiber network.

First, the concept of a multi-wavelength quantum network architecture for both regional-scale and local-area entanglement distribution is introduced. As quantum entanglement carried by photon-pairs is fragile and cannot be amplified, care must be taken in the network architecture design so as to minimize photon loss and protocol failure rate. At the same time, the photon-pair transmission rates should be maximized by full utilization of available transmission bandwidth. It is shown that for regional-scale entanglement distribution, wavelength-multiplexing with channel-matching in a hierarchical architecture improves the final entanglement distribution rate significantly. For a local-area quantum network, high reconfigurability can be achieved if photon wavelength conversion and wavelength routing devices are incorporated. The proposed architectures provide an overarching framework for subsequent theoretical studies and experimental work.

To implement the proposed architectures, a source of highly entangled photon-pairs suitable for distribution over optical fiber must first be realized. A pulse-pumped source of high quality polarization-entangled photon-pairs in the telecom-band is proposed. It is based on a single 1-mm-long periodically-poled lithium niobate waveguide placed in a polarization-diversity loop configuration without temperature control. Very high state purity and entanglement fidelity have been observed in the low-rate regime. The proposed source is extremely stable and well-suited for use in a local-area network. A theoretical model that allows an entanglement distributor to quickly determine the optimal photon-pair generation rate for any pair of users within the network is also devised. Usefulness of the model is demonstrated in an entanglement distribution experiment over 82 km and 132 km of optical fiber.

Following that, the concept of wavelength-multiplexed entanglement distribution is introduced. As all existing sources of entangled photon-pairs are relatively narrowband compared to the available fiber transmission bandwidth, a service provider would have to multiplex many such narrowband sources in order to fully utilize the available transmission bandwidth of optical fiber, and this is not cost-effective. As a better solution, a single broadband source of polarization-entangled photon-pairs well-suited for wavelength-multiplexed entanglement distribution is proposed. A broadband source that is capable of supporting up to forty-four independent wavelength channels in the telecom-band is demonstrated experimentally. Wavelength-multiplexed distribution of forty-four channels of highly-entangled photon-pairs over 10 km of optical fiber is also demonstrated for the first time. This work has led to a better understanding on entanglement distribution system design issues.

Finally, the role and implementation of photon wavelength conversion in a multi-wavelength quantum entanglement distribution optical fiber network are discussed. One can expect it to take many more decades for a quantum entanglement distribution optical fiber network to be realized and implemented. Nevertheless, the overarching framework and the experimental results provided in this thesis have advanced current level of understanding and technology, and they are expected to help shape and speed-up future development of this field.

A26. 選択領域有機金属気相成長の反応モデリングとモノリシック集積光デバイス設計応用に関する研究
塩田 偉也
Modeling of selective area metal-organic vapor phase epitaxy and its application for the design of photonic devices
By Tomonari Shioda

A27. 有限差分時間領域法によるフォトニック結晶の設計と高Q値3次元フォトニック結晶ナノ共振
タンデーシーヌラット アニワット
Design of Photonic Crystals by FDTD Method and Fabrication of High-Q Three-Dimensional Photonic Crystal Nanocavities
By Tandaechanurat Aniwat

Photonic crystals (PhC), man-made periodic arrangements of dielectric media, have recently attracted much interest as a promising platform to manipulate light on wavelength-sized length scale. Photonic crystals can have photonic bandgaps (PBG) that prohibit the propagation of light at certain directions and frequencies, making them very useful to control and confine light. In particular, a three-dimensional (3D) PhC could be designed to possess a complete PBG and thus provide a full control of light in all directions. One of the greatest challenges in photonics is a construction of optical cavities with small mode volumes and large quality factors (Q), for efficient localization of light. A PhC nanocavity with cavity modes lying within the bandgap can be created by introducing a defect into a perfect crystal. With proper design of the cavities along with a well-established fabrication technique, PhC nanocavities supporting cavity modes with high Q factor and small mode volume in the order of cubic wavelength can be achieved. This thesis focuses on the design and fabrication of high-Q 2D and 3D PhC nanocavities. The Three-dimensional Finite-Difference Time-Domain method (3D-FDTD), which is based on the discretization of Maxwell’s equations in space and time, is used as a computational tool to design and optimize the nanocavities.

First, the 2D “air-bridge” PhC nanocavities have been discussed. We concentrate on increasing the Q factor by using
the concept of decoupling between the cavity modes and the leaky modes. Using this concept, high-Q cavities can be achieved regardless of the existence of the PBG. This finding will contribute to extending the freedom of cavity design, such as applications to PhC cavity with low refractive index and PhC cavity for quantum cascade lasers, which usually have no PBG for a range of frequency of interest or at best very narrow. Two such cavity designs are presented. Firstly, we introduce a new way to increase the Q factor by optimizing the slab thickness, which is a parameter of design that can be precisely controlled by using epitaxial growth techniques such as molecular beam epitaxy (MBE) or metal-organic chemical vapor deposition (MOCVD). We numerically and experimentally demonstrate a significant increase of Q factor of dipole modes in PhC H1-defect nanocavity after closing of the photonic bandgap by tuning the slab thickness. The highest Q factor is obtained when the slab thickness is equal to a wavelength of light confined in the cavity. At this slab thickness, the PBG is already closed. The strong light confinement of the cavity in the in-plane direction is then not caused by the PBG effect due to a lack of the PBG but resulted from the mode mismatching between the cavity mode and the guided mode in the momentum space yielding only weak coupling between these two modes. We then extend the concept of mode decoupling not only to the in-plane direction but also to the vertical direction to design a new type of doubly-degenerated modes by gradually modulating air hole radii in square lattice PhC nanocavity. The momentum analysis reveals that the cavity modes hardly couple to either the guided modes or the radiation modes. An ultra-high ratio of Q factor to mode volume, desired for applications such as entangled photon source, of these modes has been achieved and this value is about two times higher than the highest value reported so far. In addition, we also demonstrate an emission from colloidal nanocrystals embedded in this cavity, which is directly fabricated on a low-index resist layer, for the first time. The high Q factor of 700 has been obtained.

Due to the complexity in fabrication, the Q factor of the 3D PhC nanocavities is usually limited by a number of periodicity surrounding the cavity that can be fabricated. In this thesis, we experimentally demonstrate a coupling of quantum dots (QDs) with 3D “woodpile” PhC nanocavity fabricated by using a micromanipulation technique with the highest Q factor for 3D PhC cavities ever reported. The Q factor of more than 7,700, which is a new World's record, has been achieved by increasing a number of unit cells in the stacking direction of the fabricated woodpile structure and by well defining the structural parameters, such as size of the cavity and rod width, to tune a cavity mode with high designed Q factor to the frequency of interest. This improvement of Q factor is an important step for 3D PhC nanocavities toward many promising applications, including ultralow threshold lasers and quantum information processing. Moreover, we theoretically predict that the Q factor can be further increased about an order of magnitude by slightly modifying the arrangement of dielectric rods surrounding the cavity site, while the structural size of the 3D PhC structure is kept constant.

As VLSI process technology advances, the gap between gate delay and (global) interconnect delay is getting wider and wider. This makes interconnect delays (especially global interconnect delays) one of the most important factors that can affect performance. Under such situation, many state-of-the-art researches in high level synthesis try to consider the effect of interconnect delays. These researches indeed achieve better performance compared with traditional ones that ignore interconnect delays. However, when applications contain large loops (e.g., digital signal processing algorithms), there is still much room to improve performance, since usually, such applications contain computations that can be executed concurrently, they offer the possibilities of exploiting the parallelism.

In this work, we, for the first time, propose the idea to utilize pipelining techniques and take interconnect delays into account together into high level synthesis so as to improve its quality. This is not an easy task, since interconnect delays are unknown at the stage of high level synthesis. Usually they are not understood until after placement and routing.

In order to facilitate the estimation of interconnect delays, we propose a novel architecture, called regular distributed-register architecture for dynamic routing (RDR-dr). It divides a chip into a two dimensional array of islands, and the interconnect delay can be roughly estimated from the location of related islands.

Then, with the estimated interconnect delay information, we try to solve the problem of integrating both the effect of interconnect delay and pipelining techniques into high level synthesis by using exact solution methods such as Integer Linear Programming (ILP) and Boolean Satisfiability (SAT). We formulate the problem in the form of ILP/SAT, and then utilize commercial existing ILP/SAT solvers to find the solutions. As a result, for small examples, the exact methods can solve. But for relatively large examples, the exact methods can not solve within eighteen hours.

In order to improve the efficiency, we then propose a heuristic pipeline scheduling algorithm for array based architectures considering interconnect delays, and develop corresponding interconnect-aware pipeline synthesis system. The proposed method has the following two characteristics: 1) it separates the consideration of interconnect delay from computation delay, and allows concurrent data transfer and computation; 2) it belongs to modulo scheduling framework, in the sense that all iterations have identical schedules, and are initiated periodically. We evaluate the proposed heuristic method from different points of view and the experimental results show that: (a) our proposed interconnect-aware pipeline...
All-optical switches, and thus we clarify the main motivation of this research. By the chapter end, we present the outline of this thesis.

Chapter 2 begins by explaining the basic properties of passive and active MMIs. Important concepts like single and multiple imaging and restricted interference are detailed for passive MMIs. For active ones we highlight effects like lack of ref. index uniformity, carrier diffusion and spontaneous emission noise. We then investigate by simulation the cross phase modulation (XPM) between two different CW optical signals inserted into the active MMI through separate ports. The simulation program is based on a computational algorithm that takes into account the distribution of carriers, gain, ref. index as well as optical photons. For 10 to 12 μm-wide active MMIs and specific material parameters, steady state results show that a phase shift amounting to several multiples of π could be induced in the data signal at low injected current densities (3.2 kA/cm²) and for achievable control power values.

In Chapter 3 in order to investigate XPM between optical pulses we develop a new modeling and simulation approach. In this approach, carrier density distribution in active MMI is modeled by few lateral profiles added to the average density. The coefficients of these profiles and average density are functions of time and longitudinal position. A separate update equation is derived for each of them from the carrier rate equation that takes into account carrier diffusion, detailed recombination and stimulated emission by optical signals. At the same time, following the approximation of first order perturbation an adapted wave equation is derived for each propagating modal phase and power. The resulting system of equations is solved by the FDTD method, after artificial interleaving in time and space for all variables. Dynamic XPM and carrier recovery are then examined by a simulation program.

The experimental part of our study starts in Chapter 4 which presents the fabrication details of all devices included in this research. We managed to fabricate workable discrete active MMIs with passive ports and active-MMI-based all-optical switches using the monolithic integration technique of offset quantum well. To reach this end, some modifications have been added to a pre-developed fabrication process, e.g. we have enabled wider contact openings in the devices’ active regions. We have also contributed to the reduction of optical propagation loss in waveguides etched by the inductive coupled plasma (ICP) machine. The chapter also includes a comparison of current integration techniques for optical devices, details of epitaxial growth by the MOVPE machine as well as the main fabrication difficulties and our attempts to overcome them.

Chapter 5 includes basic device characterization and experimental switching results obtained by our fabricated devices. Cross-port cross gain modulation (XGM) has been measured in the fabricated discrete active MMIs. Moreover, all-optical switching has been demonstrated (by 10 dBs) in the fabricated all-optical switch for an input control power of 7 dBm and with a reduction in control power coupled to the data.
port by approx. 4 dBs. These results would clearly serve as a proof of concept, and we believe that further optimization would much enhance the new switch performance.

In Chapter 6 before giving our final remarks on this study, we briefly highlight some suggested alternatives that would make an active MMI a more power-efficient device for all-optical switching.

A30. InP 基板上光集積回路における一方向性導波路型光デバイスの研究

Avoiding the problems caused by undesired reflections of light is a matter of great importance in photonic integrated circuits (PICs). For this purpose, this paper describes waveguide-based unidirectional devices that can be monolithically fabricated with other optoelectronic devices on a PIC. There are two promising ways of creating such devices. One is based on nonreciprocal propagation loss in an absorbing magneto-optic waveguide; the other is based on nonreciprocal polarization conversion in an asymmetric waveguide with a garnet layer.

1) Nonreciprocal-loss waveguide optical isolator

The nonreciprocal loss is a phenomenon where—in an optical waveguide combined with an absorbing ferromagnetic material—the propagation loss of light is larger in backward than in forward propagation. Taking a 1.5-um-band TM-mode isolator, we explained the theory, fabricating process, and operation of the device on the basis of our research. The isolator consists of an InGaAlAs/InP optical waveguide with a layer of ferromagnetic manganese pnictide (MnAs and MnSb) that is attached to the waveguide. The magnetized layer produces the magneto-optical Kerr effect, which induces the nonreciprocal loss in light traveling along the waveguide. Finally, an isolator with a MnSb layer we made had an isolation ratio of 12 dB/mm at a wavelength of 1.54 um in the temperature range 20-70°C.

2) Nonreciprocal polarization converter

We proposed a nonreciprocal TE-TM polarization converter that can be used to eliminate the disturbances caused by back reflection of light in InP-based photonic integrated circuits. Our device consists of an asymmetric InGaAsP waveguide combined with a ferrimagnetic Ce:YIG layer, making use of the magneto-optical transverse Kerr effect and the change in the state of polarization in the waveguide. We described the guiding principle to design the optimal structure of the device. We also confirmed the operation of nonreciprocal TE-TM conversion by means of electromagnetic simulation. The results showed that a nonreciprocal conversion efficiency of 93% could be obtained with a device length of 0.27 mm at 1.55-um wavelength. Our device can be upgraded to a waveguide isolator simply by combining with a polarizer or mode splitter. Our nonreciprocal polarization converter should be useful in integrating variety of optical devices on a photonic integrated circuit.

A31. 電源電圧としきい値電圧制御によるナノメートル CMOS LSI の最適化

Optimization of Nanometer CMOS LSI’s through Adaptive Control of Supply and Threshold Voltage

By Yasumi Nakamura

Power integrity and power consumption have become a more serious issue as LSI’s scaling of technology continues into nanometer region. While scaling of transistors results in faster yet low-power circuits, increased power supply current causes problem of switching for saving power consumption, which restricts the power efficiency of LSI’s. Furthermore, systematic or random variations induced by its design and process result in excessive margin and higher power consumption. To cope with this problem, an adaptive noise canceller and global power optimization scheme is proposed and investigated.

The thesis is organized into 5 chapters. The first chapter describes trends and problems in nanometer CMOS LSI’s as the background. Along scaling, the operation speed increases, on the other hand, leakage power does not scale well in nanometer CMOS LSI’s, and process variation increases along scaling, which leads to large margin to obtain enough yield. To reduce cost and power consumption, adaptive control of supply and threshold voltage is essential because these post-Si tuning technologies do not only reduce the power consumption but also improve the yield, which lead to cost reduction.

Chapter 2 introduces conventional low-power techniques for system-on-chip (SoC) systems. This includes time-domain fine-grained adaptive controls and area-domain fine-grained adaptive controls. Time-domain control is to adaptively change the supply voltage or to switch the supply voltage of specific circuit block to reduce leakage when it is not in operation and preserve performance when in operation. Various sophisticated controls are available, though they have problem of switching noise to the supply line. This problem is treated in Chapter 3. Area-domain control is used to compensate process variation using frequency monitor and back-bias generating circuit. Conventional control of this type has large area overhead due to the bias generator, and within-die process variation is becoming more random along process scaling, which makes it difficult to implement. A solution to this is shown in Chapter 4.

Chapter 3 proposes novel power supply line noise canceller using higher voltage supply for supply voltage droop in wake-up. Proposed canceller uses additional higher-than-VDD power supply, namely VDDH, to allow more current flow through restricted power supply.
network, which enables to cancel the noise without large wire or power supply network overhead. Moreover, optimum control of the switch between VDDH and VDD, and the amount of the noise cancelling current are discussed. With noise cancelling current as large as the load current and slow turn-off, the canceller is stable and optimum cancelling effect is achieved.

To optimize the power consumption of CMOS LSIs, not only dynamic control of the supply voltage or switching the circuit to reduce leakage, but also coping with within-die variation to reduce excessive margin which consumes excessive power is essential. Chapter 4 proposes a fine-grained global threshold voltage optimization scheme for digital circuit. Nanometer CMOS LSIs have not only random variation but also systematic variation, which derive from both design and process variations. By dividing the circuit into blocks and applying different body-bias voltages for each blocks, both systematic variations can be cancelled. This means digital circuits have some not necessary fast part and necessary fast part, and to drive the first part in fast mode consumes excessive power. The principle and detailed design consideration and flow are also described in this chapter.

In chapter 5, a power gating switch with MEMS technology is presented. Conventional power gating switch with CMOS technology has finite leakage current, which becomes problem especially for very low power systems. With the MEMS switch, leakage current can be cut to almost zero, though the on-resistance of the fabricated chip is high. From this, the MEMS switch is for very low power systems which can accept kΩ order of on-resistance and which cannot accept on/off ratio as low as 105. Furthermore, the durability of the MEMS switch is discussed in this chapter, and a circuit technology to extend its life time is also presented.

Finally, the thesis concludes in chapter 6.

A32. 直接交調を用いた単一レーザダイオードからの光コム発生

Uniaxial Strain Effects on Silicon Nanowire MOSFETs and Single-Electron/Hole Transistors at Room-Temperature

By YeonJoo Jeong

The size of a metal-oxide-semiconductor field-effect-transistor (MOSFET) in very-large-scale integrated circuits (VLSI) have been scaled down for higher integration and higher performance. However, potential coupling between source and drain becomes prominent as a gate length is shrunk below to sub-50 nm and this provokes large short-channel-effects (SCEs). As a result, gate controllability to surface potential is weakened, and accordingly, subthreshold leak current becomes remarkable. In order to obtain high SCE immunity using conventional bulk planar-type MOSFETs, high channel doping concentration is required, but high doping level causes mobility degradation and worsens characteristic fluctuation of MOSFETs. Thus, continuous scaling of the conventional bulk planer-type MOSFETs is now facing difficult situation and is challenged by physical and technological limitation.

Silicon nanowire is one of the most promising structure for future ultra-scaled device due to extremely small size and has two attractive devices: gate-all-around (GAA) nanowire MOSFET (NW FET) and SET/SHT. NW FET and SET/SHT are promising devices for ultra scaled nano regime device due to superior SCE immunity and high functionality, respectively. By recent progress in silicon nano-structure fabrication technique, high performance NW FETs having uniform channel size is fabricated, and large Coulomb blockade oscillation in SET/SHT is observed even at room-temperature. On the other hands, strain technology is extensively investigated for mobility enhancement in MOSFET. However, most of the studies have paid attention only to three-dimensional (3D) or two-dimensional (2D) channel MOSFETs, not to ultra-nano scaled one-dimensional (1D) or zero-dimensional (0D) devices, such as NW FET and SET/SHT. Although driving current is gradually not affected by mobility term as device scaled to sub-20 nm because ballistic transport becomes dominant, effective mass which determines incidence velocity is still influential on drain current and the effective mass is controllable by using strain technology. Also, strain in SET/SHT is expected to discover new physics of SET/SHT and improve understanding of operation principals. Therefore, demonstration of strain technology and confirmation of the effects on the NW FET and SET/SHT are strongly desired.

The objective of this work is to investigate the strain technology in the future nano-scaled NW FET and SET/SHT. We confirm the effectiveness of the strain even at ultra narrow NW FET and nanowire size dependency is studied systematically. Also, the strain effect on the novel device SET/SHT which is operated by tunneling mechanism is discussed to discover physics of SET/SHT.

After NW FETs and SETs/SHTs are fabricated by using ultra-narrow channel method, two directions of strain are applied by mechanically. In NW FETs, we observe simple strain effects, namely Vth shift and mobility modulation at low Vover and high Vover, respectively. NW pFETs provide greater ΔId/Id than NW nFETs, and nanowire width dependency of the effects is observed for the first time only in NW pFETs because the effective mass m* modulation is decreased as nanowire width becomes narrower. In SETs/SHTs case, in addition to Vth shift and mobility enhancement, Coulomb blockade oscillation characteristics are changed by the strain. While current modulation is very complicated in SETs, strain effects on SHTs are easily analyzed by means of m* modulation. More current improvement and characteristics modification can be expected, if relatively larger strain (~ GPa) is applied.
The function and performance of modular robots is greatly influenced by the number of modules. Modular robots can be changed to suit a particular purpose when hardware resources are limited. Recently these robots have been developed for exploring unknown areas such as planets or disaster sites. While conventional robots have a choice between wheels and multiple legs for their locomotion system, modular robots have a much greater degree of freedom. This freedom and flexibility in modular robots leads to higher search costs when deciding their configurations and actions, but we can get better performance by optimizing their shape.

A block-based modular robot, ROBOCUBE, is used for the experiment. Although one core block and one power source are essential for one robot body, once they are available, the robot is activated regardless of the connection; therefore, an enormous number of combination patterns exist.

We used a tiled pattern as a genotype in order to represent poly-cubes in our genetic algorithm. The tiled pattern is a set of connection rules given as an integer sequence with fixed length. An 8 bits integer is partitioned into two parts. The upper 5 bits gives a block number of the parent for the connection. The lower 3 bits gives a direction for its length. Each experiment was repeated twice.

Concerning the maximum fitness values, they are almost same. Increasing the size does not always lead to better fitness. However, the evolved shape has its own characteristics. We performed the same experiment with the actual machines and observed the behavior in the real world. We can see this task as a co-evolution of body and legs. Cooperative patterns are essential for a normal motion. Note that not only the shape but also moving methods change by the increase of the module size.

A Study on Structure Search for Modular Robots
By Takahiro Tohge

We suggest a new framework which discerns discrete components of tone and supports sound recognition in music learning.

A tone has various factors such as tone color, velocity, pitch and tone length, and the importance of each factor changes due to a variety of learning domains. For instance, time information including the tone length and timing is essential in learning rhythm, and frequency information including tone color or pitch plays a critical role in learning to sing. This means that in rhythm lessons learners have to recognize the factors regarding time information and in singing lessons they are required to recognize the factors regarding frequency information. It is a very demanding task for beginners to extract the target factor depending on the domain and priority and also to recognize more than one factor at the same moment.

In our framework, the factor which is essential in one learning domain is transformed into a different form and is provided to learners through some medium that appeals to either the visual sense, tactile sense or deep sense in combination with auditory sense. This makes it easy of beginners to extract and recognize the target factor from many factors, and it supports music learning. We evaluated our framework through two case studies of rhythm lessons and singing lessons.

In a rhythm lesson, the student discerns timing information with the help of our system’s tactile actuators. Tactile input is recognized by the superior sense, which reacts first to external stimuli and is better at handling timing information compared to the other senses. In ensemble situations, we support rhythm learners by providing them with information corresponding to the rhythm of the phrases through their tactile sense and encourage them to recognize time information which plays an important role in learning rhythm.

In a singing lesson, the student discerns frequency information from the sound produced by the vocal cords and the supporting medium. Tactile input is recognized by the superior sense, which reacts first to external stimuli and is better at handling frequency information compared to the other senses. In ensemble situations, we support rhythm learners by providing them with information corresponding to the rhythm of the phrases through their tactile sense and encourage them to recognize frequency information which plays an important role in learning rhythm.
information with the help of our system’s visual information. At an early stage of a singing lesson, learners have to learn voice production. A student’s voice is characterized by frequency structures. Unlike visual information, voice information disappears as time advances; therefore it is difficult for beginners to identify small variations in pitch and tone quality.

We enable learners to compare their current voice with their voice at a previous moment by providing frequency structure information with time through visual representation. This encourages students to recognize the changing of the frequency structure and supports them in acquiring singing skills.

Through these two case studies, we evaluate 1) the enhancement of recognizing tone factors and learning speed, 2) the enhancement of recognizing rhythm in ensemble in rhythm lessons, and ascertain 3) whether learners can recognize the small differences in their own voice over time and 4) whether they can understand how to vocalize in order to produce the target voice in a singing lesson. The results show that our framework is significantly useful in supporting music learning in both cases.

A36. 當話型進化論的計算による作曲支援に関する研究
A Study about Application of Interactive Evolutionary Computation System in Composition-Aid System
By Daichi Ando

A37. 安帯域無線通信システムにおけるランダムアクセス方式に関する研究
Random Access Process in Broadband Wireless Access Systems
By Doohwan Lee

Rapid changes and improvements of recent mobile and network technologies have been realizing ubiquitous network services. Even though the present wireless access technologies already provide wireless data communication services, there still exists the request for the high-speed wireless data transmission. To satisfy this request, researches on broadband wireless access technologies are ongoing. Broadband wireless access systems include various technologies such as random access process, radio resource management, interference cancelation, power control, and so on. Among them, this dissertation focuses on the random access process because it is one of the fundamental technologies for the initialization of the broadband wireless access systems.

Random access process in the broadband wireless access systems refers to the contention-based random access, and provides functions of the initial network entry, the bandwidth request, and the network entry during handover. The procedure of random access process in the broadband wireless access systems is conducted as follows. First, the base station (BS) periodically broadcasts the necessary information for random access process such as the location of random access channel. Second, multiple mobile stations (MSs) simultaneously transmit randomly chosen random access code to the BS. Third, the BS carries out the multiuser resolution process to identify transmitted random access codes. If BS successfully identifies random access codes, it allocates some resources to each MS and notifies this information to MSs. Fourth, each MS transmits the detailed information to the BS using the allocated channel. Random access process in the broadband wireless access systems have following two key features. First, it is performed by the code-based multiple random access. Polling or CSMA-CA based random access scheme cannot be adopted because the number of MSs in typical broadband wireless access systems such as WiMAX and LTE systems is significantly large. Second, random access signals experience the multipath fading channel environment due to the relatively large cell size. This dissertation analyzes the performance of random access process in the broadband wireless access systems considering above stated two features.

In the mean time, the interference problem in the relay-deployed network, which is caused by the unbalanced transmit power between the BS and the relay station (RS), should be taken into account as well. Hence, this dissertation also scrutinizes the interference problem of random access process in the relay-deployed network and provides a novel transmit power control algorithm. Followings are detailed descriptions of this dissertation.

This dissertation provides the mathematical modeling of random access process in the broadband wireless access systems and derives the probability density function of received random access signals. Using the characteristics of random access signal and the central limit theorem, received random access signals are modeled into Rayleigh random variable. By this modeling, the coarse performance analysis of random access process is feasible, which is considerable beneficial for the initial system design.

This dissertation also provides the finite performance analysis of random access process in the broadband wireless access systems. For the thorough performance analysis, four performance evaluation metrics are defined: 1) the probability of detection success, which refers to the probability for a MS to succeed random access process, 2) the probability of detection miss, which refers to the probability that the transmitted random access code is not detected, 3) the probability of detection false alarm, which refers to the probability that not transmitted random access code is detected as the transmitted code, 4) the average necessary random access success time, which refers to the average necessary time for a MS to succeed random access process including retransmission, random backoff, and penalty time. Based on above defined evaluation metrics, the performance analysis of random access process in the broadband wireless access
A38. IEEE 802.11 無線ネットワークにおける高速ハンドオフ機構に関する研究  玉載旭

Improving Handoff Performance in IEEE 802.11 Wireless Networks
By Jaeouk Ok

This dissertation describes the design and development of systems to improve handoff performance in IEEE 802.11 wireless networks. Handoff is the process through which a client switches the associated access point. To achieve handoff faster means to provide not only higher throughput to best-effort applications, but also uninterrupted service to delay-sensitive applications on the move. The original IEEE 802.11 standard does not support it, because it was designed to provide wireless connectivity for fixed, portable, and moving clients mainly within a basic service set.

Link-layer handoff is composed of four sequential phases: detection, channel scanning, link-layer authentication and reassociation. The standard handoff incurs latency in the magnitude of hundreds of milliseconds to several seconds, and the channel scanning latency accounts for more than 90% of that. The necessity of channel scanning phase comes from a client's inability to acquire information about nearby APs on different channels while communicating with the currently associated AP. Its large latency lies on the inefficiency that the standard mandates a client not only to scan through all the channels regardless of AP's existence on it, but also to wait for a fixed amount of time at each channel just in case more responses might arrive.

We propose two fast handoff methods to address these inability and inefficiency, respectively. As for handling inability, we aim to completely eliminate channel scanning phase by enabling clients to obtain information about the APs available in range while exchanging data frames with a currently associated AP. We further require that 1) nearby AP information should be promptly updated in a dynamically changing radio environment, and 2) the ease of deployment, which is the biggest strength of IEEE 802.11 wireless networks, should be kept. As for handling inefficiency, we aim to improve channel scanning phase by proposing a novel usage of the open system authentication phase, which became redundant with the advent of WPA. We further require that 1) no modification should be made to the current standard, 2) the handoff metrics (e.g. signal strength, traffic load, etc) should be promptly acquired during the handoff procedure, and 3) the fast handoff scheme should work with only software upgrade on the client side.

To achieve the first improvement, we have developed a fast handoff scheme, called AuthScan, that provides a novel usage of the open system authentication phase for reducing
channel scanning latency. The basic idea behind AuthScan is to exploit multiple Authentication Request/Response. AuthScan maintains a target AP list cached from a client's previous handoffs, and performs unicast scanning by transmitting not Probe Request frames, but Authentication Request frames only to the selected APs. The next AP is selected by comparing quickly acquired handoff metrics during the handoff procedure. In this dissertation, we show the theoretical handoff latency in comparison to related work, and the effectiveness of our system through implementation and experiments.

In addition, as a real case application, we extend AuthScan to enjoy a publish/subscribe service such as podcasts, while traveling by subway. In Tokyo, approximately 97% of subway stations are densely covered by three different service providers, but effectively utilizing network connection on the move requires a greater degree of management due to its intermittent connectivity. We aim to increase the connected time to already deployed 802.11 wireless networks while traveling by subway in Tokyo. To understand the target environment, we investigated the commercial 802.11 HOTSPOT networks deployed in Tokyo Metro. One of the findings against the common belief regarding long distance mobility is that the main contributor to mitigate the available connected time is link layer connection management, not IP layer mobility support because of the widely deployed VLANs across the target networks. Based on this finding, we propose an optimized solution for this subway environment to reduce the delay experienced when establishing the wireless connection after coming out of non-coverage area in the tunnel and when switching the wireless connection to the next AP while crossing overlapping coverage areas at stations.

Our method addresses the first issue by building a chain that links the last AP in the previous station before the tunnel with the first AP in the next station after the tunnel, which we will call border APs. By referring to this chain when leaving a station, a client can reduce the delay to establish the connection through the use of passive scan only on the channel corresponding to the upcoming border AP. The second issue is addressed by building a list of the APs available in each station for which a client has connection authorization, that we will call preferred APs. By referring to this list when crossing overlapping coverage areas in a station, a client can reduce the delay to switch the connection through the use of unicast scan using Authentication Request frames to the limited number of preferred APs. This is feasible by taking advantage of the key attributes of the target environment: strong mobility pattern along a railroad and centrally managed limited number of APs. In our analysis, our method allows to establish terminated wireless connections with 5.6% of the delay obtained using passive scan, and switch wireless connection to the next AP with 5.8% of the delay obtained using active scan. The effectiveness of our system is also shown through implementation and experiments.

In summary, this dissertation describes two fast handoff methods to address inability and inefficiency of the standard channel scanning phase in the IEEE 802.11 wireless networks. We also describe a real case application of AuthScan to increase the connected time to 802.11 HotSpots while traveling by subway in Tokyo. All the proposed methods are implemented and their performances are investigated through field experiments.

A39. 方向性エッジ情報を利用した動きフィールド特徴表現に基づく観察者動作認識システム

An Ego-Motion Detection System Employing Directional-Edge-Based Motion Field Representations
By Jia Hao

Benefiting from the remarkable development of VLSI technology according to Moore's law, computer owns the powerful computing ability exceeding that of humans. It has taken most of the charge of computing works instead of us, and has contributed much to scientific computation. However, in spite of this success in logical and dedicated computation, computers are still not good at flexible intelligent processing, such as “recognition”. This sets the research of human-like intelligence irreplaceable tendency for the next generation of computer system. Since for humans, visual information, and especially visual motion information, is one of the most critical sources for recognition tasks, we explore machine intelligence by taking visual motion analysis as a breakthrough.

As the prerequisite of any motion analysis system, ego-motion detection that analyzes the relative motion of an observer with respect to the environment has been drawing a lot of interest in research. It plays an essential role in navigational tasks, such as automotive vehicle guidance, real-time robot control, etc. The performances of these systems are essentially determined by two major characteristics. First is the system's flexibility in adapting to disturbances, viz. illumination change, irregular observer motion due to a variation in speed or bumping and shaking of the observer and so forth. The other is the system's operating speed that ensures a real-time response capability. Since an increase in a system's flexibility is offset by an increase in computational cost, how to compromise between these two aspects is of prime importance in building such systems.

Many contributions have been achieved for ego-motion detection by means of feature tracking, environment modeling, and so forth. Unfortunately, most of them are developed for specific missions, assuming comparative ideal circumstances such as constant illumination condition, smooth motion, etc. They therefore suffer from degradation of accuracy under severe circumstances. Moreover, most of these algorithms involve operations in frequency and spatial domain, i.e., estimating the motion models by solving some complex equations with floating-point calculations. Since the circuitry needed for the calculation of floating-point numbers is very complicated, it is difficult to implement these algorithms as a VLSI system, therefore by no means real-time practical.
On the other hand, biological systems are robust against these problems. Since the discovery by Hubel and Wiesel in the study of visual cortex of animals, it is well known that edge information plays an essential role in early visual processing. The illumination invariance of edge information makes the perception systems work well even under serious illumination conditions. In addition, for the motion interpretation stage, "an associative architecture" directly inspired by human physiology can more easily execute recognition process instead of the large number of numerical computations required by conventional methods, which has been successfully demonstrated by applying it to still image recognition.

The purpose of this research is to accomplish more complex recognition task, ego-motion detection, based on these biological principles, where edge information is utilized as the very basis of the system, and the "recognition" process of motion analysis is executed in the "associative" manner. The system is composed of two stages: extracting motion information from a scene, and interpreting the accumulated information. In the first stage, motion field generation, directional edge maps generated from original gray-scale images are utilized as the input. Using edge information renders the system robust against dynamic illumination variation and weak texture, while the histogram matching scheme based on edge maps for local motion detection drastically reduces the computational cost than conventional block matching. In the second stage, motion characteristics are extracted from two perspectives of a motion field and are represented by two kinds of feature vectors. They are jointly utilized in the hierarchical classification scheme for a concise and efficient estimation of motion pattern. Multi-clue template matching in this scheme makes the algorithm robust against the motion ambiguity problem, such as distinguishing tracking and panning motions of the same direction. Moreover, by introducing a new scheme in hierarchical classification, motion field distortion due to camera shaking during video capture has also been resolved.

All operations in both the motion field generation stage and the hierarchical motion pattern classification stage are executed with integer or 1-bit calculation, namely fixed-point operation, thus it is easy to implement the algorithm with compact hardware circuitry to meet real-time need.

The ego-motion detection system has also been applied to motion estimation of hand-held devices, such as mobile phones. Digit-writing gesture recognition was taken as a target problem, where the writing stroke is recorded from a video image sequence taken by a moving camera. The automatic speed adaptation capability developed in the motion detection system has enabled very robust writing stroke detection. As a result, the temporal stroke distortion due to irregular writing speed has been eliminated. Since the writing stroke is correctly reconstructed by integrating direction and magnitude of motion results, feature vector for each digit character was constructed by connecting feature distribution in each direction. As a result, handwriting gesture recognition is achieved by simple template matching. The system performance has been evaluated by digit-writing gesture recognition with irregular writing speed, different users, or cursive writing. Recognition of hand-writing Chinese characters is also attempted and the potentiality for more complicated hand-writing patterns by the algorithm has been examined. The result shows that it is possible to build higher level interacing based on only vision information and broader use of ego motion detection to motion estimation of mobile can be expected.

In this research, an ego motion detection system employing directional-edge-based motion field representations has been developed, and successfully applied to camera motion estimation, and digit-writing gesture recognition. Usage of directional edge information renders the illumination-independent performance in motion field generation. Hierarchical vector representation of motion field has resolved the problems of motion ambiguity and motion field distortion by simple vector processing. The introduction of the speed adaptation scheme is very effective for correct camera motion detection and therefore correct stroke generation for trajectory recognition. The algorithms proposed in this work have enabled us to build real-time response systems using the dedicated VLSI chips developed for the processing. The flexibility and the speed performance of the system simultaneously are achieved. The performance of the system has been evaluated under various circumstances and the capability of the directional edge-based motion field representation algorithm in performing robust visual motion perception has thus been verified.

A40. 連想プロセッサに基づく認識システムのためのアナログ回路技術

Swi Trong Tu

Associative-Processor-Based Recognition Systems

Associative processing or template matching plays an important role in computational scheme in intelligent information processing. Because such a process is computationally very expensive and time-consuming, it would be better if this process is carried out by dedicated VLSI associative processors rather than programs running on a general-purpose computer. Generally, the associative processor is a maximum-likelihood search engine having a huge cache memory for fast experience or knowledge and a parallel search architecture. In this thesis, several analog VLSI associative processors have been developed for a variety of purposes of intelligent information processing.

Recently, nanoscale devices have attracted much attention because of its ability in terms of enhanced integration density and ultra low-power consumption. Resonance characteristics are typical inherent non-linear characteristics observed in such devices. There would be a great opportunity for building large scale intelligent systems if we could use such kind of characteristics directly in computation. In addition, as devices
at the nanoscale have a higher probability of being defective than conventional CMOS devices, designing reliable circuits with such devices is a major challenge. Thus nanoscale devices are more suitable for building majority-decision-making systems like the operation of associative systems than building logic functions. However, nano devices are still in the research phases, and most demonstrations have been just achieved at the device level or simple circuitry. The work in this dissertation can provide an answer to the question: “How can we use the exotic non-linear characteristics of nano devices to build computing systems”. This is because, in this study, resonance characteristics of these quantum devices were emulated by using a simple NMOS circuitry and utilized to build a large scale system.

Firstly, a single-core associative processor has been developed featuring resonance (or bell-shaped) characteristics and device characteristics variability problem. The key feature in this work is the proposal of a calibration scheme that can mitigate the problem of device mismatches caused by process variations. In addition, the matching cell requires only eight NMOS transistors to implement, enabling a very compact implementation of a matching-cell array. Furthermore, the matching cell can operate in the subthreshold regime which yields an opportunity of very low-power operation. The prototype chip was fabricated using 0.35 μm CMOS technology. The chip operation has been verified by measurement results.

In order to make the system more intelligent by increasing the number of template data, a multi-core/multi-chip scalable architecture has been developed. The system has the possibility of a large database capacity. The global winner is determined by employing a three-stage time-domain winner-take-all (WTA) circuit. Device mismatch problems as well as decision errors associated with inter-chip communication delays have been resolved by introducing a majority-code-decision circuit. Design ideas have been verified by measurement results of the proof-of-concept chip fabricated in a 0.18 μm CMOS technology.

Nonlinear filters, such as MIN, MAX or MEDIAN filters play an important role in image and speech processing. These filters can be implemented by using rank-order filters (ROF’s) by setting appropriate rank-order values. In this regard, an analog implementation of rank-order searching circuit for building ROF’s has been developed by using a time-domain computation scheme. The architecture can preserve the accuracy of digital implementations but achieves advantages of analog implementations in terms of low-power dissipation and small chip real estate. The searching function is an important operation in associative processing. Thus, such kind of searching circuit mentioned here is applicable to build not only ROF’s but also associative processors. The circuit operation has been verified by experimental results obtained from the prototype chip fabricated in a 0.18 μm CMOS technology.

In some applications where we want to search for not only the nearest-match but also an r-th nearest-match between the input data and template data, we need functions like in rank-order filters. For this purpose, we have developed an r-th nearest-match Hamming distance associative processor inheriting techniques mentioned above. Rank-order searching function is an interesting feature of the proposed architecture, making it different from conventional approaches. The simple configuration achieved in this design comes from the use of only one analog comparator in the rank-order setting circuit for any extension of the number of template words. It enables to combine several rank-order searching circuits in parallel so that a “top-k” of nearest matches can be searched for in parallel. Operation of the system is verified by simulation results of the prototype chip designed in a 0.18 μm CMOS technology.

In this study, we address analog circuit technologies and architectures for building associative processors employed in recognition systems, and illustrate those with examples of prototype VLSI chips: a single-core associative processor employing bell-shaped matching cells, a multi-core/multi-chip scalable architecture for large database capacity, a rank-order searching circuit and a Hamming distance associative processor employing time-domain computation techniques. The advantages of low-power operation and high-density integration inherited from analog circuit technologies were demonstrated, which are attractive features to enhance the performance of recognition systems.

A41. 実空間指向ユビキタスサービスプラットフォームに関する研究  川西 直

PA Study of Real World Oriented Ubiquitous Service Platform

By Nao Kawanishi

This thesis "A Study of Real World Oriented Ubiquitous Service Platform" describes the necessity of real world oriented ubiquitous service platform to enable to build context-aware services by collaborating horizontally. This thesis also describes a resource coordination framework to build context-aware services on the platform, and a real world oriented game which is realized by using the framework.
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